Soils report 7 – Con Lehane, Ballinagree

Introduction

The Heavy Soil Farm at Ballinagree is a dairy farm on 69 hectares. It is located just to the Northwest of the village, which itself is 10 km to the North of Macroom, Co. Cork (Figure 1). The farm ranges from 200 to 335 m in elevation across an undulating landscape with intermittent plateaus and inclines up to 11 degrees. The various hummocks and hollows make the ground complex which is further exacerbated by rock outcrops, together with rough surface areas due to stones. The main aspect of the farm is to the south and the River Laney is the main conduit for drainage 1.3 km to the south of the farmyard. The average yearly rainfall over 20 years is 1757 mm at the Met. station 5.5 km away.

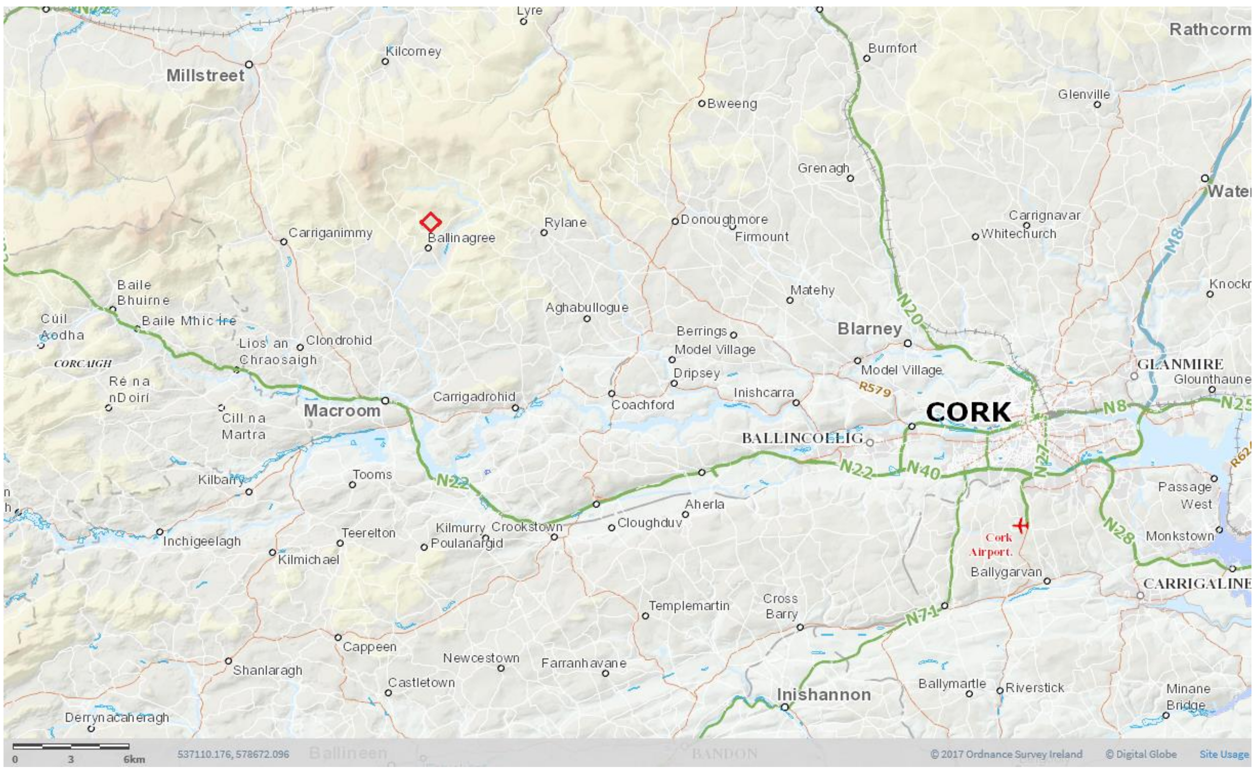

Figure 1. Location of HSP farm (red diamond) at Ballinagree Co. Cork.

The Boggeragh Mountains are found in an arc to the northwest, north and north east of the farm, one of the main pathways of relief from the mountain range is to the south through the area of the farm. During the Variscan mountain building episode, rocks in the South Munster region were compressed from the south into a series of folds on east-west axes. Subsequent erosion stripped the more soluble Carboniferous Limestones from the fold crests or ridges exposing the harder, more resistant sandstones underneath. Extensive fracturing and faulting accompanied the folding of the rocks. The current mountain/hill ridges are of the same sandstone (Sleeman, AG. and Pracht, M. (1994). The Ballinagree area is located on the northern most extent of this geologic event.

The local geology of the area is described as shale and sandstone of Namurian (undifferentiated) origin in the Geological Survey of Ireland (Pracht, 1997). Paddocks 19 and 21 to 29 are of the Caha Mountain Formation - Purple & green sandstone & siltstone (Figure 2). The lower paddocks 1 to 18 and 30 to 33 are of the Gortanimill Formation - Sandstone and siltstone. There may be till from Devonian sandstones in the area also as this till dominates to the south. Most of the soils in the area are formed from glacial deposits of the Saale period. The subsequent Weischel glaciation did not reach south as far as this region of County Cork. The soil on the hill slopes was formed by solifuction, where the rock waste was formed by severe frost action on the areas not covered by ice. The streamlines of the bedrock in the area run east to west, as did the ice advance. The drift further down the hill slopes and in the valleys was composed of shale and sandstone derived till. (Finch and Ryan, 1966).

The area has very high rainfall which is likely to develop acidic soil conditions due to weathering of the local geology and the glacial till derived from sandstone. On the upper slopes these conditions give rise to the development of Brown Podzolics with the leaching of iron and aluminium to the lower horizons and in time the formation of Podzols. Over time in the normal pedogenic process, peat begins to form due to the acidic conditions preventing the microbial action on organic matter. And the eventual hard iron pan closes off any movement of water to the lower horizons, further encouraging peat formation. These blanket peats were known to be 2 to 2.5 m deep in the area. Over the years this peat was cut away for fuel and the northern most paddocks were essentially cut away bogs decades ago and then used for rough grazing. These areas have been consequently ripped to break the iron pan and allow vertical drainage commence once again. The most recent ripping was 15 years ago and the soil turning effect lasts for 10 years, before the podzolisation process takes over again.

The central paddocks of the farm are in a plateau area where the shallow groundwater levels come into effect by restricting drainage. The area also collects the horizontal movement of water off the slopes, both at the surface and in the subsoil. In this area Groundwater Gleys and Surface-water Gleys would be expected to dominate. As one moves further south on the farm towards the main road, the slopes are shallower and the till texture is more free draining leading to more Brown Earths and Brown Podzolic soils. To the south of main road and away from the farm there is blanket peat at the bottom of the valleys and alluvium associated with the River Laney.

Historical soil information

There was no National Soil Survey Report covering North or East of County Cork. There was the West Cork Resource Survey (1963, An Forais Talúntais) which covered the soils in the area to Kilmichael 25 km SSE of Ballinagree. Here however the soils are dominated by Old Red Sandstone drift which is not prominent in this area of the farm. The next nearest soil survey report is of County Limerick, which again would describe soils on different drift and parent material. This leaves the Irish Soil Information System (Irish SIS, Creamer et al 2014), as the primary resource for soil description in County Cork. This map indicates a soil association of Ross Carbery covering the southern two thirds of the farm (Figure 3). This soil association is led by the Typical Brown Podzolic soil series of the same name.

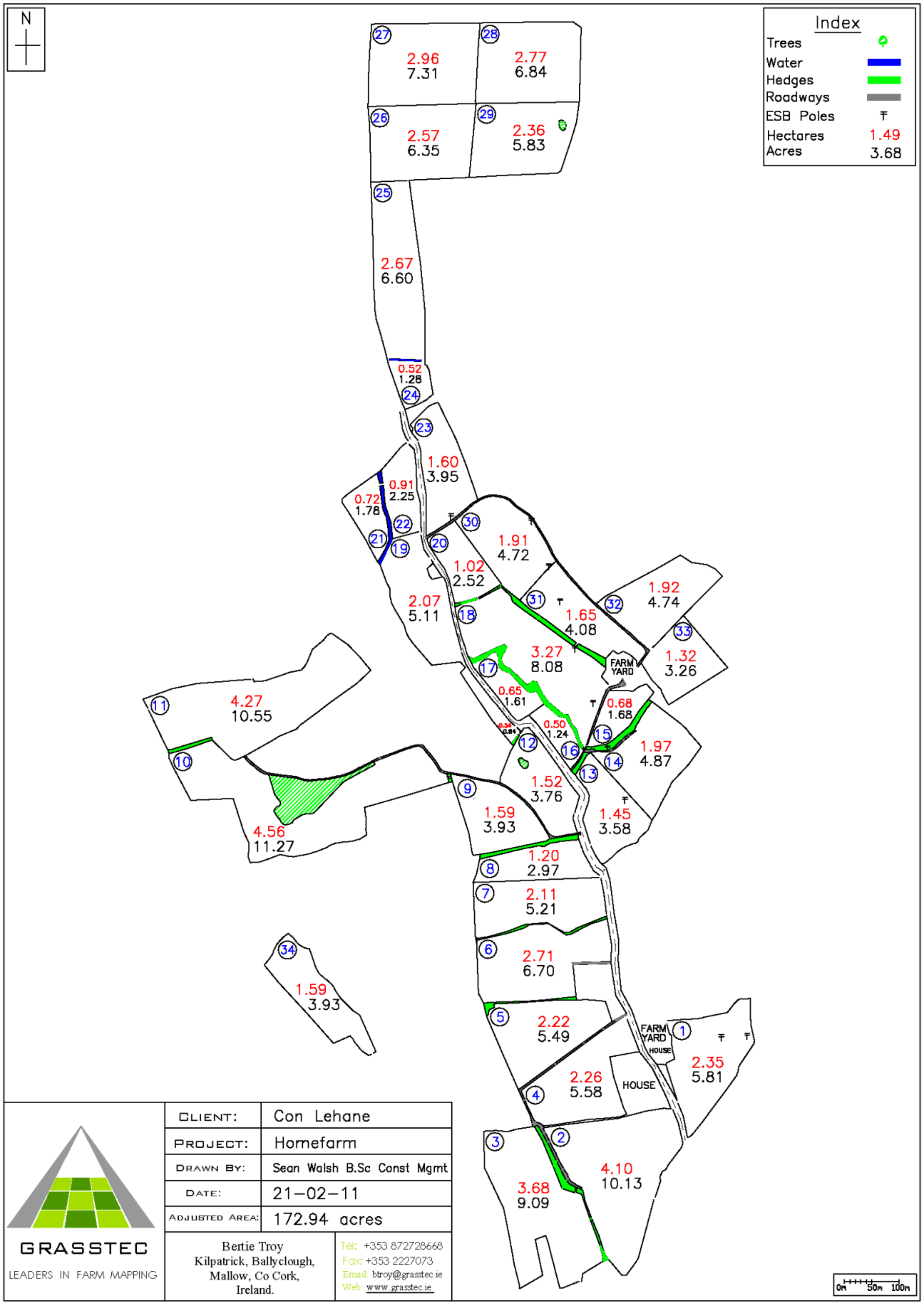

Figure 2. Paddock distribution at the Ballinagree Heavy Soil Farm, Co. Cork.

This series is described as: Coarse Loamy compact drift with siliceous stones. This coarse loamy texture would be considered moderately drained; however the compaction aspect of the drift may lead to some drainage restriction and at times this soil could be described as imperfectly drained.

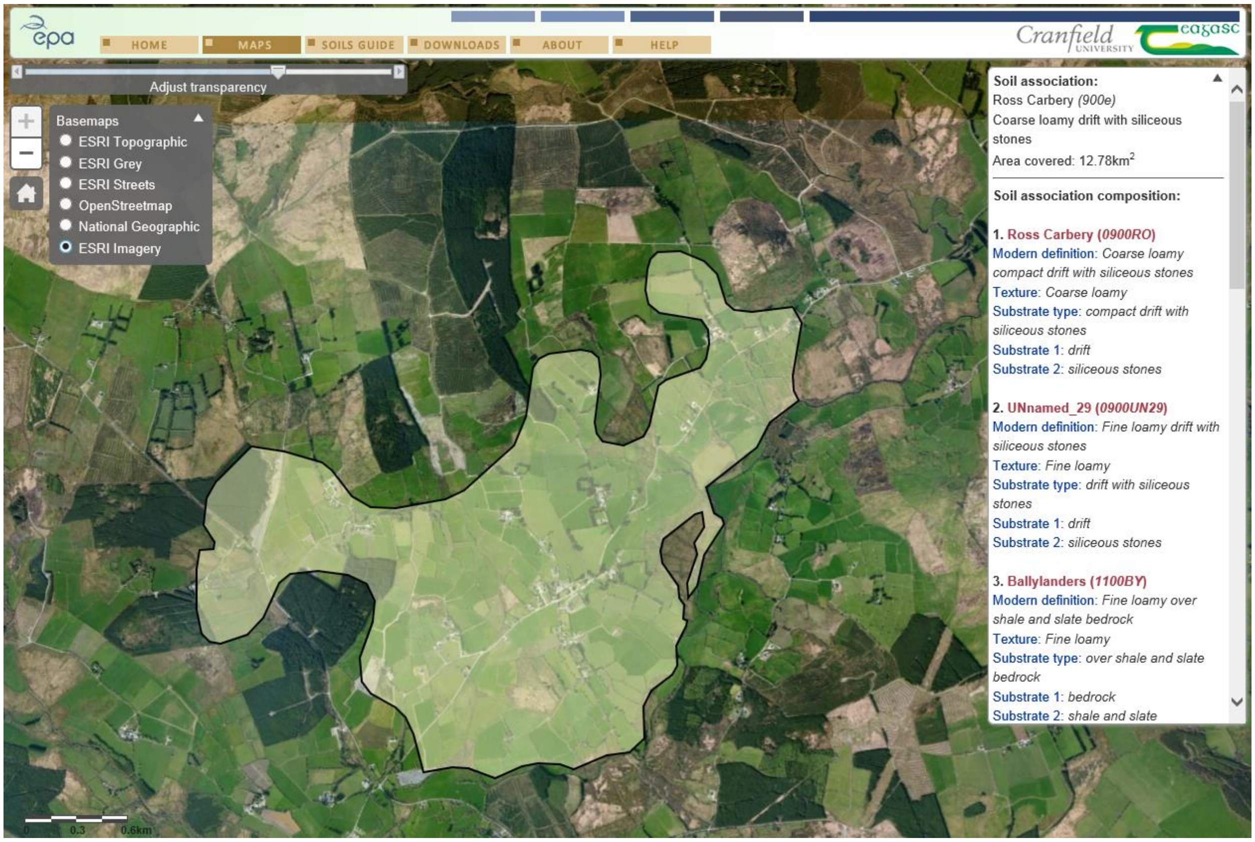

Figure 3. The Ross Carbery soil association predicted to cover the southern part of the Ballinagree farm, from the Irish SIS.

This association also contains four other Brown Podzolics (two on bedrock, two with Fine Loamy textures). It contains three Brown Earths (two Coarse Loamy, one Fine Loamy). It contains two Groundwater Gleys and one Surface-water Gley. The northern third of the farm is coved by a polygon of peat (Figure 4). This would be the Aughty association, composed of drained and cutover ombrotrophic peat. It is highly unlikely that any ombrotrophic peat in the natural state has remained in this area due to the historic management practices. Other potential soils to be found on the farm are alluded to by a polygon 1.5 km to the SW of the farm where soil association Kilrush is predicted, this is a Typical Surface-water Gley. There is river Alluvium (Boyne association) in the immediate area surrounding the River Laney to the south of the farm. There is also an Iron-Pan Stagno Podzol association lead by the series Knockastanna, which may also be possible in the farm. This occurs regularly with elevation across the Boggeragh Mountain range.

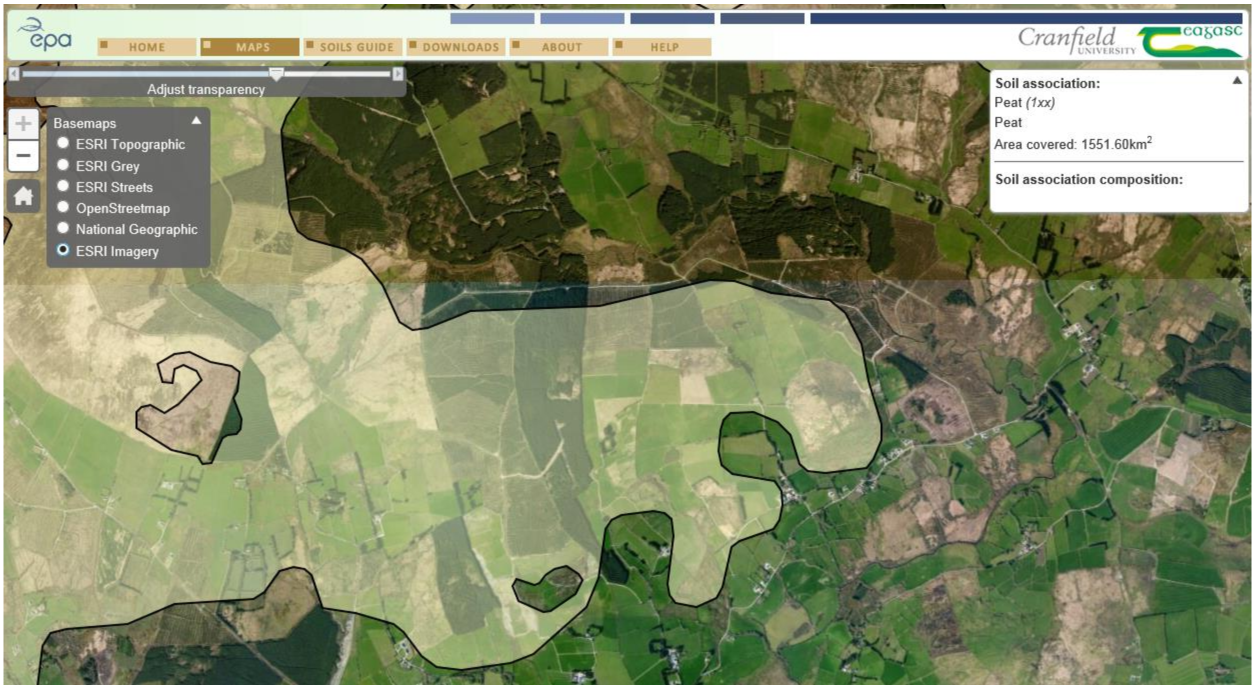

Figure 4. The Blanket Peat association covering the northern third of the Ballinagree Heavy Soil Farm, from the Irish SIS.

Auger campaign

Method

An auger bore was carried out on average every hectare to investigate the soil physical features. In practice, more or less augers were used based on landscape complexity. Their resulting distribution was a relatively even coverage in each part of the farm (Figure 5). The Dutch auger was driven into the soil to a depth of 1 metre if possible. The coordinates, landscape features and soil features were described and recorded on a field tablet. Horizon type, depth, texture, colour, mottling, structure, roots and stones were recorded along with many more physical attributes detailed in the Irish SIS soil profile handbook (Simo et al 2014).

Brown Earths

Of the 53 auger bores taken on the farm, 25 were Brown Earths representing the largest Great Group on the farm. These Brown Earths differed in their potential for productivity and their drainage capacity. 15 were Typical Brown Earths with 9 being described as well drained (Figure 6) and the other 6 were described as having moderate drainage (Figure 7). The later designation arose due to mottling occurring in the 40 to 80 cm depth of these soils. Overall these soils rarely are waterlogged throughout the year and allow good sward growth over extended periods. Most of these soils were found in the southern third of the farm around the farm yard and on the eastern part of the central third of the farm (paddocks 30 to 33).

Figure 5. Distribution of the auger bores on the Ballinagree Heavy Soil Farm.

There were then 10 Brown Earths with a drainage restriction and described as imperfectly drained. After consecutive days of rain these soils would stagnate, allowing surface water build up and poaching from cattle. In four of these soils humic material has built up as the anoxic conditions prevent complete microbial breakdown, these are Humic Brown Earths. In two other cases the main restriction is sub-surface where mottling is occurring at depth, one Gleyic Brown Earth and one Stagnic Brown Earth. These six soils are still performing well in terms of productivity and in the medium term may not change that greatly.

There are however four Anthric Brown Earths which have been dug and turned or ripped to break iron-pans (Paddock 26, 27 and 22) or clay increases (Paddock 34). These soils are likely to require this management regularly as the measures which allow relatively good drainage in the short term, regress back to their original state easily. Under current management they are productive paddocks for grazing.

Figure 6. Paddock 1 b, Typical Brown Earth, Clashmore, well drained on shallow slope and Loam texture.

Figure 7. Paddock 30 Typical Brown Earth, Ballylanders, a shallower soil on greater incline, moderately drained.

Brown Podzolics

The next largest number of auger bores came under the Brown Podzolic Great Group. There were 11 Typical Brown Podzolics where there is an increase of iron and aluminium at depth due to leaching from upper horizons. This increase leads to a Bs horizon. This can restrict the downward movement of water and is indicative of lower nutrient status. These soils were described as moderately drained, still allowing for good sward growth, regular cuts of silage and consequent traffic and low levels of poaching from animals. This drainage status is due to the favourable Loam class dominated textures with low clay contents. The soil series designations differed mainly due to the soil being on drift (Figure 8) or bedrock (Figure 9) and the definition being described as a coarse loamy texture or a fine loamy texture.

As with the Brown Earths there were Humic Brown Podzolics (four). Here there is an accumulation of organic material which cannot be broken down by microbes. It is indicative of long lived organic matter that is resistant except to very specific microbes. It also indicates physical restrictions throughout the year due to waterlogging and colder temperatures which reduce microbial performance. The later more likely with increasing altitude (Figure 10). Coupled with this is the acidic tendencies due to the parent material which restricts the microbial process further. It can also indicate that a pan is forming in the Bs which may become impenetrable (Bf, due to the concretion of the iron) and water movement is even more restrictive than Typical Brown Podzolics. There is one Stagnic Brown Podzolic due to fine texture near the surface & shallow soil (bedrock) and water collecting at the bottom of the slope in this paddock (11 c, Figure 11).

Figure 8. Paddock 5 Typical Brown Podzolic, series UN29, moderately drained on deeper soil (drift).

Figure 9. Paddock 10 b, Typical Brown Podzolic, Rathduff, moderately drained shallow soil (bedrock) with rock outcrops nearby.

Figure 10. Paddock 11 b, Humic Brown Podzolic, Borrisoleigh, imperfectly drained in plateau area.

Figure 11. Paddock 11b looking south and east to the bottom of the slope 11c, Stagnic Brown Podzolic, Flemingstown, Loamy over shallow bedrock.

<u>Podzols</u>

As the pedogenetic process continues over time (~1000 years), the podzolisation process results in the formation of an iron-pan (Bf layer). Firstly, the Bs horizon develops and eventually is found below a completely eluviated E horizon. Secondly, all the humus, iron and aluminium has moved lower down the profile and an iron-pan forms above the Bs sealing off any transport with the horizons above. There also maybe translocated humus in a Bh horizon within the Bs, below the Bf layer. This sealed off pan prevents any water movement downwards so water logging becomes problematic and the surface humic layer can become peaty in time.

If this process continues unabated the peat will accumulate to such an extent that it is greater than 40 cm depth and the soil is no longer described as a Podzol but is now considered a peat soil. As mentioned in the introduction all peat of greater than 40 cm depth has been cutaway over the years. The Podzols found on the farm have less than 40 cm peat at the surface. The other management techniques of ripping, deep ploughing and digging and turning the soil has broken the pans in many cases. however, peat can be found in lower horizons due to mixing and can be reforming at depth and at the surface, dependent on time since the measures were taken. The same can be said for the iron-pan pieces which again begin to form a continuous layer.

Figure 12. Paddock P 28, Humic Podzol, Ballyglasheen, Loamy over shale and slate bedrock. The Boggeragh mountains are rising in the background.

The Podzols found on the farm are those still with an extant Bf layer, and a humic surface horizon (paddocks 10 c, 25 b, 28 and 29). They are Humic Podzols, series Ballyglasheen (Figure 14). The E horizon is poorly expressed or lacking indicating that these are previously altered podzols that have reformed. There are many examples of Brown Pozolics and Anthric Brown Earths in other paddocks on the farm, with parts of Podzols extant and apparently reforming, especially Bf horizons.

In paddock 21, drains of three metres depth have been dug on the boundary of the paddock and the original soil on the northern end is visible in profile (Figure 15). This is a Humic Podzol with parts Humic Brown Podzolic. Now following pan breaking measures in the rest of the paddock we have a Humic Surface-water Gley soil. The Podzols are imperfectly drained or poorly drained on this farm depending on time since alteration, the greater the time difference the poorer the drainage.

Figure 13. Paddock 21, Humic Podzol on the boundary, Ballyglasheen, with most of the field with Humic Surface-water Gley soil. Dutch auger, 1 metre for scale.

Figure 14. Paddock 14 Humic Surface-water Gley, Driminidy, poorly drained. Remnant fen in background.

Gley Soils

Generally, soil textures are favourable on this farm with Loams and Sandy Loams dominating, allowing relatively free drainage. In the plateau areas and at the bottom of slopes there is potential for sub soil stagnation and accumulation of clay particles via illuviation. There are only four paddocks that have been described as Gleys, two Humic Surface-water Gleys (Driminidy, 14 & 21), one Typical Surface-water Gley (Kilrush, 13) and one Groundwater Gley (Knockroe, 34 b). As with other areas of the farm these paddocks have been modified and the result is these current Gley descriptions which may change in time.

Paddock 14 appears to be the result of the fragmentation of a fen (Figure 14). There is fen peat and marl underneath still to be found in places within the paddock. The paddock to the south which is not part of the farm still retains herbaceous species indicative of a fen. It is very likely that all the paddocks to the north drain into this area. Paddock 13 is beside 14 and is not as intensely gleyed, therefore the humic A horizon has not developed. Paddock 21 has a Peaty Loam A horizon over 40 cm deep and a gleyed C horizon that will require ongoing maintenance to prevent it regressing back to a Blanket Peat. Finally paddock 34 b which is an out paddock in the village of Ballinagree, is found on relatively flat ground. The area can receive large amounts of water from the surrounding area. This field has been managed well to produce a good sward, however the fields beside are in scrub and contain bog myrtle which alludes to the wet and acidic nature of this area. The drift in this paddock is derived from old red sandstone which is different from the main farm. All these Gley soils are described as poorly drained.

Figure 15. Paddock 19 b Typical Lithosol, Glenlane. Recently reseeded and undergone boulder removal.

Lithic

The last Great Group of soils on this farm are the Lithosols. These soils are very shallow and must be less than 30 cm deep. They can have high stone content sometimes up to 80 % coarse fragments (Figure 15). Rock outcrops are usually found nearby. There were four lithosols found in the farm all described as Loamy over shale bedrock, Glenlane (paddocks 16, 17, 19b and the control). These soils are imperfectly drained, the stone content may allow more conduits in the soil for drainage but there is very little soil matrix. The water holding capacity of these soils is very low as a consequence and very little rain can fill the limited pore spaces. On steep inclines the subsoil flow stagnates quickly and moves to the surface. These paddocks suffer from poaching readily and can only be used for rough grazing.

Bedrock and coarse fragments

34 of the 53 auger bores were considered to be on bedrock or where the stones and boulders made up to 80% of the profile. 17 of these had bedrock at <50 cm depth. There were rock outcrops in 6 of the paddocks, where the bedrock was exposed at the surface. 12 of the paddocks had surface stones alluding to the constant management required for optimum growth in large parts of the farm. With the increase in altitude piles of large boulders (>60 cm) were noted in the paddocks in the northern third of the farm. This removal and management of the coarse fragments will be a constant effort especially when traffic increases are taken into consideration (fertilisation, cutting for silage and reseeding etc.). This is likely to lead to granular convection or the “brazil nut effect” bringing more stones from depth to the surface in time. The nature of the soil is of loamy free draining textures but with the many gravels, stones and boulders, there is little soil matrix and as a result very little water holding capacity. With the rain levels in this area the soil becomes waterlogged very quickly, but on the cessation of rain the soil can drain quickly except in low incline areas.

Conclusion

This is a farm with soils of low water-holding capacity rather than a heavy soil farm, however the end result is a similar waterlogging problem. The area is fortunate to have free draining textures in the prevailing drift, Loam and Sandy Loam. There are 25 Brown Earths and 10 Brown Podzolics that are either well drained or moderately drained (Table 1). Therefore, two thirds of the soils are of good drainage status. The area has high rainfall and if it falls in small regular bursts, generally these soils can manage the water levels. However, in consecutive days of rain, the limited water holding capacity is filled and the water appears at the surface and flows over ground (and in the subsoil on inclines). This then brings large volumes of water to the already saturated plateau areas leading to longer term drainage problems and gleying.

The high levels of rain bring leaching and the removal of iron and aluminium from upper horizons and podzolisation of lower horizons. Coupled with the acidic nature of the drift, Podzols and Peat form at altitude. The ripping and management of these fields allows grass production but this process has to be maintained in the short term and is also exacerbated by the high coarse fragment levels. The complex nature of the surface with rock outcrops and hollows on large inclines means that localised collecting areas can be of poor drainage status and field boundary drains will not remediate these areas.

Table 1. Field observations of soil type during the auger campaign on Ballinagree Heavy Soil Farm. Paddocks are listed with Subgroup and Soil series based on the Irish SIS (Creamer et al 2014). The drainage class is described in Schulte et al (2015).

Paddock	SUBGROUP	Series Name	Drainage Class
1 a	0900 Typical Brown Podzolic	Clonin	Moderately
1 b	1100 Typical Brown Earth	Clashmore	Well
2 a	0900 Typical Brown Podzolic	UN29	Moderately
2 b	1100 Typical Brown Earth	Clashmore	Well
3 a	1100 Typical Brown Earth	Kells	Moderately
3 b	0900 Typical Brown Podzolic	UN29	Moderately
4 a	1100 Typical Brown Earth	Clonroche	Well
4 b	0900 Typical Brown Podzolic	Cooga	Moderately
5	0900 Typical Brown Podzolic	UN29	Moderately
6 a	1100 Typical Brown Earth	Ballylanders	Moderately
6 b	1100 Typical Brown Earth	Ballylanders	Well
7	0900 Typical Brown Podzolic	Cupidstownhill	Moderately
8	1100 Typical Brown Earth	Kells	Well
12	1120 Gleyic Brown Earth	Knock	Imperfectly
9	1100 Typical Brown Earth	Clonroche	Moderately
10 a	1100 Typical Brown Earth	Kells	Moderately
10 b	0900 Typical Brown Podzolic	Rathduff	Moderately
10 c	0860 Humic Podzol	Ballyglasheen	Poorly
11 a	0960 Humic Brown Podzolic	Knockboy	Imperfectly
11 b	0960 Humic Brown Podzolic	Borrisoleigh	Imperfectly
11 c	0930 Stagnic Brown Podzolic	Flemingstown	Imperfectly

Paddock	SUBGROUP	Series Name	Drainage Class
33	1100 Typical Brown Earth	Ballylanders	Well
32 a	1100 Typical Brown Earth	Ballylanders	Well
32 b	1100 Typical Brown Earth	Ballylanders	Well
31 a	1100 Typical Brown Earth	Kells	Moderately
31 b	1100 Typical Brown Earth	Kells	Well
30 a	1160 Humic Brown Earth	Crossabeagh	Imperfectly
30 b	1100 Typical Brown Earth	Ballylanders	Moderately
15	1130 Stagnic Brown Earth	Toreenbane	Imperfectly
14	0760 Humic Surface-water Gley	Driminidy	Poorly
13	0700 Typical Surface-water Gley	Kilrush	Poorly
18 a	0900 Typical Brown Podzolic	UN29	Moderately
18 b	0900 Typical Brown Podzolic	UN29	Moderately
18 c	0900 Typical Brown Podzolic	Cupidstownhill	Moderately
16	0400 Typical Lithosol	Glenlane	Imperfectly
17	0400 Typical Lithosol	Glenlane	Imperfectly
Control	0400 Typical Lithosol	Glenlane	Imperfectly
19 a	0900 Typical Brown Podzolic	Cupidstownhill	Imperfectly
19 b	0400 Typical Lithosol	Glenlane	Imperfectly
23 a	1160 Humic Brown Earth	Crossabeagh	Imperfectly
23 b	1160 Humic Brown Earth	Crossabeagh	Imperfectly
22	1196 Anthric Humic Brown Earth	Ashgrove Anthropic	Imperfectly
21	0760 Humic Surface-water Gley	Driminidy	Poorly
24	1160 Humic Brown Earth	Crossabeagh	Imperfectly

Paddock	SUBGROUP	Series Name	Drainage Class
25 a	0960 Humic Brown Podzolic	Borrisoleigh	Imperfectly
25 b	0860 Humic Podzol	Ballyglasheen	Imperfectly
25 c	0960 Humic Brown Podzolic	Borrisoleigh	Imperfectly
26	1190 Anthric Brown Earth	Clashmore Anthropic	Imperfectly
27	1196 Anthric Humic Brown Earth	Ashgrove Anthropic	Imperfectly
28	0860 Humic Podzol	Ballyglasheen	Imperfectly
29	0860 Humic Podzol	Ballyglasheen	Imperfectly
34 a	1190 Anthric Brown Earth	Clashmore Anthropic	Moderately
34 b	0600 Typical Groundwater Gley	Knockroe	Poorly

Representative soil profile pits

Using the auger survey as a guide, three pits were selected to represent the dominant soils on the farm and to investigate the principal drainage restrictions identified (Figure 16). Paddock 8 was to represent the Typical Brown Earths in an area with regular management efforts to remove large boulders and to smooth out the rough surfaces and hummocks and hollows. Paddock 10 was to represent the Podzols found with increasing altitude and Paddock 12 was the site of new drainage measures and represented the soils with a gleyed horizon.

Figure 16. Position of the three soil pits excavated to represent the Ballinagree Heavy Soil Farm. Paddock 10 to the West, paddock 12 central and paddock 8 to the south near the farm yard.

Paddock 8 was assigned the Great Group, Typical Brown Earth, series Kells from the auger campaign. Following the excavation of the pit in paddock 8 it was clear that this was an Anthric Brown Earth. The action of the auger can smear horizons together, especially when the layers are relatively shallow. These shallow bands can be seen clearly in the profile pit picture (Figure 17). There is an Ap horizon above a Bw horizon and again a thin A horizon mixed with a C horizon. The colour changes can be seen more clearly in the detail pictures in Figure 18. Here the B horizon is a vibrant red brown colour, however after looking at the laboratory data (Appendix), this does not qualify as a Bs and is designated a Bw. The original B horizon is only weakly expressed in the original soil layers at depth. The Cr horizon is cemented and has very little soil matrix with abundant coarse fragments (Table 2).

The texture class of the pit was Loam except for the bottom horizon which was Sandy Loam. The coarse fragments prevented bulk density measurements being taken after the Ap horizon. The pH was good at 6.6 for this profile and acidity not a major issue. The organic matter levels of the A horizon qualify this soil as humic. The burying/inverting of the added A horizon can lead to partial breakdown and the retention of organic matter. The phosphorus levels were higher than required with the potassium levels below the ideal level. Overall this is a well-balanced soil with good nutrient properties, good drainage and moderate structure that allows high productivity. In the levelling and preparation of this field, large boulders (>60 cm) were removed and were again extracted in the excavation of this pit. This allows for large amounts of infilling of the voids and fissures caused by this action.

Figure 17. Paddock 8, 1196 Anthric Humic Brown Earth, Ashgrove Anthropic series, fine loamy drift with siliceous stones.

The farmer noted that it was an ongoing process of managing this paddock (and in general), with large boulders and stones coming closer to the surface over time. These would then be removed and the area would require infilling and levelling. Decades ago when the process was commenced large hollows would have been filled and levelled with the boulders but in time these have also risen to the surface and removal is necessary.

Table 2. Soil description of paddock 8, Ballinagree, Heavy Soil Farm.

Horizon depth (cm)	Horizon designation	Description
22	Ap	Dark Brown, few mottles, many gravels, common stones, Loam, Many fine roots, Angular blocky structure.
41	Bw	Dark Reddish Brown, few mottles, many gravels, common stones, Loam, sub-angular blocky structure, common fine roots. Greasy, buried plastic.
75	CA	Dark Brown Grey, no mottles, abundant gravels, many stones. Loam. Few fine roots. Top 10 cm old A hz.
170	Cr	Light Greyish Brown, few mottles, dominant gravels, many stones. Sandy Loam, wet, massive structure, high packing density, very few fine roots. Cemented.

Figure 18. Paddock 8, detail of original buried AC horizon (~60 cm depth, original B horizon is only weakly expressed) with infilled A and Bw horizon above.

Paddock 10 was assigned as the soil series Ballyglasheen from the auger campaign. This is a poorly drained Humic Podzol. This pit was to represent the Podzol soils found on the farm. On excavating the pit an iron-pan was visible, as was a distinct E horizon which made this soil a Stagnic Iron-pan Podzol, series Knockastanna (Figure 19). This implies that the Podzols are Humic or Stagnic Iron-pan Podzols depending on the time since disturbance and the strength of the expression of the E horizon and the Bf (iron-pan) either broken and within the Bs or cemented and being continuous. The continuous Bf can be seen in detail in Figure 20. Water was found to enter the pit at 60 cm and 80 cm in this plateau area which appears to be a drainage collection area locally (Table 3). The abundant gravels become dominant at this level indicating very little soil matrix and consequent pore space for water holding capacity. The BCx horizon below this is also cemented further preventing water percolation downwards.

Figure 19. Paddock 10, 0843, Stagnic Iron-pan Podzol, series Knockastanna, Loamy over shale bedrock.

The bulk density of the Oa horizon was low at 0.44 g cm^{-3} reflecting the peat dominance of this horizon. No other bulk density measurements were possible due to coarse gragments. The pH has dropped greatly in comparison to paddock 8 with the average pH at 4.9. The E horizon was 4.6 indicating the high acidity and leaching in this soil. Horizon 4 has the highest levels of aluminium on the farm. Again, the phosphorus levels are high with potassium low.

These podzol soils require frequent fertilisation and liming to combat the nutrient deficits and the high acidity, however the peaty top soil is not conducive to machinery traffic. This results in less cuts of silage compared to the rest of the farm. There are also outcrops in the area which again reduce trafficability.

Table 3. Soil description of paddock 10, Ballinagree, Heavy Soil Farm.

Horizon depth (cm)	Horizon designation	Description
20	Oa	Very Dark Grey, no mottles, many fine and medium gravels, Loamy peat, sub-angular blocky, many fine roots. Parts of A hz due to levelling.
40	Eb	Dark Brown, no mottles., abundant gravels, weathered stones, Loam. Sub-angular blocky structure, many fine roots, greasy in places.
60	Bf/Bh	Dark Reddish Brown, cemented iron-pan top of Bs hz. Bh intrusions on LHS. Water entering at 60 cm. Irregular boundary.
40-80	Bs	Dark Brown, few mottles, dominant gravels, abundant stones. Loam, few fine roots. Slightly sticky. Crumbly structure, high packing density, gravel patches. Broken boundary. Water entering pit at 80 cm.
160	BCx	Light Yellowish Brown. No mottles. Indurated, dominant stones and gravels. Sandy Loam. No roots. Massive structure. Weathered stones, non-cemented but compacted. Double iron-pan LHS.

In plateau areas normal management may be applied to be cost effective, however the drainage problems may mean some parts of the farm with podzols are for rough grazing/summer grazing only. With the high coarse fragment content of these soils a cost effective drainage system may not be realised.

Paddock 12 was assigned Gleyic Brown Earth due to the imperfectly drained features of mottling in the auger between 40 and 80 cm depth. This paddock was excavated to represent the soils on the farm with gleying and to gather further data on the Heavy Soil Project drainage system that is in place. On opening up the soil pit it became clear that this was a Surface-water Gley, as gley colours were noted in the matrix within 40 cm of the surface (Figure 21). There were also stagnic channels between 35 cm and 75 cm depth again alluding to periods where preferential flow occurred in these areas during periods of anoxia due to waterlogging (Figure 22).

This soil is poorly drained due to the evidence above indicating long periods of waterlogging. The manganese coats found at the bottom of the BC (Table 4) are further evidence of a fluctuating water table possibly from lateral flow and the manganese coats of the Cr may be as a result of a fluctuating groundwater table. It is clear that there is more than one cause to the waterlogging but the dominant one with the greatest effect on the productivity of the field is the Surface-water stagnation caused by the perched water table. It could also be possible that these gleyic features are remnants of older processes in the soil which have been inverted and in-filled with the normal management of the farm.

Figure 20. The iron-pan continuous dark red line (Bf) appearing at the top of the Bs horizon in Paddock 10. The Eb horizon is found above the Bf.

Figure 21. Paddock 12, 0760, Humic Surface-water Gley, Driminidy, Coarse loamy drift with siliceous stones.

Table 4. Soil description of paddock 12, Ballinagree, Heavy Soil Farm.

Horizon depth (cm)	Horizon designation	Description
30	AC	Dark Greyish Brown, common mottles (A hz.), many gravels, Loam, angular blocky structure. Many fine roots. Old A hz mixed in a the bottom of this hz.
80	BC	Light Olive Grey, many mottles, many gravels, Sandy Loam, angular blocky structure, few fine and few dead roots. Manganese coats most at bottom of hz. High packing density. Irregular boundary.
116	Cr	Light Grey, few mottles, many stones, common gravels. Loam, very few fine and some dead roots. Common manganese coats, discontinuous. Massive structure. Silt lens at 120. Patches of Clay and sand. 2 vertical intrusions compacted. Water entering pit at 140 cm.

Figure 22. Paddock 12 detail of stagnic channels with gleyed centres and iron deposition on edges.

It could also be likely that the recent drainage works have resulted in the inverting of the soil, as is the case with the original A hz being mixed into the current AC at the top of the soil profile. However, none of the new drainage systems were noted within the soil profile pit area.

As is the case throughout the farm, the high stone content means there is little soil matrix for water holding capacity and small amounts of rain can fill the available pore space. The bottom horizon is also compacted allowing for very slow infiltration below 1 metre. The new drainage system designed for the site was to target a highly permeable layer at 1.7 m and exploit the water carrying capacity it has. However there could be great difficulty to get the water to move to this depth without dealing with the compacted layer which will add considerably to costs.

Looking at the laboratory data the pH holds at 5.5 with depth. The profile is not as acidic as the soil at elevation and does not surfer from extreme leaching. There is within profile movements and the precipitated manganese levels are high compared to the other profiles (Appendix). Like the other profiles the phosphorus levels are high and the potassium levels are low. In this particular case the calcium is noticeably lower and the levels of iron and aluminium are much lower. This is possibly due to much less clay in the surface horizons in this profile than in the other two profiles, therefore less small particles available for adsorption for these elements. The AC horizon qualified as humic.

Conclusion

As alluded to earlier, the soil texture class on this farm is rarely Heavy and the dominant soil textures of Loam and Sandy Loam are conducive to good drainage with high porosity. The problem on this farm is the high rainfall filling the low pore space quickly, the permeability of these soils is low and with many soils being shallow over bedrock or indeed lithic, water reaches the surface relatively quickly. Depending on the landscape position, these flushes of water can result in serious problems for particular areas of the farm. The water movement also brings leaching, which accelerates the podzolisation process especially in the more acidic soils in the northern third of the farm.

The lower two thirds of the farm has well to moderately drained Brown Earths and Brown Podzolics which have high productivity. Where there are problems with drainage it is due to landscape changes coupled with local hollows and plains which act as collecting areas. It is testament to the farmer that they have brought the more poorly drained Gleys, Podzols and Lithosols into production and have engaged in the on-going battle with the coarse fragments that increase greatly with elevation on the farm. This process must be cost effective and the performance of the new drainage measures may not be applicable to the more elevated parts of the farm.

The current management regime has a large influence on where a soil is classified at a given time. It is clear into the future that many of the Brown Podzolics and Anthric Brown Earths may return to their pre management states without the breaking of the iron-pans and the turning of the soil. This also keeps back the growth of peat that once covered a majority of the northern third of the farm. The current soil map is available below (Figure 24).

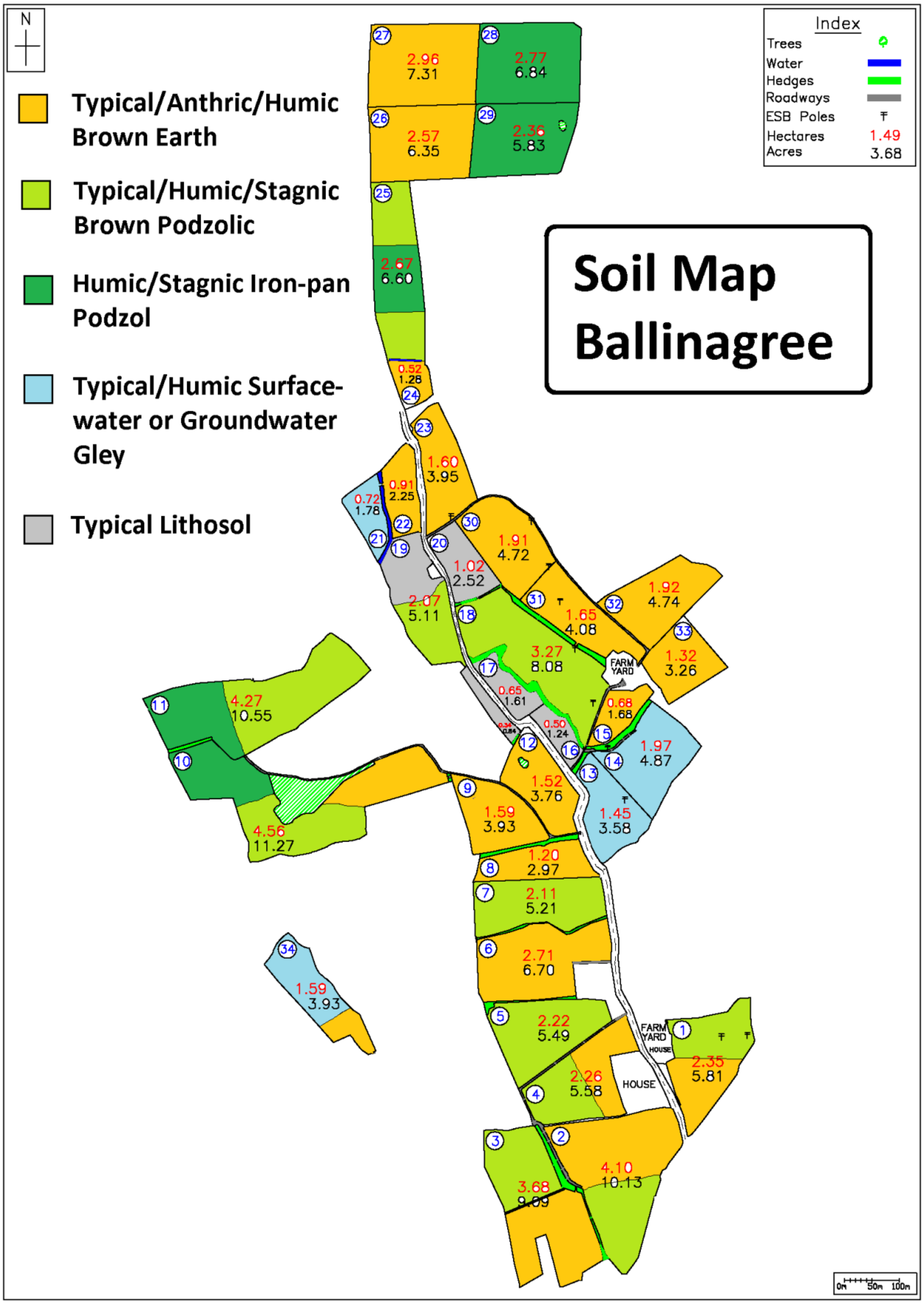

Figure 24. Soil map of the dominant Great Group found within paddocks and parts of paddocks on the Ballinagree Heavy Soil Farm. Resolution 1:5000 approx.

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Appendix.

Table 5. Laboratory data for samples taken from soil pits at Ballinagree HSP farm.

Paddock	Sample	Clay (%)	Silt (%)	Sand (%)	Dry Density	Bulk Density	Gravimetric Moisture	Total Exchange	pH	Organic Matter	Estimated Nitrogen
12	HZ1	15	34	51	1.00	1.49	37.09%	5.98	5.5	7.49	112
12	HZ2	9	31	60	1.64	1.94	14.10%	2.44	5.5	0.68	27
12	HZ3	11	41	48	Too many stones-no samples			2.15	5.6	0.63	25
10	HZ1	30	39	31	0.44	1.09	118.98%	19.94	5.2	35.6	> 130
10	HZ2	21	44	35	Too many stones-no samples			6.33	4.6	8.88	119
10	HZ3	12	20	68	Too many stones-no samples			9.38	5.3	5.5	102
10	HZ4	10	36	54	Too many stones-no samples			3.53	5.4	1.01	40
8	HZ1	20	36	44	0.81	1.30	43.97%	11.45	6.7	9.35	122
8	HZ2	23	43	34	Too many stones-no samples			9.01	6.5	7.32	112
8	HZ3	26	37	37	Too many stones-no samples			9.18	6.6	7.44	112
8	HZ4	10	36	54	Too many stones-no samples			2.75	6.4	1.14	43

Table 5 continued…

Paddock	Sample	S* (ppm)	P* (mg/kg)	Bray II P (mg/kg)	Ca* (mg/kg)	Mg* (mg/kg)	K* (mg/kg)	Na* (mg/kg)	Ca** (%)	Mg** (%)	K** (%)	Na** (%)
12	HZ1	18	98	61	597	62	70	28	49.92	8.64	3	2.04
12	HZ2	24	12	11	209	41	23	25	42.83	14	2.42	4.45
12	HZ3	15	22	24	178	46	20	25	41.4	17.83	2.39	5.06
10	HZ1	18	40	44	1852	131	88	44	46.44	5.47	1.13	0.96
10	HZ2	21	70	14	373	41	48	29	29.46	5.4	1.94	1.99
10	HZ3	59	9	21	1006	16	28	30	53.62	1.42	0.77	1.39
10	HZ4	23	60	77	373	11	20	28	52.83	2.6	1.45	3.45
8	HZ1	20	67	60	1903	65	63	42	83.1	4.73	1.41	1.59
8	HZ2	17	14	13	1407	68	55	35	78.08	6.29	1.57	1.69
8	HZ3	17	166	35	1462	67	67	34	79.63	6.08	1.87	1.61
8	HZ4	14	55	52	397	20	38	26	72.18	6.06	3.54	4.11

Paddock	Sample	Other Bases**(%)	H** (%)	B* (mg/kg)	Fe* (mg/kg)	Mn* (mg/kg)	Cu* (mg/kg)	Zn* (mg/kg)	Al* (mg/kg)	% Fe	% Al
12	HZ1	6.4	30	0.21	180	54	1.55	1.24	908	0.018	0.0908
12	HZ2	6.4	30	< 0.20	41	10	1.25	< 0.4	711	0.0041	0.0711
12	HZ3	6.2	27	< 0.20	54	122	0.8	< 0.4	730	0.0054	0.073
10	HZ1	7	39	0.47	450	30	0.31	3.15	1067	0.045	0.1067
10	HZ2	8.2	53	< 0.20	172	6	3.64	0.53	1537	0.0172	0.1537
10	HZ3	6.8	36	< 0.20	104	21	0.52	< 0.4	2274	0.0104	0.2274
10	HZ4	6.6	33	0.41	91	13	0.45	< 0.4	1750	0.0091	0.175
8	HZ1	4.7	4.5	0.67	267	23	2.2	1.47	788	0.0267	0.0788
8	HZ2	4.9	7.5	0.54	288	14	1.39	< 0.4	920	0.0288	0.092
8	HZ3	4.8	6	0.46	119	13	1.1	0.75	845	0.0119	0.0845
8	HZ4	5	9	0.21	123	8	0.73	0.61	1084	0.0123	0.1084