Soils Report 10, David Brady, Stradone

Introduction

The Heavy Soil Farm at Stradone is a dairy farm of 51.5 hectares. There are 85 cows being milked and there is also a poultry unit on the home farm in egg production. The farm is located in County Cavan, 12 km east of the county town and 10 km west of Bailieborough (Figure 1). Drainage work on farm has changed poor fields grass production from 2 t/ha to 10 t/ha. This extra grass is intended to allow herd expansion to 100 cows. The local phenomenon of "boil ups" where springs appear at the surface are problematic. These features can change yearly following the insertion of shores (sub surface drains) to alleviate the problem and are very localised, ~2-3 m in diameter.

The landscape is marked by the drumlins synonymous with this county and its neighbour Monaghan. The area is drained by many small streams between drumlins which link and diverge regularly. There is a stream running along the north of paddock 40 and then turning south along the eastern border of the paddock and the wooded area. This continues to flow south along paddock 39, 38 and then turning east along the boundary of paddock 37 (Figure 2). The home farm is made up of 36 hectares with two out farms of 7.5 hectares each to the west of it. The two principle tributaries in the area are one which drains into Nadreegeel Lough at Ballyjamesduff and the other which drains into Gallon Lough. Both lakes then drain into Lough Ramor at Virginia and join the River Blackwater system from there.

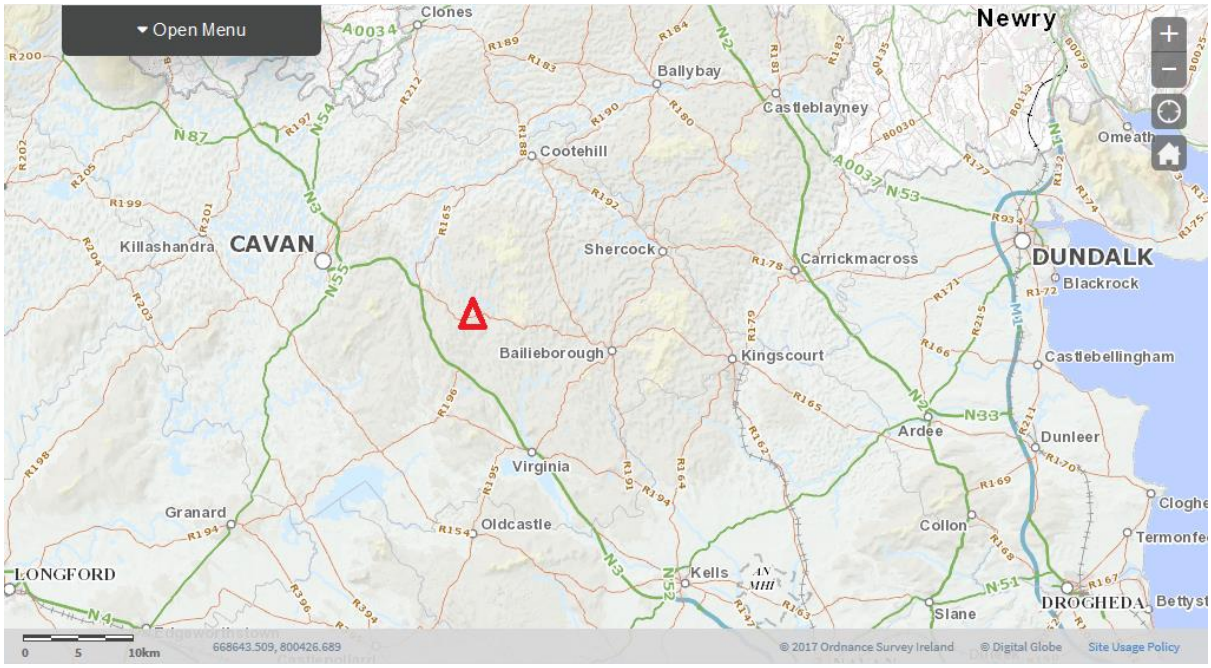

Figure 1. Location of Stradone HSP farm (red triangle), Co. Cavan.

The farm is found on a drumlin belt of between 150 and 200 metres in elevation. This area is east of Cavan town and the village of Stradone marks the beginning of the Drumlin belt. This runs eastwards to the hills greater than 300 metres, to the east again of Bailieborough. There are many small lakes between the drumlins and areas of peat at the foot of the hills. The elevation makes this half of Cavan a degree cooler than the lower lands to the west of the town. Mean yearly rainfall is 1100 mm

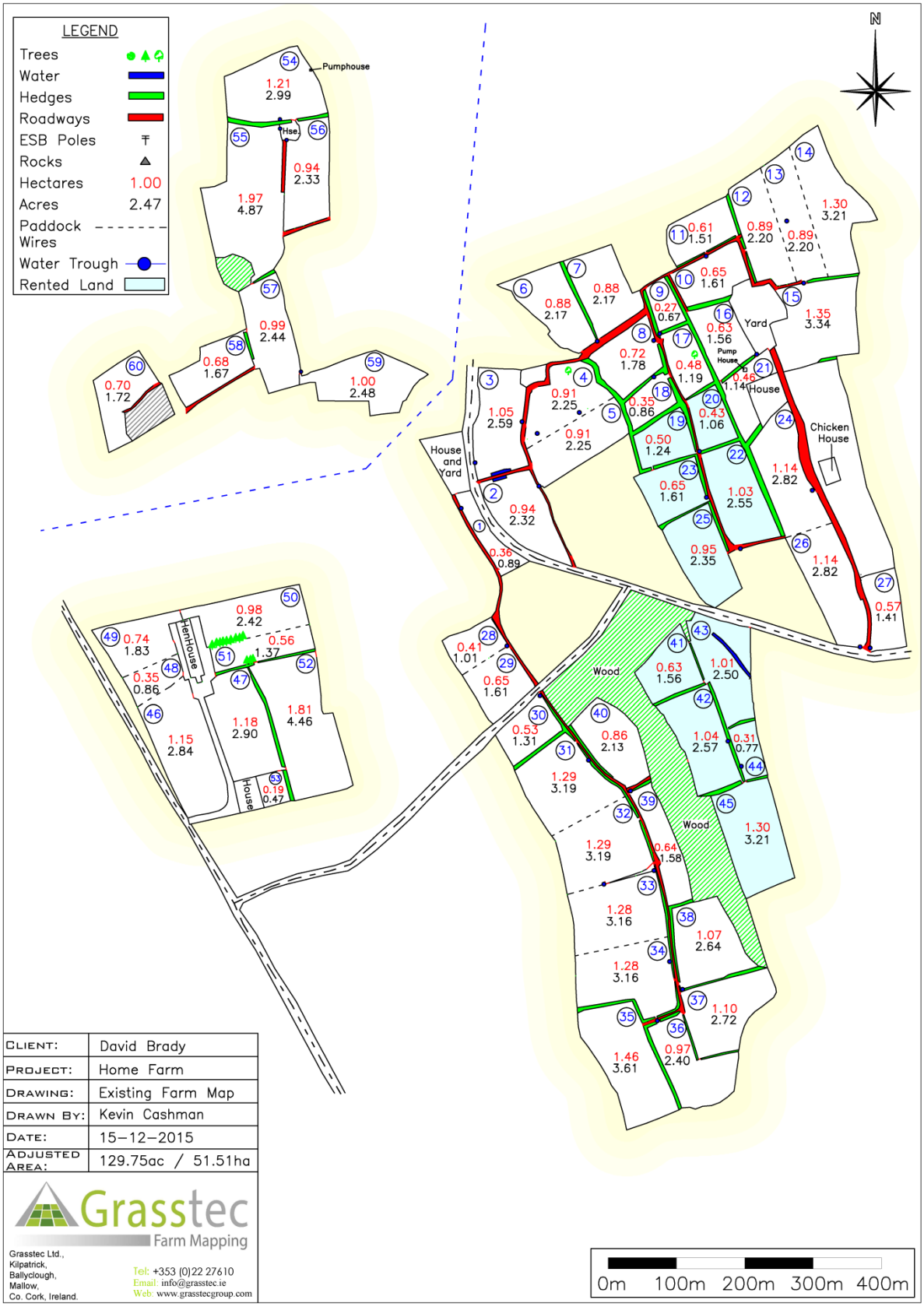

Figure 2. The paddock distribution at the Stradone Heavy Soil Farm.

The bedrock geology of the area is described as the Oghill formation containing massive sandstone and microconglomerate. The sandstone is grey to green-grey, greywacke and there is occasional shale-mudstone. There is turbidite to the south east and black shale to the north east and south west (GSI spatial resources, 2017). There is also an area of rock outcrops in the west of this area, so shallow soils and soils of high coarse fragments are likely to be expected.

The Midlandian glaciation obliterated all the evidence of previous glaciations in Cavan up to the period 11,000 years before present. The drift geology at the site consists of glacial deposits comprising boulder clay with small areas of moraine sands and gravels. This till was deposited by glacial ice. Glacial deposits in the form of drumlins typify the landscape surrounding the study area. Enclosed hollows are found between drumlins giving rise to bogs and small lakes. For this reason, drumlin areas provide a variety of habitats which are of ecological importance.

Drumlins are smooth, oval shaped hills consisting mostly of deposited boulder clay or till. The long-axis runs parallel to the direction of the ice flow with the higher wider 'stoss' side upstream, tapering down to a pointed 'lee' end (West 1968). Thus, the drumlins in this area were formed with the ice moving from north to south direction. Two different types of drumlins occur, rock and till. Till or drift drumlins are comprised of compact, unstratified glacial till or drift. In contrast, rock drumlins are mostly made up of rock core with a concentric covering of drift. Rock drumlins tend to have a slightly better drainage status than till drumlins due to their tendency to have a wider extent of freer-draining soils (Soils of Ireland, in press).

The whole footprint of the farm is a ribbed moraine formation running north to south, with a drumlin in the northern part of the home farm above the R165 and another commencing to the south of this road. There is another drumlin peak in paddock 55 in the out farm. The Geological Survey of Ireland quaternary map, predicts the area would be covered in till derived from Lower Palaeozoic sandstones and shales (GSI, 2017). Cut over raised peat is predicted in the toe slopes in the northern drumlin in parts of paddock 14 and 15. The southern drumlin has peat predicted in paddocks 43, 44 and part of 45. Peat would also be predicted along the western boundary of paddocks 30 to 33, which eventually gives way to alluvium in paddocks 34 and 35. In both out farms there is a sub-glacial lineation indicating a crag and tail formation. Here the glacier has removed most of the soil in a north south direction and has exposed bedrock at the surfaces. Shallow soils are predicted to be found in these areas along with rock outcrops.

Further afield there is cut over raised peat in the foothills of the drumlin connecting from the north to Tirlahode lough. This peat is found once again to the south of the road and much of this area is now conifer plantation corresponding to the peat dominated areas.

Historical soil information

County Cavan did not have a National Soil Survey report or map published for the area. As part of the An Forais Talúntais general soils map of Ireland (1980) a reconnaissance survey of the area was carried out. Consequently, it was mapped indicating the county to be composed of acid brown earthy soils with inter-drumlin peat and peaty gleys. These soils were reported as having formed mainly from shale drift from gravels of mixed origin. Brown earths were described as mature, well-drained, mineral soils that have a relatively uniform profile. These soils are acidic in nature as they occur on lime-deficient parent material. They have a medium texture of sandy loam, loam and sandy

clay loam. Brown earth soils are extensively cultivated soils owing to their texture and good drainage characteristics. Peaty gleys are poorly drained soils with a low base status. The weak structure of the mineral profile and the high silt content of these soils are mainly responsible for the poor drainage. McCabe and Collins (1977) found five great soil groups within one drumlin in Co. Cavan: Brown Earths; Brown Podzolics; Luvisols; Groundwater Gley and Surface-water Gley. This is testament to the complexity of the soil formation in this area and combination of soil slope and topsoil depth leading to heterogeneity. The local name of "channel" referred to in this paper relates to the fragipan characteristics found in the area due to a compacted subsoil, with very little permeability.

The Irish Soil Information System (Irish SIS, Creamer et al 2014), is now the primary resource available for soils in this area. In the map viewer, there are two soil associations dominating the area. The first is described in a polygon on the northern side of the R165 (Figure 3 a), Kilrush, a Typical Surface-water Gley. Within this association there are 2 more Surface-water Gleys; series Driminidy and Gortaclareen, 3 Groundwater Gleys; series Tourmakeady, Heathtown and Corlea. There is also drained fen peat, Banagher and Blanket peat, Aughty. And a Luvisol Dunboyne.

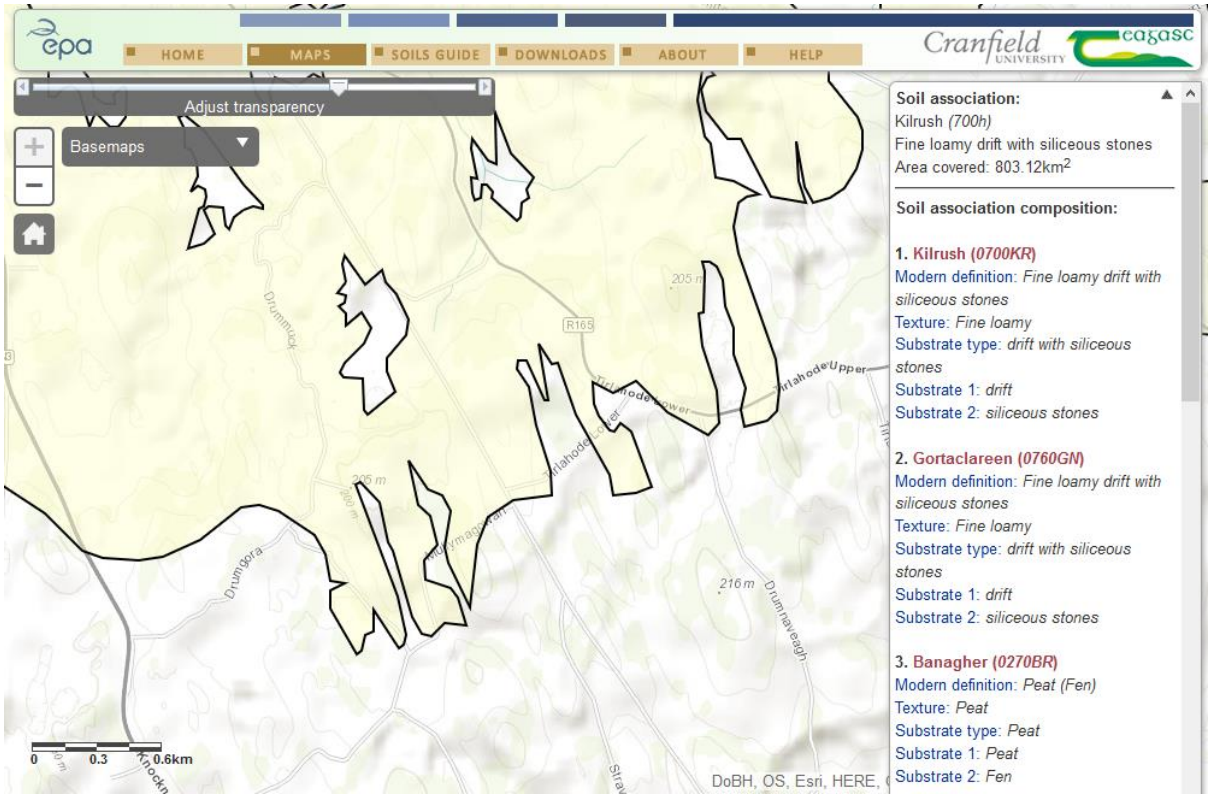

Figure 3 a. The Kilrush soil association dominating the farm north of the R165.

The second polygon is to the south of the R165, the soil association Moord dominates the area (Figure 3 b). It contains two Brown Earth series, Brosna and Gneaves. It also has two Surface-water Gleys, Kilrush and Gortaclareen. It also contains one Luvisol, series Dunboyne. A peat polygon is described along the east flank of the home farm, which then crosses the R165 (Figure 3 c). Here it covers paddocks 39 to 45. It likely that this is raised peat due to the number of small lakes and streams in the area. This indicates a shallow groundwater table predominates at the toe slopes of the drumlins and hills of the area. In many cases this peat may be of fen origin associated with the shores of these lakes and the banks along the stream channels.

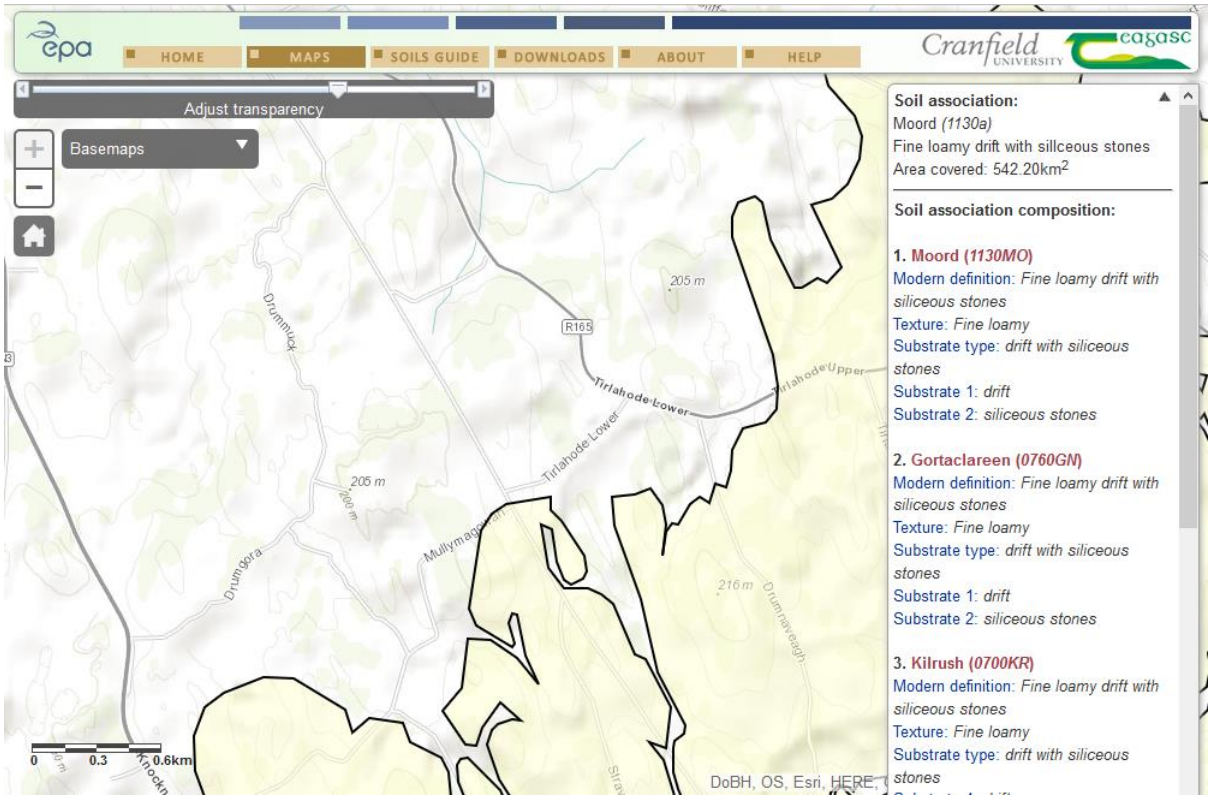

Figure 3 b. The Moord soil association dominating the area of the farm south of the R165.

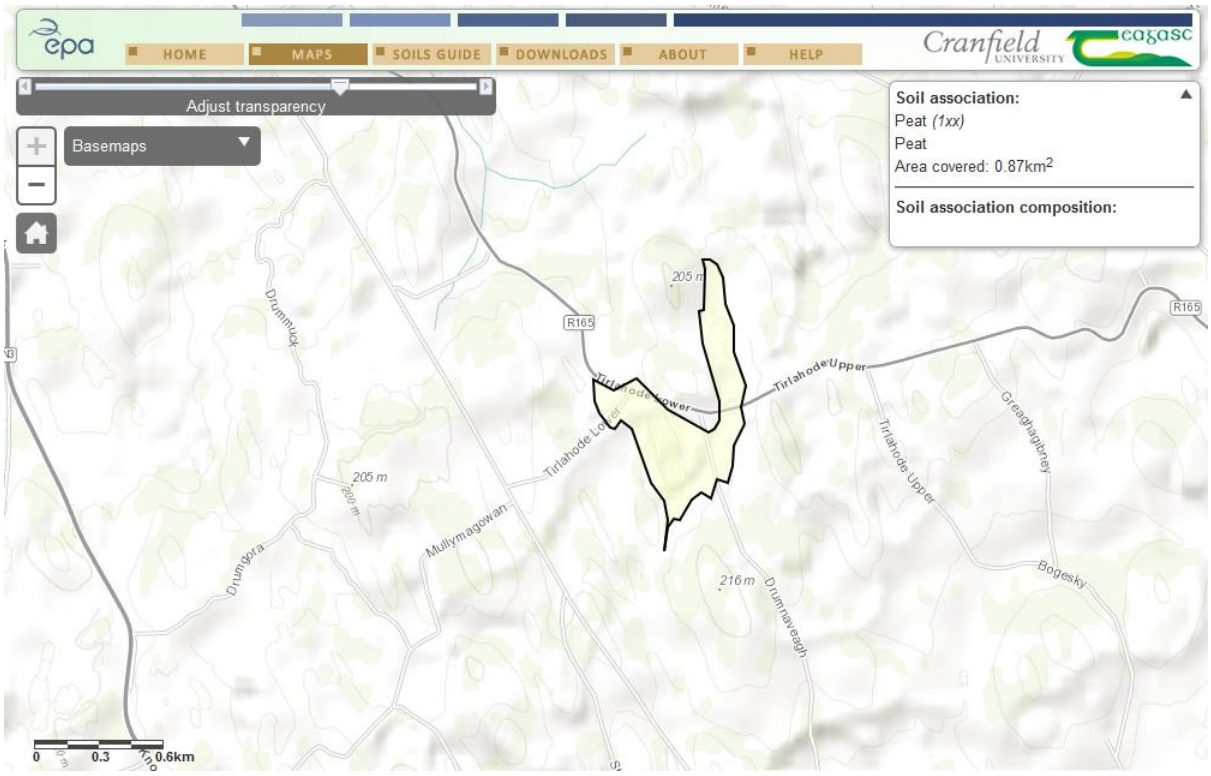

Figure 3 c. Peat found immediately south of the R165 and along paddocks 14, 15 and 27.

Auger campaign

Method

An auger bore was carried out on average every hectare to investigate the soil physical features. In practice, more augers were used based on landscape complexity. Their resulting distribution was a relatively even coverage in each part of the farm (Figure 4 a and b). 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).

Figure 4. Auger point distribution across the Stradone Heavy Soil Farm.

Brown Earths

There are 62 auger records for this farm and almost half are designated to the soil Great Group, Brown Earths (29 records). There are 16 Stagnic Brown Earths where water is impeded from flowing downwards due to increases in clay or silt levels in the B horizon. The stagnation may also occur due to many or abundant coarse fragments (gravels & stones) impeding water movement. Here some

mottles form after the water eventually percolates downwards, however this is never severe enough to create a gleyed horizon at this depth. Where this occurs on drift it is soil series Moord (7 records) and over bedrock it is named series Duarrigle (Figure 5, 9 records). There are also 13 Typical Brown Earths where there is no water restriction (well drained). These relatively young soils are very good for productivity as they have a good balance between pore space to allow drainage and loam texture allowing retention of high nutrient status (Figure 6). There are 5 soil series, Ballylanders occurring over shale bedrock with fine loamy texture. Four occurring over shale bedrock with coarse loamy textures, soil series Kells. There are three of soil series, Clonroche, fine loamy drift over siliceous stones. There is one Typical Brown Earth with silty texture on shale bedrock, soil series Knockreagh.

Figure 5. Paddock 12 A. Stagnic Brown Earth (11.3.0), soil series Duarrigle. A shallow soil over shale bedrock. Looking northwards on the crest of a drumlin.

Surface-water Gleys

There are 14 auger records for this farm which fall under the soil Great Group of Surface-water Gleys. These soils have a Btg horizon where there was an increase in clay due to illuviation but there was also an increase in mottling and a gleying of the horizon. The increase in clay is leading to stagnation of water on a regular basis (poorly drained). The amounts of water falling in rainfall regularly exceed the percolating capacity of the soil pore space. This can be described as a perched water table, found much closer to the surface than the actual groundwater table. These soils are known as the soil series Kilrush when the drift is fine loamy and 80 cm depth and deeper (Figure 7, 8 augers) and soil series Coolykereen when the drift is silty in nature (Figure 8, 4 augers).

One of the augers had a silty texture but was over bedrock, series Lismeelcunnin. This was in paddock 40 close to the fen peat and possibly previously of alluvial origin. One auger was series Ballyphilip which is derived from igneous and metamorphic drift that may be formed in turbidite drift found to the north east of the farm.

Figure 6. Paddock 57. Typical Brown Earth (11.0.0), soil series Ballylanders, looking south to the crest of the Drumlin.

Figure 7 Paddock 6a and 22. Both Typical Surface-water Gley (07.0.0), soil series Kilrush. This soil was common at shallow inclines from mid slope to lower slope.

Alluvial Soils

There are 10 augers on the farm described as alluvial soils, indicating their origin is from deposition via river or lake. Five of the augers are described as Typical Alluvial Soils, where there is gleying within 40 cm of the surface. Here the shallow groundwater table rises regularly and gleyic features become apparent in the sub-surface horizons, such as common to many mottles in a grey matrix. There may also be surface stagnation due to texture/coarse fragments. Where the deposition is loamy, the series is Lyre (river) or Gurteen (lake, Figure 9). If there is a histic or humic surface horizon the soil was designated to the series Ardglass, loamy lake alluvium (Figure 10 and 11). In this case there is a build-up of organic material at the surface. This is due to a reduction of the

breakdown of organic material due to anaerobic conditions where only specialist microbes can consume the material. It also creates more resistant biproducts of microbial digestion. Therefore, litter and humus begin to accumulate. There is one soils series Suir (paddock 3 b), where this silty river alluvium has been drained successfully and there no longer is extensive gleying, a Typical Drained Alluvial Soil.

Figure 8. Paddock 48 & 50. Typical Surface-water Gley (07.0.0), soil series Coolykereen. Found on the upper slopes at low inclines on the out-farm.

Figure 9. Paddock 24 a. Typical Alluvial Soil (05.0.0), soil series Gurteen. Pond area at low/toe slope. Recent drainage has occurred, and this may become a Drained Alluvial Soil (05.7.0) in time.

Figure 10. Paddock 30. Humic Alluvial Soil (05.6.0), soil series Ardglass. Pond area in background.

Figure 11. Paddock 37. Recently drained Humic Alluvial Soil, Ardglass, may become Clohamon soil series in time, at toe slope along stream bank.

Luvisol

There are 5 Luvisols on the farm. Luvisols are where there is a distinct increase in clay content within 30 cm of the surface. The illuviation process has leached clay from the surface layer, these soils also tend to be decalcified. Generally, these soils are still highly productive and have good drainage. These soils were found mid slope on the farm and had fine loamy textures. Two were soil series Dromkeen found over shale bedrock. One in drift, series Dunboyne (Figure 12). These three were Typical Luvisols that were well drained on shallow inclines. Two Luvisols had drainage restrictions and were found on inclines closer to 10 degrees, usually upslope of Surface-water Gleys. Soil series Crosstown found in paddock 54 had common mottles above 40 cm indicating periods of stagnation

(Figure 12). Soil series Ballyduff, found in paddock 4, had stagnic and humic features and would be described as imperfectly to poorly drained. It is likely if left in its current status it will develop pedo-genetically in time to become a Surface-water Gley without appropriate measures.

Figure 12. Paddock 11. Typical Luvisol (10.0.0), series Dunboyne. Paddock 54. Stagnic Luvisol (10.3.0), Crosstown.

Other soils

The remainder of the soils on the farm were described as Drained Minerotrophic Peat soils (02.7.0), series Banagher. This was found in paddocks 14 and 43 and remains poorly drained despite having been drained in the past. The waterlogging caused by the fens in these areas continues and peat formation still occurs in the anaerobic conditions. Parts of other paddocks may have been drained more efficiently and the peat accumulation has been restricted as a result. Large parts of the old fens have been afforested with conifers.

There is one Humic Groundwater Gley (06.6.0), series Tourmakeady. Here the groundwater table is regularly close to the surface causing gleying in the subsurface horizons. This causes anaerobic conditions which has promoted the growth of a humic layer at the surface. This paddock (27) is poorly drained.

There were two Typical Brown Podzolics (09.0.0), series Cupidstownhill described in the auger campaign, paddocks 2 and 5 (Figure 13). Here there is an increase in iron and/or aluminium content at depth to be designated a Bs horizon. In this case the iron increase was in a BC horizon which felt very greasy compared to the Ap horizon above it. This is an indication of increased iron content. However, this Bs horizon was found just above a fragic (compacted) C horizon and this restricts the productivity more than the iron increase in the medium to long term.

Conclusion

In general, the soils on the crest and upper/medium slopes on this farm are well to moderately drained. These are likely to be Brown Earths and Luvisols and stagnic versions of the same due to the high rainfall and compacted, high coarse fragments contents of the soils. These soils do not tend to have a shallow groundwater table and most water movement is the sub soil it lateral. As we move down the slopes and the inclines become shallower, the stagnation becomes worse and Surface-

water Gleys begin to dominate. In pooling areas Alluvial soils appear both these great soil groups are poorly or imperfectly drained.

The heavy textures dominated by silt and clay prevent and relief from water infiltration and in some cases humic material begins to accumulate. Other alluvial soils develop along the channels of streams and in some cases peat has developed over time in these areas and along the shores of the ponds/lakes. This was evident in many augers (14) where the water-table was found within 60 cm of the surface despite many weeks without rain at the time of sampling. There was one area where podzolization was evident in parts of paddocks 2,4 and 5. This particularly shallow area had Brown Podzolic soils where iron was evident in the B horizons. This is not a good sign for productivity however, the shallow bedrock was more of a problem in relation to drainage inhibiting growth in these areas, still new drainage has allowed increased grass growth.

The shallow bedrock was found in 37 augers and in 13 of these a fragipan was recorded. This compacted layer is almost cemented and allows very little water movement through it. Due to the shallow nature of this layer of 50 cm with high coarse fragments there is very little soil in the horizons, this leads to poor drainage (Table 1). As a consequence, the soil pore space fills quickly and water stagnates at the surface readily. If rainfall levels increase in this area, more of the soils as you move upslope will become problematic in regard to drainage.

In Table 1, the soils found on the farm are listed along with their drainage status. Poorly drained soils dominate the augers with almost half in this class (27). The next group is the well-drained status of 18 records. Moderately drained described 15 records and two were imperfectly drained.

Figure 13. Paddock 5. Typical Brown Podzolic (09.0.0), series Cupidstownhill. This area has been reclaimed, reseeded and a new drainage system has been installed recently.

Table 1. Field observations of soil type during the auger campaign on Stradone 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
30	05.6.0	Ardglass	Poorly
31	05.6.0	Ardglass	Poorly
32	05.0.0	Gurteen	Poorly
33	05.6.0	Ardglass	Poorly
34 a	10.0.0	Dromkeen	Well
34 b	11.3.0	Duarrigle	Moderately
35	11.3.0	Duarrigle	Moderately
36	11.0.0	Ballylanders	Well
37 a	11.0.0	Ballylanders	Well
37 b	05.6.0	Ardglass	Poorly
38	07.0.0	Kilrush	Poorly
39	05.0.0	Lyre	Poorly
40	07.0.0	Lismeelcunnin	Poorly
42	11.0.0	Kells	Well
45	11.0.0	Ballylanders	Well
43	02.7.0	Banagher	Poorly
41	11.0.0	Kells	Well
29	11.0.0	Kells	Well
1	11.0.0	Kells	Well
46	07.0.0	Coolykereen	Poorly
47	11.0.0	Clonroche	Well
48	07.0.0	Coolykereen	Poorly
50 a	07.0.0	Coolykereen	Poorly
50 b	11.3.0	Knockreagh	Moderately
60	11.0.0	Ballylanders	Well
58	11.3.0	Duarrigle	Moderately
57	11.0.0	Ballylanders	Well
59	07.0.0	Coolykereen	Poorly
55	11.3.0	Duarrigle	Moderately
56	11.3.0	Moord	Moderately
54	11.3.0	Moord	Moderately
12 a	11.3.0	Duarrigle	Moderately
12 b	11.3.0	Duarrigle	Moderately
14	02.7.0	Banagher	Poorly
15	11.3.0	Duarrigle	Moderately
21 a	11.3.0	Ballylanders	Moderately
21 b	11.3.0	Duarrigle	Moderately
16	10.3.0	Crosstown	Moderately
10	10.0.0	Dromkeen	Well
11	10.0.0	Dunboyne	Well

Paddock	Subgroup	Series Name	Drainage Class
9	07.0.0	Kilrush	Poorly
17	11.0.0	Clonroche	Well
20	07.0.0	Kilrush	Poorly
22	07.0.0	Kilrush	Poorly
25	11.0.0	Clonroche	Well
23	07.0.0	Kilrush	Poorly
19	07.0.0	Kilrush	Poorly
18	05.0.0	Lyre	Poorly
8	11.3.0	Duarrigle	Moderately
6 a	07.0.0	Kilrush	Poorly
6 b	05.0.0	Lyre	Poorly
7 a	07.0.0	Ballyphilip	Poorly
7 b	11.0.0	Clonroche	Well
4	10.6.0	Ballyduff	Imperfectly
5	09.0.0	Cupidstownhill	Well
3 b	05.7.0	Suir	Poorly
3 a	11.3.0	Moord	Moderately
2	09.0.0	Cupidstownhill	Well
24 a	05.0.0	Gurteen	Poorly
26 a	07.0.0	Kilrush	Poorly
26 b	11.3.6	Gneaves	Imperfectly
27	06.6.0	Tourmakeady	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 any significant drainage restrictions throughout the farm (Figure 14). Paddock 39 was selected to represent the Drained Alluvial Soils on the farm that are poorly drained. Paddock 13 was selected to represent the Stagnic Brown Earth soils on the farm that maybe well to imperfectly drained. Paddock 20 was selected to represent the Typical Surface-water Gleys, having poor drainage. The excavation of a soil profile pit coupled with detailed chemical and physical tests will give a clearer picture of the soil formation, productivity, drainage and classification. The results may contrast in some cases but ultimately enhance the auger survey covering the whole farm area.

Figure 14. Location of the soil profile pits on the Stradone, Heavy Soil Farm.

The profile pit excavated in paddock 39 was a Humic Alluvial Soil (05.6.0), soil series Ardglass, Loamy Lake Alluvium. Looking at figure 15, many layers can be seen down through the profile. The changes are abrupt occurring every 10-15 cm depth. This is very characteristic of alluvial deposition. The texture can change readily between these horizons and the stone content also changes with water sorting. In the recent past this area has had soil additions which have been dug into the surface horizons (BOC). Drainage has also been implemented allowing for the compaction and shrinkage of the original O horizon (Figure 16). This soil is now likely to perform as a Drained Alluvial Soil (05.7.0) into the future with these drainage measures and the final breakdown of the O material. Currently the A horizon qualifies as humic due to organic matter content.

Figure 15. Paddock 39. Humic Alluvial Soil (05.6.0), series Arglass. Loamy lake alluvium.

Figure 16. Water infiltration into pit via root channel at 40 cm depth. Remnant of drained organic horizon, compacted at 20 cm depth. Added material containing previous C horizon at the surface.

There is a lake bed deposit in the bottom horizon 2C (Table 2) which indicates a far greater lake system in the past. This area may have alternated between lake and river conditions in the past and then eventually became dominated by peat with reduced water flow.

With the compaction described in horizon 2 and 3, downward water flow is highly restricted. Movement was possible only via preferential flow pathways in stagnic channels (Figure 17). The central part of the channel is waterlogged for extended periods and has become completely gleyed. With the return of oxygen iron is deposited on the walls of the channel to give the distinctive red colour.

Figure 17. Detail of the stagnic channels found in the lower horizons of paddock 39.

Table 2. Soil profile description of paddock 39, Stradone Heavy Soil farm.

Horizon depth (cm)	Horizon designation	Description
16	Ap	Brown, few mottles, common gravels, Clay Loam, many fine roots, sub angular blocky structure. Compacted due to poaching/machinery. Wet.
35	BOC	Greyish Brown, common mottles, common gravels, Loam, few fine roots, sub angular blocky. Compacted machinery, irregular boundary, C is silty clay. Coarse clods of C and O mixed into horizon.
80	Cg1	Greyish Brown, many and abundant strong brown and yellow red mottles, common angular gravels, Sandy clay loam, very few fine roots, few iron coats. Massive, water entering at 70 cm,
105	Cg2	Brown, common olive mottles, abundant gravels, Clay Loam, massive. Fragipan, compacted, could not disturb with spade.
130	2c	Dark Greenish Grey, Clay Loam. Lithological discontinuity. Previous deposition of lake bed.

Paddock 13 was selected to represent the Stagnic Brown Earths (11.3.0) on the farm. This soil is relatively free draining in the two upper horizons of the soil profile Ap and Bwg (Table 3). Despite the mottling the matrix of the soil is not showing signs of gleying. The soil drains laterally downslope with moderate rainfall. When there are extended periods of rain, the soil pore space is filled, and no water can penetrate downwards through the fragipan found in horizon C. As a result, manganese deposition is evident in parts of the B horizon. This compaction is due to the abundant gravels in the

C horizon with very little soil matrix present. This is likely to have developed with the passing of the glacier when the drumlin formation was occurring. If rainfall amounts are to increase as predicted into the future this fragipan will become more problematic. The boil ups were noticed in this area of the farm, and are more likely to occur where the fragipan is closer to the surface. The A horizon qualifies as humic possibly due to recent manure additions.

Figure 18 Paddock 13. Stagnic Brown Earth (11.3.0) series Moord, fine loamy drift with siliceous stones.

Table 3. Soil profile description of paddock 13, Stradone Heavy Soil Farm.

Horizon depth (cm)	Horizon designation	Description
28	Ap	Dark Greyish Brown, common root mottles, common gravels, Loam, common fine roots. Sub angular blocky structure.
44	Bwg	Brown, common mottles, common gravels, Clay Loam, few fine roots, few manganese coats. Sub angular blocky, more stagnation on RHS.
140	Cg	Dark Grey. Many and abundant mottles, brown and yellow red. Many and abundant stones. Clay loam, firm, very few roots, massive. Fragipan.

The soil profile pit excavated in paddock 20 was to represent the Typical Surface-water Gley soils found on the farm (Figure 19). This soil profile has a gleyed horizon commencing at 29 cm where there is a Bg horizon that grades into a Cg horizon to become designated BCg overall. This horizon is to 78 cm depth. The mottling is abundant and roots struggle to grow at this depth (Table 4).

Figure 19 Paddock 20. Humic Surface-water Gley (07.6.0), series Gortaclareen, fine loamy drift with siliceous stones.

Figure 20. Detail of the transition from the gleyed BC to the intensely gleyed CG, in paddock 20 of the Stradone Heavy Soil farm.

There has not been an increase in clay at this depth to give rise to the stagnation. It is more than likely caused by a combination of lateral water flow in the subsoil downhill and a raising of the shallow groundwater table. Following periods of heavy rain, the limited soil pore space of the soil matrix is filled. The gravel and stone content do not allow water retention and the fragipan does not allow further downwards movement. This water stays in situ and stagnates. The distinctive manganese coasts are found in this BCg horizon due to anaerobic microbial respiration in the presence of high organic matter content.

Table 4. Soil description of paddock 20, Stradone Heavy Soil Farm.

Horizon depth (cm)	Horizon designation	Description
28	Apg	Dark Greyish Brown, common mottles, common gravels, Loam, common fine roots, sub angular blocky structure. Manure additions.
78	BCg	Brown, light grey grey and strong brown abundant mottles, common gravels and few stones. Clay Loam, very few fine roots. Common manganese coats. Slightly plastic and sticky, changing textures, few coarse dead roots. Massive in places, weathered stones.
130	CG	Light Bluish Grey, very few mottles, many gravels, common stones, Sandy Clay Loam, Massive, fragipan. Compacted, fine and coarse dead roots. Weathered stones.

The local phenomenon of “boil ups” or springs were found on the southern side of this field. As stated before, where the fragipan occurs closer to the surface this water may arrive under pressure at the surface. Sub-surface drains or “shores” were being excavated on the day of the profile pit survey. The water readily flowed in these drains and the soil matrix was saturated from the surface to the point where the 2 to 3 metre radius of the boil up, quaked when pressure was applied.

The third horizon the CG is an intensely gleyed horizon under reduced conditions. This is a partially ripened sediment that contains relatively high organic matter content and has remained waterlogged most of the time since deposition. The weathered stones also support the age of the profile at this depth, as they have broken down in situ. The presence of fine and coarse roots indicate that at one point it could support higher vegetation, but this ended abruptly and the roots were preserved in situ. It is possible that this was in an area of transition into a lake sediment, like a shoreline for example.

This profile was considered the Typical example of Surface-water Gley however, the laboratory data indicated high organic matter and therefore it qualifies as the Humic variant, soil series Gortaclareen. Again, this could be due to the spreading of hen manure throughout the farm.

Conclusion

Almost half of the soils on this farm are described as poorly drained, this includes the Surface-water Gleys, the Alluvial soils and the peat. These soils tend to be waterlogged for extended periods (over 3 days) at numerous points throughout the year. Over a quarter are considered well drained where the rainfall can be managed by the soil allowing a good balance between water holding capacity and the through put of the water down the profile (hydraulic conductivity). It is not excessively drained where the nutrients are lost with the water going through the profile and nutrient retention is good to allow high productivity. The water does not regularly remain throughout the profile for periods longer than three days. These soils are the Brown Earths and the Luvisols and to a lesser extent the Brown Podzolics. The remaining soils, just under a quarter of the farm are described as moderately drained, these are the stagnic and gleyic sub groups of the great groups listed above. There are periods where the water can stagnate during the year and mottles develop. There is no gleying of the horizons at this point but it could happen in the future. The accurate drainage of these soil types allows for good productivity and this is why the management on this farm has reaped the rewards of increase grass tonnage per hectare. If there is a humic surface horizon, then these soils are considered imperfectly drained.

The bulk density levels increase to 1.5 g cm^{-3} or higher in all 3 profiles (appendix) reflecting the lack of pore space and the predominance of fragipans at depth. With increasing rainfall this could become more of a challenge for the soils water holding capacity and the drainage regime. The low bulk density of horizon 1 in paddock 39 (0.5 g cm^{-3}) reflects the mixing of the organic peat into the A horizon. The pH became more acidic in paddocks 39 and 13 but increased with depth for paddock 20. Perhaps in the past this deposit at depth was from a limestone area and has not become decalcified over time. The Ca levels are reflected in the appendix. This profile had more bases available at depth generally. The phosphorus levels were moderate in the Brown Earth, were high in the Surface-water Gley and were very high in the Alluvial soil. The potassium levels were moderate to high for the Gley and Brown Earth, but again were very high for the Alluvial Soil. These levels may reflect relatively recent manure spreading on the farm.

The soil map of the farm in figure 21 indicates the soil great group throughout the paddocks. The general trend is for Brown Earths and Luvisols to occur in the upper slopes of the farm. As the slope incline decreases, Surface-water Gleys become more common. The Alluvial soils are found in hollows between hills and the lower side of stream areas. These areas may have Groundwater Gleys present also. The peat soils are also found in these areas (greater than 40 cm of peat at the surface). If the peat has been cut-over or drained, the soils may now be described as Alluvial or Gleys corresponding to the original mineral material at depth. There is one area of Brown Podzolics with shallow soils between two drumlins in a mini plateau.

Overall on this farm drainage is key to prevent humic and histic accumulation restarting. It also is needed to deal with the “channel”, the fragipan, which can occur at shallow depths. The “boil ups” or springs associated with this are a particular management concern given their random changing nature. It was evident that the farmer took on this challenge and was determined to use specific drainage to alleviate the problem rather than a standard drainage design.

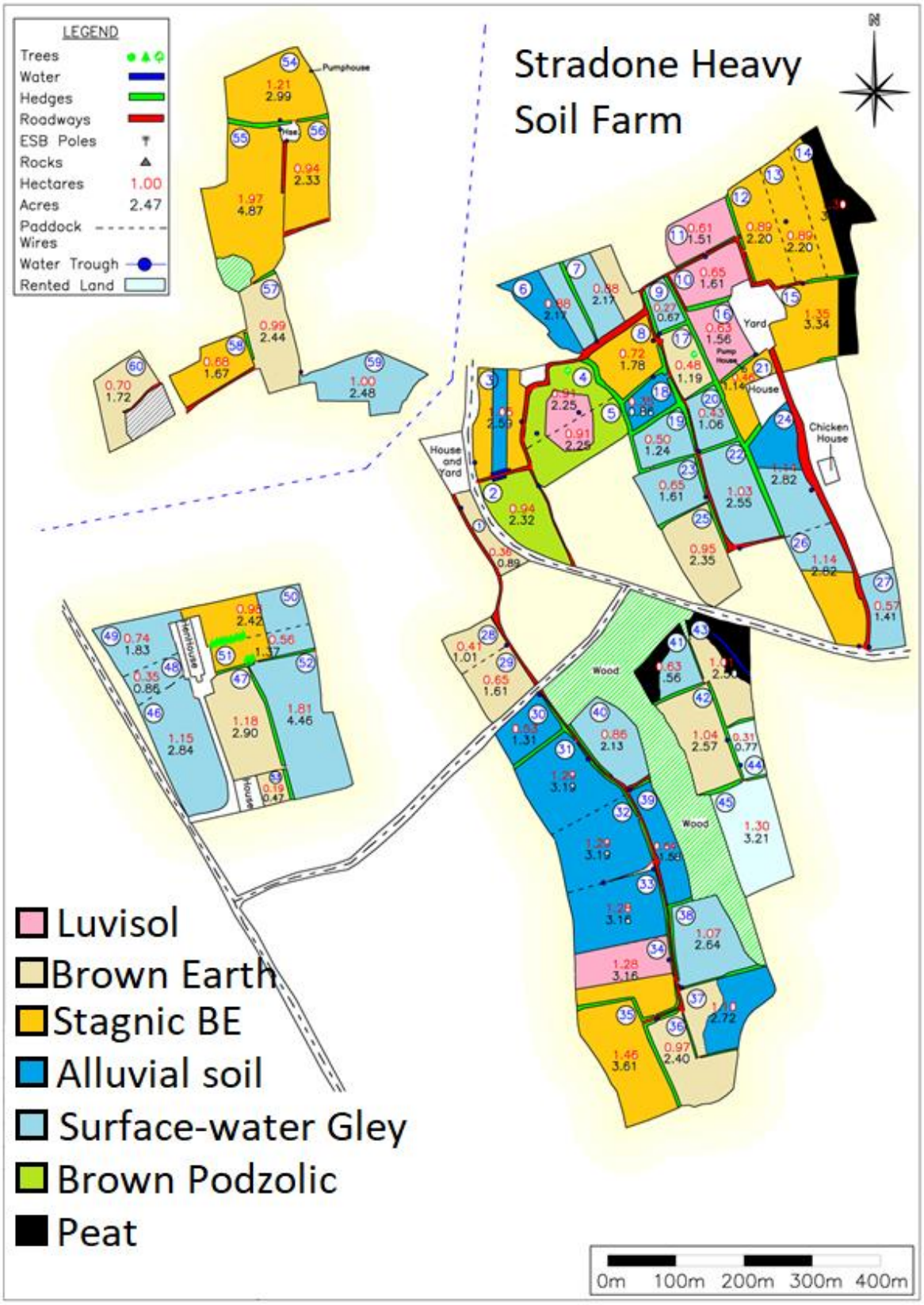

Figure 21. Soil map of the dominant Great Group found within paddocks and parts of paddocks on the Stradone Heavy Soil Farm. Resolution 1:5000 approx.

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Appendix.

Table 5. Laboratory data for samples taken from soil pits at Stradone Heavy Soil Farm.

Paddock	Sample	Clay (%)	Silt (%)	Sand (%)	Dry Density (g/cm^3)	Bulk Density (g/cm^3)	Gravimetric Moisture Content (%)	Total Exchange Capacity (meq/100 g)	pH	Organic Matter (%)	Estimated Nitrogen Release (#'s N/acre)
39	HZ1	30	37	33	0.51	1.28	143.77%	13.22	6.5	21.78	> 130
39	HZ2	26	40	34	1.21	1.71	36.26%	6.56	5.3	7.33	112
39	HZ3	18	37	45	1.60	1.95	17.49%	3.87	5.2	1.25	45
20	HZ1	28	36	36	0.97	1.49	47.08%	7.43	5.8	10.02	125
20	HZ2	24	35	41	1.47	1.92	29.51%	8.39	6.2	1.76	55
20	HZ3	17	35	48	1.73	2.10	20.41%	8.98	6.5	1.41	48
13	HZ1	33	38	29	0.89	1.43	57.71%	11.41	6.7	10.57	125
13	HZ2	24	36	40	1.19	1.64	31.02%	5.32	6.4	3.24	82
13	HZ3	31	34	35	1.56	1.84	15.47%	14.9	5.3	1.47	49

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** (%)
39	HZ1	22	135	133	1728	189	455	46	65.36	11.91	8.83	1.51
39	HZ2	16	24	40	551	57	146	34	42	7.24	5.71	2.25
39	HZ3	15	65	83	245	67	65	32	31.65	14.43	4.31	3.6
20	HZ1	20	46	54	811	91	179	39	54.58	10.21	6.18	2.28
20	HZ2	8	2	1	1013	197	34	35	60.37	19.57	1.04	1.81
20	HZ3	11	1	65	1256	160	36	38	69.93	14.85	1.03	1.84
13	HZ1	13	29	30	1833	94	100	36	80.32	6.87	2.25	1.37
13	HZ2	18	11	12	781	44	66	31	73.4	6.89	3.18	2.53
13	HZ3	20	9	9	798	499	62	49	26.78	27.91	1.07	1.43

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
39	HZ1	4.9	7.5	0.64	306	21	3.01	5.26	1043	0.0306	0.1043
39	HZ2	6.8	36	0.36	415	40	2.73	1.76	1721	0.0415	0.1721
39	HZ3	7	39	0.26	369	42	6.72	3.54	1264	0.0369	0.1264
20	HZ1	5.8	21	0.35	361	36	6.42	2.68	1061	0.0361	0.1061
20	HZ2	5.2	12	< 0.20	100	124	2.3	0.69	769	0.01	0.0769
20	HZ3	4.9	7.5	0.42	537	39	4.51	1.58	598	0.0537	0.0598
13	HZ1	4.7	4.5	0.58	236	32	6.79	1.51	780	0.0236	0.078
13	HZ2	5	9	0.23	209	30	2.04	0.53	1247	0.0209	0.1247
13	HZ3	6.8	36	0.28	182	56	2.38	1.25	976	0.0182	0.0976