Soils Report 8, Alan Wood, Crossmolina

Introduction

The Heavy Soil Farm at Crossmolina is a beef farm made up of 50 suckler cows including a herd of 15 pedigree Charolais cows. It is located 2 km to the south of Crossmolina, itself 10 km west of Ballina Co. Mayo (Figure 1). The farm is made up of a home farm ~ 32 hectares (Mullenmore) and an out farm ~22 hectares (Longford), on the northwest and northern banks of Lough Conn respectively (Figure 2 a and b). The landscape is low in elevation, with ranges between 0 (lake shore) to 22 m on the hills and the largest incline is 5 degrees. The small hills are found on the Mullenmore part of the farm to the south and south west. Large areas are alluvial floodplains which may be inundated at high lake water levels on both parts of the farm. The River Deel runs 2 km away to the west northwest of Mullenmore and 1 km north of Longford and local streams are the main conduits of drainage directly into Lough Conn.

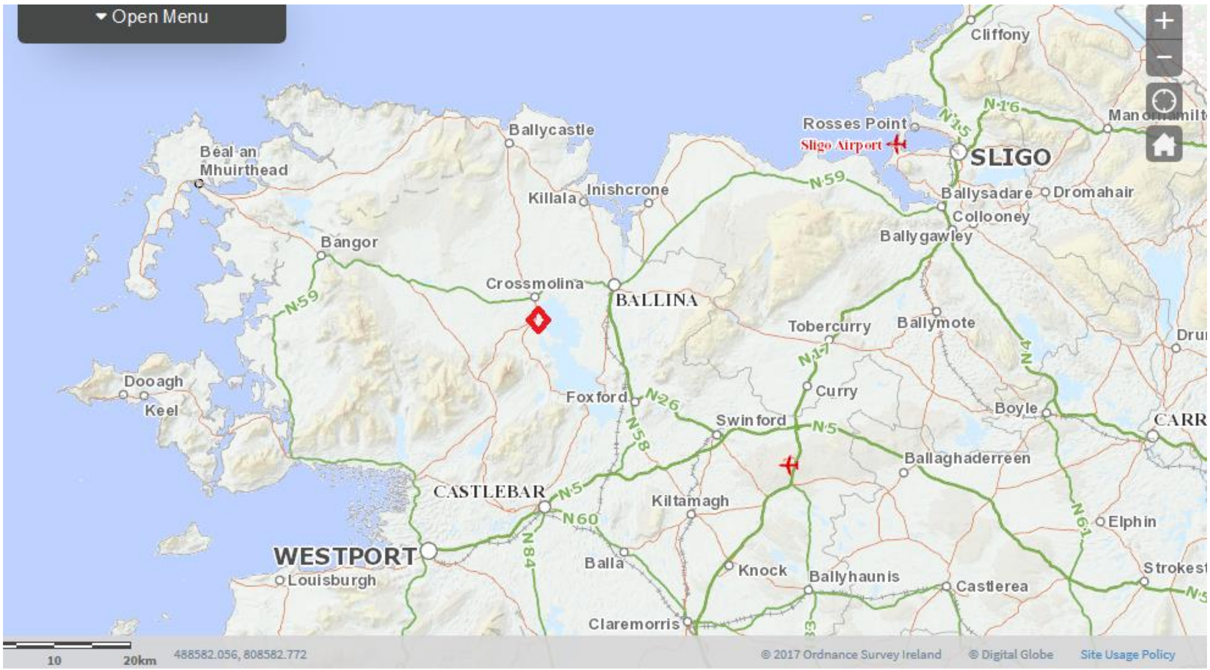

Figure 1. Location of HSP farm (red diamond) at Crossmolina, Co. Mayo.

The area to the north and west of Lough Conn where the farm is found is relatively flat with pastoral plains and blanket peat covering much of the area. The land takes much of the rainfall draining from Nephin and Nephin Beg mountain ranges which are to the south and south west of the area. The average rain fall at the farm is between 1200 and 1400 mm per year. With the mountain ranges taking 1600 to 2000 mm per year.

The geology of Mayo is composed of terranes where sequences of rocks that were formed in one place are now found alongside other sequences that were originally formed a long way apart. Some of the rocks to the west of the Nephin area are 1750 million years old. The bedrock of the area is Dinantian pure bedded limestones, directly in the immediate area of the farm and surrounding the lake. With Dinantian upper impure limestone to the west. Along with Dinantian sandstones further to the west and early sandstones, shales and limestones (Geological Survey of Ireland, Generalised bedrock [rock unit groups]). To the east and south there are bedrock deposits of quartz, gneiss and schist.

The local geology at the surface of the area is Dinantian sandstone, Lower Carboniferous sandstones with Lower Carboniferous limestone close by. The Midlandian glaciation obliterated all the evidence of previous glaciations in Mayo up to the period 11,000 years before present. The glaciers advanced in a northwest direction around lough Conn and retreated to the south east. Therefore, the sandstones of the north and west dominate the glaciate till rather than the limestone of the bedrock directly in the farm area.

There are many glacial morraines deposited quiet closely (500 m to 1 km apart) in the immediate area of the farm. They have resulted in some small hills of boulder clay, unsorted glacial till. These hummocky deposits of sand and gravel can be covered subsequently by alluvial deposits as the levels of water in the lake rise and fall with changes in climate. There are likely to be some deposits of gravels derived from limestones, due to the prevalence of this bedrock in the areas close by also. With the lack of any great relief in the area coupled with the high rainfall amounts blanket peat has developed in places.

On getting closer to the shore of the lake, lacustrine deposits become more prevalent with sorting of deposits into bands found in the alluvial soils there. These alluvial soils are likely to be dominated by silt soil textures and have significant amounts of clay present. There are also likely to be peats derived from fens associated with small streams and changes in the lake shore over the millennia. These peats are formed from groundwater principally rather than rainwater fed. Any persistent shores for a long period between water level changes results in sand and gravel deposits.

Historical soil information

There was a reconnaissance survey in West Mayo which produced a map published in 1974, however the soil survey bulletin No. 32 was never published. The map covered an area up to 1 km west of the farm. This was described as a complex, Rake Street – Crossmolina, which was over 6,000 hectares in size. Rake Street was a Humic Rendzina (less than 30 cm thick), coarse loamy over calcareous gravels. This has now been rationalised into another Humic Rendzina, soil series Crush. The Crossmolina soil series was a Humic Brown Podzolic, loamy drift with limestones. This series has been rationalised into NBE 17, Humic Brown Earth. Contained within this map unit were small areas of Blanket peat, Allen, which were cutover. The map is suggesting that loamy drift with limestones would be dominating the area at least up to the area of lake influence.

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 is a polygon covering over 90 % of the farm area, this is soil association Cooga (Figure 3). It is led by the Typical Brown Podzolic of the same name. This soil is in contrast to the old soil survey, as the drift is coarse loamy with siliceous stones not derived from limestone till. All the soils within this association are of siliceous drift not limestone drift. There are three more Brown Podzolics, two Brown Earths, a Humic Groundwater Gley and a Ferric Podzol making up this association. There are two polygons of raised peat one just outside the farm to the south west of Mullenmore (near paddocks 14 – 17) and another to the northwest of Longford (near paddocks 26 – 29).

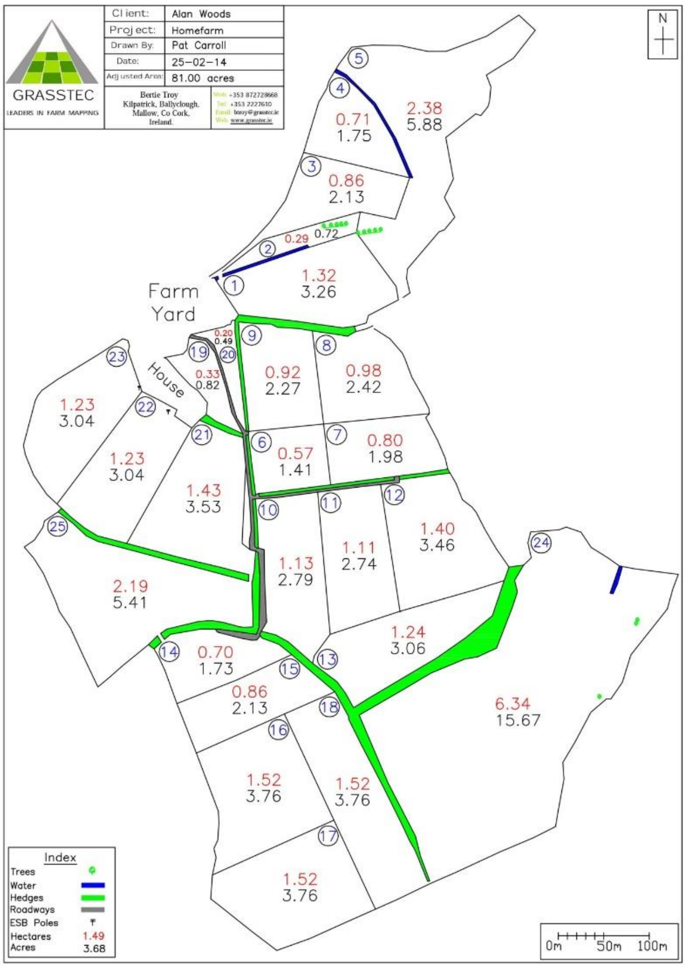

Figure 2 a. Paddock distribution at the home farm, Mullenmore, Crossmolina Heavy Soil farm.

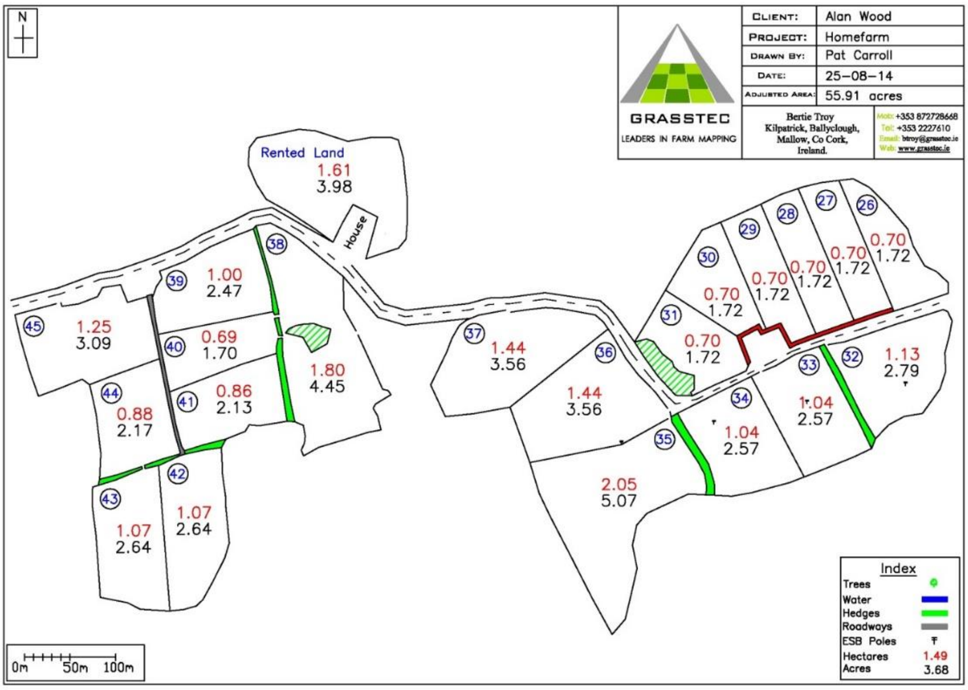

Figure 2 b. Paddock distribution at the out farm, Longford, Crossmolina Heavy Soil farm.

Looking further afield there are alluvial soil polygons associated with the River Deel and streams in the area. Within 5 km of the farm there are also polygons of the soil association Clashmore, Typical Brown Earth, coarse loamy drift with siliceous stones and Mullabane, coarse loamy drift with Limestones. The old map was at 1:125,000 resolution and the Irish SIS map is at 1:200,000 resolution, this survey provides an ideal opportunity to finalise the composition of the drift of these local soils at 1:5,000 resolution.

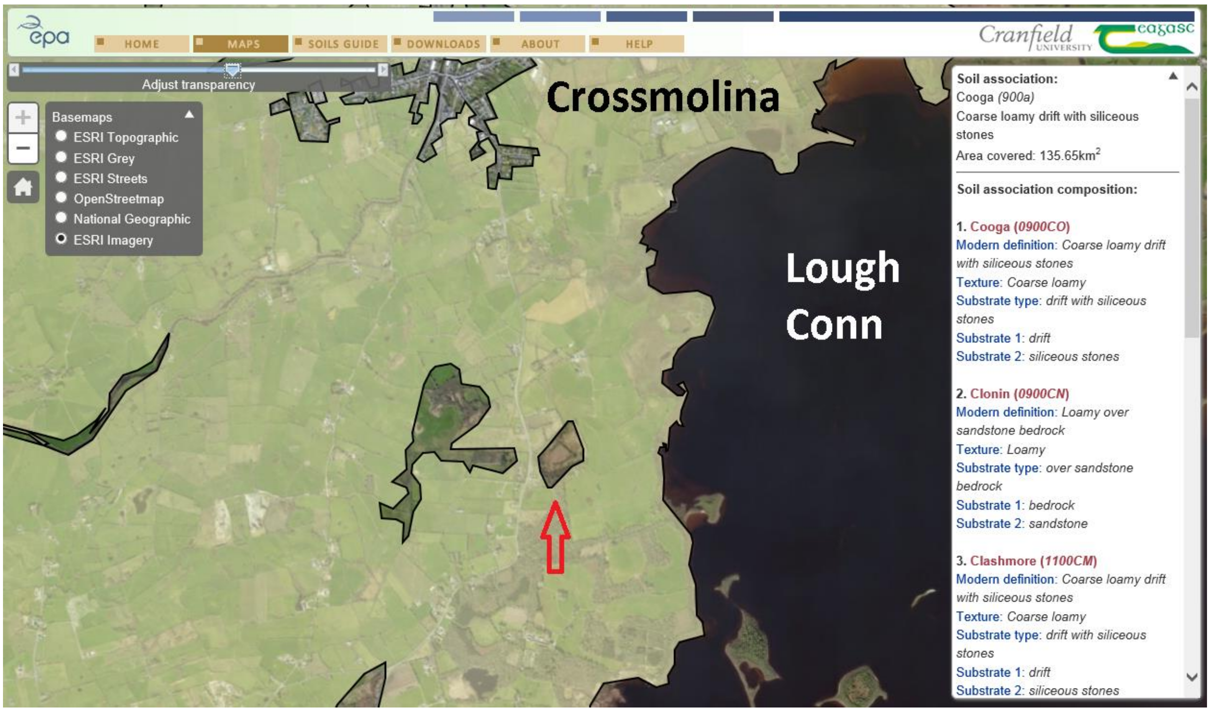

Figure 3. The Cooga soil association predicted to cover over 90 % of the farm, from the Irish SIS. The red arrow indicates an area of raised peat just west of Mullenmore.

Auger campaign

<u>Method</u>

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).

<u>Luvisols</u>

Of the 56 augers on the farm 19 were Luvisols representing the largest Soil Great Group on the farm. Luvisols are where there is a distinct increase in clay content within 30 cm of the surface horizon. 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. The most common soil series was Dunboyne, Typical Luvisol, fine loamy drift with siliceous stones (9 augers, Figure 5).

Figure 4 a. Auger distribution on the home farm, Mullenmore, with Lough Conn to the East.

Figure 4 b. Auger distribution on the out farm, Longford, with Lough Conn to Southeast.

There was one Typical Luvisol with coarse loamy texture, Dungarvan (Figure 6). The Typical Luvisols in paddock 19 and 20 were on Limestone drift (Elton, Figure 7 and Kellistown), it is likely that this was imported more recently as these two paddocks were between the farm house and the yard. The remaining Stagnic Luvisols were found in Longford. They would be moderately drained, mostly Gortavoher series, fine silty drift with siliceous stones and some areas of Crosstown, fine loamy. It is likely that as silt levels fluctuate in paddocks, these soils are found together and the extra silt leads to stagnation. Another possibility is that they are former Alluvial soils which have leached clay to lower horizons over the millennia.

Figure 5. Paddock 7, Typical Luvisol, Dunboyne, moderately drained. On a plateau, possibly alluvial at depth with a thin dense layer.

Figure 6. Paddock 12, Typical Luvisol, Dungarvan coarse loamy well drained on incline.

Figure 7. Paddock 19, Typical Luvisol, series Elton, fine loamy on limestone drift, likely imported/inverted sourced at depth.

Alluvial Soils

The next largest Great group is the Alluvial Soils, which is not surprising given the proximity of Lough Conn. These soils exhibit distinct layering due to changes in deposition over time due to water transportation and sorting. They tend to have very few stones and imperfectly to moderately drained, but can be productive if the layers are mixed and were not originally homogenous high clay soils. Alluvial soils are found in paddocks 5, 24 and 25 in Mullenmore and in all the Eastern paddocks of Longford. There are 8 Typical Alluvial Soils with Loamy lake alluvium, soil series Gurteen (Figure 8). These soils have been drained to prevent stagnation and can produce a good sward.

There are three Humic Alluvial Soils (series Ardglass) where organic material is still evident in the surface horizon, this can be due to drainage works being recent (material will break down shortly) or previous works are not as effective and require maintenance. Paddock 26 to 31 in Longford were recently drained with a new design as part of the Heavy Soil Project. These measures have performed well allowing multiple cuts of silage with associated machinery working in the area. This area appears to be a former bay when lake levels were much higher in the past. There was one Histic Alluvial Soil, series Abhainn, here the organic matter at the surface is less than 40 cm thick but still contains active peat formation. This is an active fen associated with the lake shore in paddock 25.

Figure 8. Paddock 29 a, Typical Alluvial Soil, series Gurteen. This is the area which has been recently drained as part of the Heavy Soils Project.

Brown Earths

There are 11 augers belonging to this Great Group. There are 5 soils of the Clonroche series (Figure 9), fine loamy drift with siliceous stones and two of series, Clashmore, coarse loamy drift with siliceous stones. Both of these Typical Brown Earths are ideal for productivity, being well drained and do not suffer from leaching. There are two Stagnic Brown Earths, series Moord, found in paddocks 13 and 14. These are imperfectly drained as the runoff from the hills to the south can bring large volumes of water which can lead to restricted downward flow. However, this is a limited occurrence and drains nearby prevent any great changes in management compared to the more elevated paddocks. There are also two Gleyic Brown Earths, series UN16, found in Longford. Here the problem arises intermittently from the groundwater. If there are long periods of rain and the watertable rises there can be gleying of the deeper horizons. Again these events are rare and these soils are described as moderately drained.

Histic Soils

There are 8 soils on the farm which have organic material built up at the surface to depth of 40 cm or greater. As these soils are waterlogged, there is no air for microorganisms to break down the organic material. It is broken down less efficiently by anaerobic microorganisms, the process is much slower and accumulation begins. The peats have formed due to the groundwater level being close to the surface at the lake shores and due to the groundwater levels at nearby streams flowing into the lake. These peats are classed as Mineratrophic Peat Soils and most (7) have had some drainage measures in place (Figures 10 a and b). Paddock 5 b has no apparent drainage measures and is considered Natural Mineratrophic Peat Soil, series Pollardstown. All the soils of this Great Group are still considered to be poorly drained.

Figure 9. Paddock 17, Typical Brown Earth series Clonroche, well drained.

Figure 10 a and b. Paddock 4 and 24 both Drained Mineratrophic Peat Soil series Banagher. Strong growth of rushes is indicative of the poor drainage of this soil.

<u>Gleys</u>

There are three gley soils on the farm, all found at Mullenmore. Two are Typical Surface-water Gleys one Kilrush with fine loamy texture, the other Newport with coarse loamy texture. Both of these soils had 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 (Paddocks 1 b and 21). The increase in clay is leading to stagnation on a regular basis. Moving away from the lake, alluvial soils will give way to Surface-water gleys both suffering from stagnation due to the high clay contents. These Gleys however have unsorted gravels/stones present, with no layering. There is also a Humic Groundwater Gley in paddock 25 a (Figure 11), here the shallow groundwater table is regularly near the surface and humic material has built up close to the surface as waterlogging prevents microbial decomposition. This soil is series Puckane, coarse loamy drift with siliceous stones. In time without drainage measures this could become histic like paddock 25 b which is a poorly drained Histic Alluvial Soil. In this instance, the waterlogging is extensive for periods long enough to generate peat. The position of this paddock in the landscape makes it very difficult to drain. This is a natural collecting area off the surrounding hills with consequent restrictions on finding a suitable outlet for the excess water.

Figure 11. Paddock 25 a, Humic Groundwater Gley, series Puckane.

Podzol

There are two Podzols found on the farm, both at Mullenmore in paddock 5 (Figure 12 a and b). The area appears to be an ancient lake shore where wave action has created sand deposits. There are iron concretions but no pan in the stoneless Glenbough variant of paddock 5 c. There are some deposits of organic material in patches which may allude to a Bh layer below the iron concretions. There are some fine gravels in paddock 5 d, along with a continuous iron pan Bf. On site, further Bf bands were noted at depth as this pedogenetic process was repeated over the millennia. This is the Stagnic Iron-pan Podzol, series, Glenary.

Figure 12 a and b. Paddock 5 c Humic Podzol, series Glenbough variant, Sandy stoneless drift. Paddock 5 d, Stagnic Iron-pan Podzol, series, Glenary, Loamy drift with siliceous stones.

<u>Conclusions</u>

The auger survey is indicating that this is an area of transition from Alluvial soils due to proximity with Lough Conn and to Fluvio-glacial soils deposited along with moraines in the Mullenmore area (Table 1). The lack of any limestone drift supports the Irish SIS prediction of the drift arriving from the sandstone bedrock deposits in the north west of the area. This is likely to have superseded any limestone drift there previously. There is also an esker to the west of Mullenmore suggesting a much larger lake with meltwater rivers filling it. The deposition of the alluvial soils can be more recent with fluctuating levels of the lake water. This was evident in paddocks 6, 7, 8 and 11, where a dense 10 cm band of high clay was found in small hills at 30 -35 cm depth, suggesting they were once covered by lake mud.

Of the soils formed on drift, the textures are coarse loamy and fine loamy and generally the porosity it moderate to high, they can drain quiet well in intermittent rain. The problem is they have no capacity and in extensive periods of rain, the lack of permeability means the soils pore space is filled quiet quickly. The lack of soil subgroups of stagnic and gleyic properties is testament that this does not occur continuously. A greater problem is the fluctuating groundwater table in such close proximity to the lake shore and to small streams in its catchment. The formation of peat and soils with humic sub group properties reveals an ongoing battle to prevent waterlogged conditions on the farm.

The Irish SIS prediction of Brown Podzolic soils appears to be unlikely as the soils in the area are relatively young and have not undergone the pedogenetic process extensively. Therefore, there are many Brown Earths. With the high rainfall, the leaching has created many Luvisols, and together with the Alluvial soils associated with the lake, these two great soil groups dominate the farm.

Table 1. Field observations of soil type during the auger campaign on Crossmolina 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
19	Typical Luvisol	Elton	Well
20	Typical Luvisol	Kellistown	Moderately
9	Typical Luvisol	Dunboyne	Well
7	Typical Luvisol	Dunboyne	Well
8	Typical Brown Earth	Clashmore	Well
6	Typical Luvisol	Dungarvan	Well
10	Typical Luvisol	Dunboyne	Moderately
11	Typical Brown Earth	Clonroche	Moderately
12	Typical Luvisol	Dungarvan	Well
13	Stagnic Brown Earth	Moord	Imperfectly
14	Stagnic Luvisol	Crosstown	Imperfectly
15	Stagnic Brown Earth	Moord	Imperfectly
16	Typical Brown Earth	Clonroche	Well
17	Typical Brown Earth	Clonroche	Well
18	Drained Mineratrophic Peat Soil	Banagher	Poorly
21	Typical Surface-water Gley	Kilrush	Poorly
22	Typical Brown Earth	Clonroche	Moderately
23	Typical Brown Earth	Clonroche	Moderately
25 a	Humic Groundwater Gley	Puckane	Poorly
25 b	Histic Alluvial Soil	Abhainn	Poorly
24 a	Drained Mineratrophic Peat Soil	Banagher	Poorly
24 b	Drained Mineratrophic Peat Soil	Banagher	Poorly
24 c	Humic Alluvial Soil	Ardglass	Poorly
1 a	Drained Mineratrophic Peat Soil	Banagher	Poorly
1 b	Typical Surface-water Gley	Newport	Poorly
3	Drained Mineratrophic Peat Soil	Banagher	Poorly
4	Drained Mineratrophic Peat Soil	Banagher	Poorly
5 a	Typical Alluvial Soil	Gurteen	Imperfectly
5 b	Natural Mineratrophic Peat Soil	Pollardstown	Poorly
5 c	Humic Podzol	Glenbough v.	Imperfectly
5 d	Stagnic Iron-pan Podzol	Glenary	Imperfectly
26	Typical Alluvial Soil	Gurteen	Imperfectly
27	Typical Alluvial Soil	Gurteen	Imperfectly
29 a	Typical Luvisol	Dunboyne	Well
29 b	Typical Alluvial Soil	Gurteen	Imperfectly
30	Typical Alluvial Soil	Gurteen	Imperfectly
31	Typical Alluvial Soil	Gurteen	Imperfectly
34	Humic Alluvial Soil	Ardglass	Poorly
33	Typical Alluvial Soil	Gurteen	Imperfectly

Paddock	SUBGROUP	Series Name	Drainage Class
32 a	Typical Alluvial Soil	Gurteen	Poorly
32 b	Humic Alluvial Soil	Ardglass	Poorly
35 a	Typical Luvisol	Dunboyne	Moderately
35 b	Stagnic Luvisol	Crosstown	Imperfectly
36	Typical Luvisol	Dunboyne	Moderately
37	Typical Luvisol	Dunboyne	Moderately
Rent a	Gleyic Brown Earth	UN 16	Moderately
Rent b	Typical Luvisol	Dunboyne	Moderately
38 a	Typical Luvisol	Dunboyne	Moderately
38 b	Drained Mineratrophic Peat Soil	Banagher	Poorly
40	Typical Luvisol	Dunboyne	Moderately
41	Gleyic Brown Earth	UN 16	Moderately
42	Stagnic Luvisol	Gortavoher	Moderately
43	Stagnic Luvisol	Gortavoher	Moderately
44	Stagnic Luvisol	Gortavoher	Moderately
45	Stagnic Luvisol	Gortavoher	Moderately
39	Typical Brown Earth	Clashmore	Well

Representative Soil Profile pits

Using the auger survey as a guide, four pits were selected to represent the dominant soils on the farm and any significant drainage restrictions throughout the farm (Figure 13). Paddock 16 represents a well-drained Typical Brown Earth, with coarse loamy texture. Paddock 21 is a poorly drained Typical Surface-water Gley, with many stones. Paddock 42 is a Typical Luvisol that is moderately drained (due to high silt content) and paddock 32 is a Humic Alluvial Gley that is poorly drained due to clay loam and silt loam textures.

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 13. Location of soil profile pits on the Crossmolina Heavy Soil Farm. Mullenmore South West and Longford North East

Table 2. Soil description of paddock 16, Crossmolina Heavy Soil Farm.

Horizon depth (cm)	Horizon designation	Description
28	Ap	Dark Greyish Brown, few mottles, few gravels, Loam, common fine roots, sub angular blocky structure. Weathered stones, clay loam band RHS bottom of hz.
65	Bw	Dark Grey, abundant brown mottles, no stones, Loamy sand, single grain, few fine roots. Ice wedge in centre of hz, Sandy Loam.
140	2C	Yellow/Grey Brown, common mottles, dominant and abundant gravels. Sandy Loam. Few fine roots. Massive to single grain. Water entry at 70 cm. Clay band at 80 cm. Limestone at 110 cm. weathered mud stones
180	3C1	Light Yellow Brown, Sand. Single grain. Very few fine roots. Many bands of different grades of sand. Fluvio-glacial sorting.
200	3C2	Light Brownish Grey, common boulders, Silty Clay Loam, massive

On reviewing the field and laboratory data, paddock 16 is now a Gleyic Brown Earth, Knock series, coarse loamy drift with siliceous stones. The gleyic designation is due to the common mottles and gley matrix colour commencing in horizon 3 from 65 cm (Table 2). This gleying is due to the watertable rising quickly through the highly porous sand of horizon 4 but then being restricted by

Figure 14. Paddock 16, 1120 Gleyic Brown Earth, Knock series, coarse loamy drift with siliceous stones.

the Sandy loam texture and high amount of gravels of horizon 3. On reaching horizon 2 the Loamy sand texture allows water movement more readily here. This also allows lateral movement down the hill slope of water in the pore spaces. As the restriction is greater than 40 cm depth, this soil is still productive close to the surface and is well drained. There is an ideal loam texture in the Ap horizon with very little mottling. The sand bands of hz 2 and 4 alluded to the changing pattern of deposition over the millennia (Figure 14). Horizon two could be an old shore deposit of the lake and horizon 4 could be a fluvio-glacial deposit from the beginning of the retreat of the glaciers. This then had the moraine deposit of horizon 3 laid subsequently.

The Limestone found at 140 cm was a stone and not a calcareous reaction in the matrix. Therefore, at greater depth the drift could be from the local limestone bedrock. It would appear to have little influence this deep down, however the pH is just below neutral for all 3 upper horizons, horizon 4 is just alkaline (Appendix). The bulk density does not fluctuate greatly. The p levels are satisfactory and the k levels are a little below optimum. On the whole, this soil is very good in terms of productivity in this area.

Figure 15. Detail of crinoid fossils within limestone found in horizon 3, paddock 16.

Horizon depth (cm)	Horizon designation	Description
32	Apg	Dark Greyish Brown, abundant root mottles, common gravels, Loam, Many fine roots, sub angular blocky structure, weathered stones, iron coats.
65	Bg	Dark Greyish and Yellowish Brown, many mottles, few gravels, Sandy Loam, Angular blocky structure, few fine roots. Greasy, compacted, clay band 35-45 cm. 50 cm water entry. Manganese coats, audible $CaCO_3$ reaction.
90	Cg	Brown, with grey and reddish yellow mottles, common gravels, Sandy Loam. Limestones, visible reaction. Few fine roots. Massive. Compacted. High packing density, low porosity. Medium and coarse dead roots. Indurated.
140	Cr	Dark Greenish Gray, few mottles, common gravels, abundant stones. Loam, wet, Limestone strongly visible. massive structure, high packing density, very few fine roots. Compacted, fissures. Weathered stones.

Table 3. Soil description of paddock 21, Crossmolina Heavy Soil Farm.

The soil of paddock 21 is Typical Surface-water Gley, series Straffan, Coarse Loamy drift with Limestones. The lower three horizons are compacted and allow for very little permeability (Table 3). As a consequence water cannot percolate downwards and a perched watertable is evident. The bulk density rises from horizon 1, 1.11 g cm^{-3} to 1.67 g cm^{-3} and to 1.76 g cm^{-3} in horizon 3 (Appendix). This compaction may have been due to far greater depths of soil being above the current horizons at the surface in the distant past. Subsequent glacial events removed this soil and the deeper compacted layers are now more exposed.

Water was evident in the soil matrix at 30 cm and at 140 cm depth. The farmer spoke of his troubles of waterlogging with this paddock and had ripped the area two years ago. The gleyed colours are evident from 40 to 65 cm especially. Here the angular blocky structure becomes dominant and at greater depth there is virtually no soil structure (massive, Figure 16). There is a reaction to $CaCO_3$ with acid in the soil matrix and limestones were noted for the deeper three horizons.

Figure 16. 0700 Typical Surface-water Gley, series Straffan, Coarse Loamy drift with Limestones.

This is also reflected in the pH values where the surface horizon is acidic at 5.7, however the deeper three horizons are all alkaline at 7.1, 8.1 and 8.2 (Appendix). The phosphorus and potassium levels of the lower three horizon are all sub optimal and do not allow for high productivity. There are very few roots and common dead roots in these horizons, which reflects the paucity of these and how fertilisation would have minimal impact at depth. Small regular amounts at the surface horizon may

Horizon depth (cm)	Horizon designation	Description
30	Apg	Dark Greyish Brown, strong brown and yellowish red many mottles, common gravels, few stones, Loam, Many fine and few medium roots, Angular blocky structure.
58	Bwg	Brown, common brown and grey mottles, few gravels, very few stones, Loam, common manganese coats. sub-angular blocky structure, high packing density, common fine roots.
140	C	Brown, few strong brown mottles, few gravels, few stones. Silty Clay Loam. Very few fine roots. Clay coats common, firm, plastic, massive. Compacted due to clay. Clay texture in places.
180	2Cr	Dark Grey, massive, common boulders limestone, weathered mudstones.

have the greatest response.

Table 4. Soil description of paddock 42, Crossmolina Heavy Soil Farm.

This soil at paddock 42 is a Stagnic Brown Earth, series Moord, fine loamy drift with siliceous stones. Originally this was described as a Stagnic Luvisol from the auger survey. The mottles in horizon (hz.) 2 and the manganese coats (Table 4) indicated a problem with stagnation in this profile. However, it was also described as having an increase in clay from hz.1 to hz.2, (within 30 cm of the surface) this was not found to be the case in the laboratory analysis with the clay content being 22 and 21 % respectively (Appendix). A probable reason for this was the preceding 3 weeks of dry weather making higher levels of moisture at depth appear as a clay increase with hand texturing.

The reason for the stagnation is due to the third horizon commencing at 58 cm depth, here the texture is described as Silty Clay Loam (Figure 17). The clay has increased from 21 to 33 % and the silt from 42 to 60 %. The horizon is now compacted due to the clay and silt, and its structure is massive. This is evident in Figure 18, where the smearing of the soil profile is evident from scouring with a trowel. The bulk density increases from 1.10 to 1.42 and to 1.54 g cm^{-3} no bulk density measurement was possible in hz. 4. pH is acidic 5.4 to 6.0 with depth. Phosphorus levels are sub optimal and potassium levels are reasonable at the surface (Appendix).

This soil was reclaimed 8 years ago and may have been an alluvial soil in the past formed by fluvio-glacial or more recently alluvial processes. Horizons 2 and 3 have very low stone and gravel content. This covers hz. 4 which again indicates a lithological discontinuity as large boulders are present of limestone, along with weathered mudstones. This reflects the underlying bedrock of Limestone and that the siliceous material was imported later.

This soil has moderate drainage, the loam texture of hz. 1 allows downward movement readily. Occasionally this stagnates in hz. 2 where the mottles and the manganese coats are located. This hz. still has a loam texture but the pore spaces fill quickly if there is persistent rain. Very little water can get into horizon 3 with the compaction and texture. There is evidence that the soil pore space fills in hz. 2 and that this effects hz.1 where root mottling is evident with some matrix mottling. It is likely in time post reclamation that the stagnation may get worse with leaching without more rigorous drainage in this area.

Figure 17. 1130 Stagnic Brown Earth, series Moord, fine loamy drift with siliceous stones.

Horizon depth (cm)	Horizon designation	Description
30	OA	Very Dark Greyish Brown, coarse mottle of old AB horizon mixed into peat in two places, no stones. Angular blocky structure, fibrous peat, H3, Many medium roots, wet. Water infiltration at 30 cm.
70	Bg	Grey with olive yellow and yellow brown mottles common, very few gravels, Clay Loam, parts Silt Loam. Firm, massive, few fine roots. Compacted. Sand lens 40 to 70 cm on RHS. Large weathered stone centre of hz. Fine and coarse dead roots.
160	Cg	Grey, common yellow grey mottles, common gravels. Some limestones visible reaction. Silt Loam. Few fine roots. Slightly plastic. Massive,

Figure 18. Detail of Silty Clay Loam layer (Paddock 42) which leads to stagnation in the upper horizons due to low porosity.

Table 5. Soil description of paddock 32, Crossmolina Heavy Soil Farm.

		Compacted due to clay. Gravel intrusions, indurated, dead roots.

The soil of paddock 32 is an Alluvial Soil with a Histic surface horizon, series Abhainn. The alluvial soil is lake derived and the shore of Lough Conn is less than 200 m away. There was standing water at the surface, despite three weeks of dry weather having passed. Water was entering the pit at 30 cm (Table 5). Attempts had been made to reclaim the field with turning and mixing the top 50 cm. This is the reason for coarse fragments of the lower hz. (AB), being present closer to the surface. The peat was fibrous suggesting it being of recent origin. The top of hz 2 had a sticky, silty clay band causing waterlogging, at this level, at its maximum width 10 cm thick (Figure 20).

In Figure 19, the weathered stone at 40 cm is visible in the centre of the profile, also the sand lens encroaching on the right-hand side between 40 and 70 cm with a more cream brown colour than the rest of the hz. matrix. Both of these are indicative of fluvio-glacial sorting and transport at some point. The prominence of silt within the texture is more evidence for alluvial or lacustrine development of these sediments. The dead roots of hz. 2 indicated that conditions must have been drier in the past to allow some deep roots to survive, but consequent climate change lead to death in waterlogging.

The surface horizon was acidic with a pH of 5.5. hz 2 and hz 3 were alkaline with 7.8 and 8.1 pH (Appendix). There was no visible reaction to acid on the soil matrix for hz 2, but hz 3 did have a visible reaction indicating a calcareous matrix. Hz 2 and 3 were compacted and had bulk densities of 1.58 and 1.68 g cm^{-3}. Water did enter the pit from horizon 3 overnight, this was associated with stones and gravels acting as a conduit on the right-hand side of the profile. On the left-hand side of the profile in hz. 3, a Silty Clay deposit with very few stones was noticeable. This was virtually dry indicating no pore space for water movement.

The phosphorus levels of the surface horizon were high and then suboptimal in the mineral hz. The potassium was sub optimal in the surface horizon and very low in the mineral horizons. This soil is poorly drained and has obvious mineral deficiencies. There were many wild flowers growing in the paddock along with alder saplings indicating the water loading in the area. The recently dug open drains along the paddock boundary were removing some water but this does not seem sufficient in terms of productivity. Rough grazing is the current management status of this type of soil.

Figure 19. 0551, Histic Alluvial Soil, series Abhainn, Peat over lake alluvium

Figure 20. Detail of weathered stone and Silt clay loam band at the top of horizon 2.

Conclusion

Over half of the soils on this farm have good drainage. They fall into the well to moderately drained categories or following drainage measures and/or reclamation are now considered imperfectly drained. Brown Earths and Luvisols make up the best soils in terms of productivity and drainage capacity. Many of the alluvial soils now have good drainage capacity following management efforts. The peats and the gleys are still poorly drained as are the humic and histic alluvial soils. The persistence of humic material indicates that measures were recent and the organic material is yet to break down or the measures are older and the drainage system may require some maintenance to reverse the water problems. It could also be that the ideal drainage response is not cost effective to achieve. These areas may have to remain as rough grazing paddocks.

The raised areas of Mullenmore contain the free draining soils whilst the poorly drained soils are in the toe of hill slopes or are groundwater fed problems. The area is of transition from moraine deposits to lacustrine or alluvial formation. In the areas of transition where stagnic soil subgroups occur, this is due to the complex interchange over the millennia of drift arriving and then being moved and superseded by other drift or an alluvial deposit. This changes the water holding capacity from horizon to horizon and creates stagnation and perched watertables.

The lake shore has clearly moved with fluctuations in water levels, due to changes in climate over time. The soils of Longford on slightly raised areas have responded well to reclamation and drainage and generally have favourable textures. However, those at low elevation have persistent waterlogging and unfavourable textures. The heavy soils project drainage system has allowed improvement of these low-lying soils.

No podzolisation was apparent on the farm except for the lake shore, therefore the soils on the farm are relatively new and are more influenced by lacustrine changes. In time leaching may become a greater factor due to the high rainfall in the area, without an abrupt increase in water levels. The heavy soils of this farm are associated with the alluvial soils or drift at depth.

The farmers measures appear to be working well farm wide to improve drainage capacity and productivity on this farm. This will be a constant work in progress in the low-lying areas which will take considerable effort and cost to maintain. It may be worth considering the long-term strategy of prioritising slightly elevated areas over shallower areas, if predicted rainfall increases are to materialise in the west of the country.

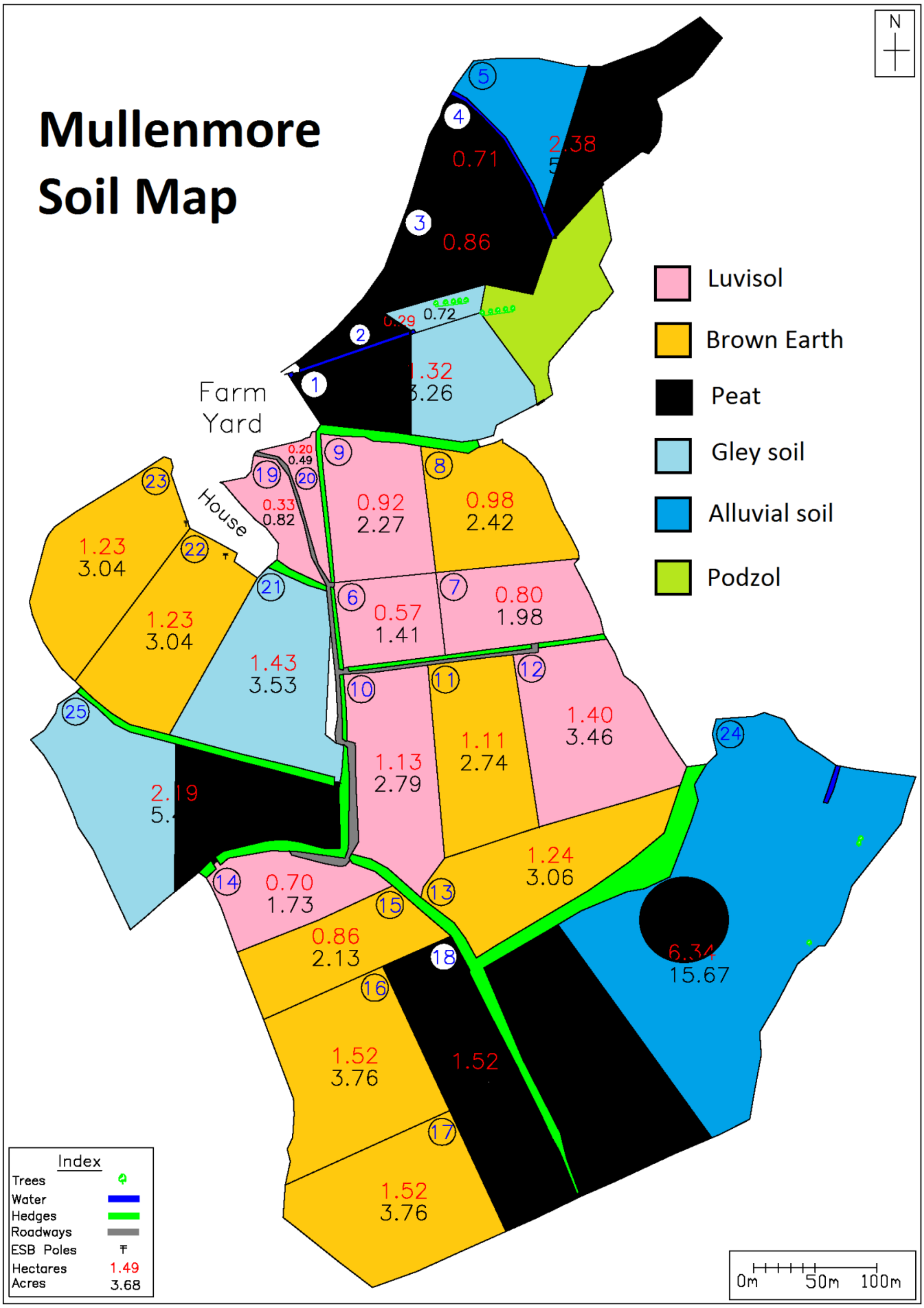

Figure 21 a. Soil map of the dominant Great Group found within paddocks and parts of paddocks on the Crossmolina Heavy Soil Farm - Mullenmore. Resolution 1:5000 approx.

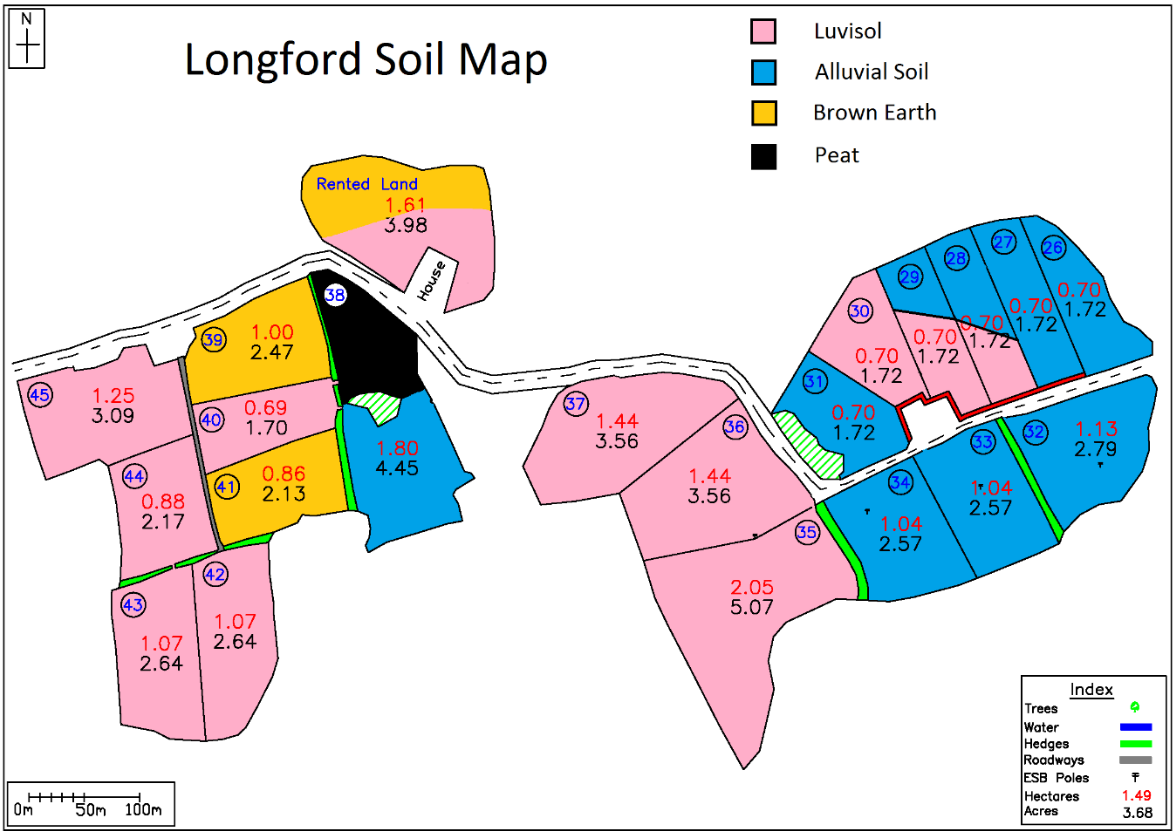

Figure 21 b. Soil map of the dominant Great Group found within paddocks and parts of paddocks on the Crossmolina Heavy Soil Farm - Longford. Resolution 1:5000 approx.

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Appendix.

Table 6. Laboratory data for samples taken from soil pits at Crossmolina HSP 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)
16	HZ1	18	32	50	1.26	1.72	36.60%	8.07	6.3	5.37	102
16	HZ2	12	12	76	1.35	1.62	20.39%	5.17	6.7	1.67	53
16	HZ3	11	22	67	1.19	1.52	23.28%	4.9	6.7	1.43	49
16	HZ4	5	28	67	1.34	1.69	26.23%	3.24	7.2	0.79	32
21	HZ1	18	32	50	1.11	1.59	39.05%	10.2	5.9	7.51	113
21	HZ2	12	28	60	1.67	2.04	20.93%	5.44	7.1	1.13	43
21	HZ3	11	34	55	1.76	2.10	18.91%	43.98	8.1	0.5	20
21	HZ4	10	41	49	Too many stones-no samples			114.59	8.2	0.63	25
42	HZ1	22	40	38	1.10	1.60	45.73%	9.28	5.4	6.84	109
42	HZ2	21	42	37	1.42	1.87	31.80%	7.62	5.8	3.31	83
42	HZ3	33	60	7	1.54	1.97	27.79%	9.04	6	1.61	52
32	HZ1	34	24	42	0.40	1.22	234.32%	17.1	5.5	39.23	> 130
32	HZ2	10	55	35	1.58	2.01	27.43%	13	7.8	0.96	38
32	HZ3	12	66	22	1.68	2.09	24.57%	48.16	8.1	0.77	31

Table 6 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** (%)
16	HZ1	15	43	58	1021	158	73	46	63.26	16.32	2.32	2.48
16	HZ2	14	22	26	712	96	64	40	68.86	15.47	3.17	3.36
16	HZ3	11	12	17	704	77	51	36	71.84	13.1	2.67	3.19
16	HZ4	8	4	30	521	37	19	32	80.4	9.52	1.5	4.29
21	HZ1	18	47	49	1345	81	78	45	65.93	6.62	1.96	1.92
21	HZ2	11	4	25	884	67	35	32	81.25	10.26	1.65	2.56
21	HZ3	9	< 1	< 1	8239	136	24	32	93.67	2.58	0.14	0.32
21	HZ4	27	< 1	< 1	21701	266	24	33	94.69	1.93	0.05	0.13
42	HZ1	18	71	90	885	100	58	46	47.68	8.98	1.6	2.16
42	HZ2	12	10	3	911	92	30	41	59.78	10.06	1.01	2.34
42	HZ3	8	3	2	1189	109	55	46	65.76	10.05	1.56	2.21
32	HZ1	41	38	48	1921	112	51	47	56.17	5.46	0.76	1.2
32	HZ2	9	2	42	2350	71	19	33	90.38	4.55	0.37	1.1
32	HZ3	16	1	< 1	9014	152	36	33	93.58	2.63	0.19	0.3

Table 6 continued…

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
16	HZ1	5.1	10.5	0.54	314	27	6.09	1.23	803	0.0314	0.0803
16	HZ2	4.7	4.5	< 0.20	111	7	1.76	0.45	1396	0.0111	0.1396
16	HZ3	4.7	4.5	< 0.20	67	12	0.88	< 0.4	1454	0.0067	0.1454
16	HZ4	4.2	0	< 0.20	65	33	0.89	< 0.4	917	0.0065	0.0917
21	HZ1	5.6	18	0.62	460	13	10.74	1.31	710	0.046	0.071
21	HZ2	4.3	0	< 0.20	102	40	1.96	0.59	562	0.0102	0.0562
21	HZ3	3.3	0	< 0.20	46	57	1.57	0.45	35	0.0046	0.0035
21	HZ4	3.2	0	0.32	114	46	1.91	0.64	7	0.0114	0.0007
42	HZ1	6.6	33	0.46	475	44	1.66	2.23	910	0.0475	0.091
42	HZ2	5.8	21	0.31	228	39	1.1	0.43	896	0.0228	0.0896
42	HZ3	5.4	15	< 0.20	104	21	0.66	0.45	1035	0.0104	0.1035
32	HZ1	6.4	30	0.83	540	12	0.64	1.72	640	0.054	0.064
32	HZ2	3.6	0	< 0.20	191	7	1.86	< 0.4	308	0.0191	0.0308
32	HZ3	3.3	0	0.22	172	43	2.44	0.5	28	0.0172	0.0028