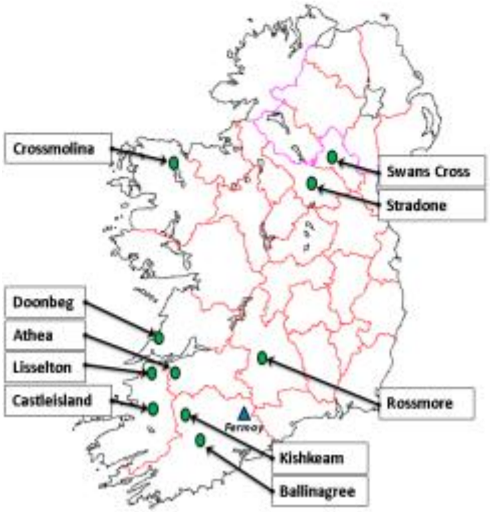
Teagasc Heavy Soils Programme

Teagasc Animal and Grassland Research and Innovation Centre

Tralee IT-B.Sc: Agricultural Science

22/11/2019

Background



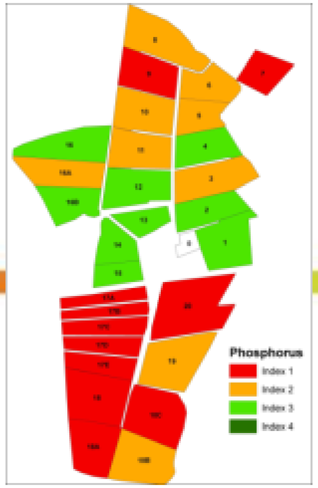
- The Heavy soils programme aims to increase profitability, improve productivity and decrease volatility on farms with poorly drained soils.

- The programme has 10 commercial farm participants; in 8 Counties.

- Focus areas include land drainage, soil fertility and nutrient cycling, soil characterization, grassland management, fodder reserves, farm infrastructure and farm profitability.

- Farms are subjected to intensive monitoring. The data being generated allows for analysis of farm systems and the development of strategies to achieve programme aims

- Collaboration between AGRIP, CELUP and Advisory with support from Co-ops (Kerry, Dairygold, Tipperary, LacPatrick)



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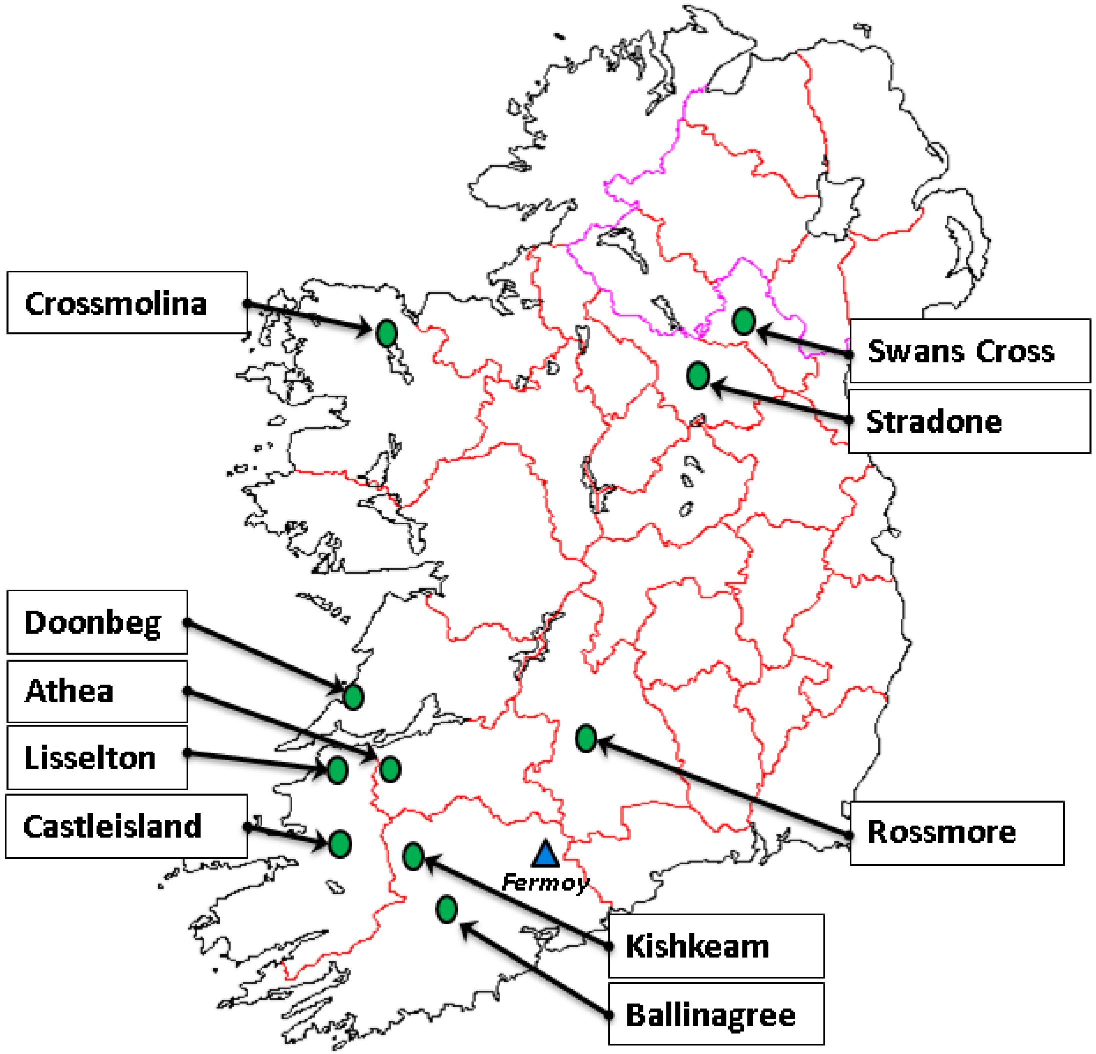
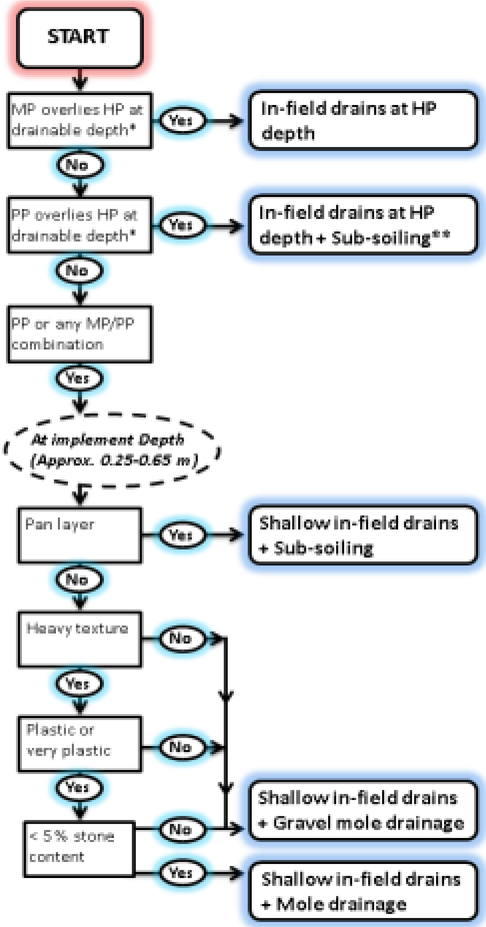
Heavy Soils Programme Farms



Land drainage system design

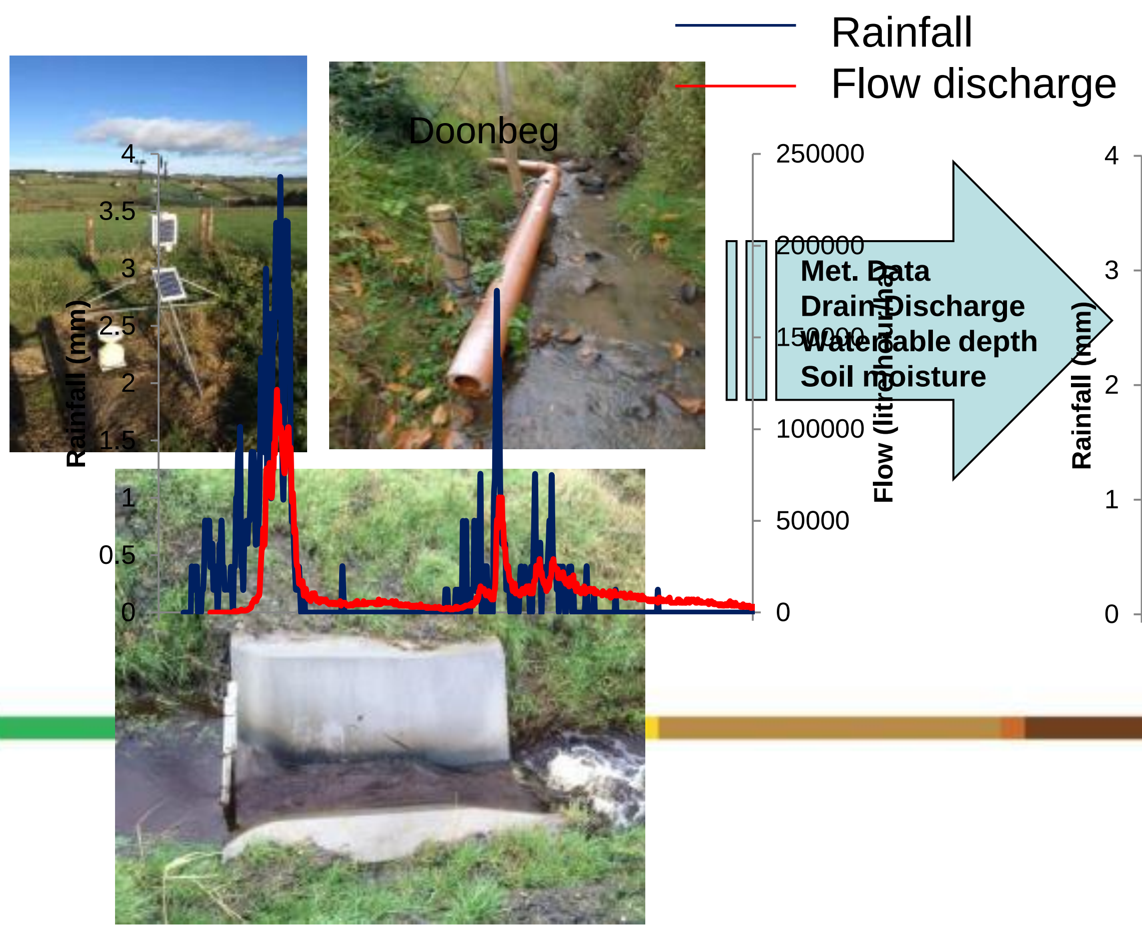
<u>Development of a practical site-specific drainage design methodology</u>

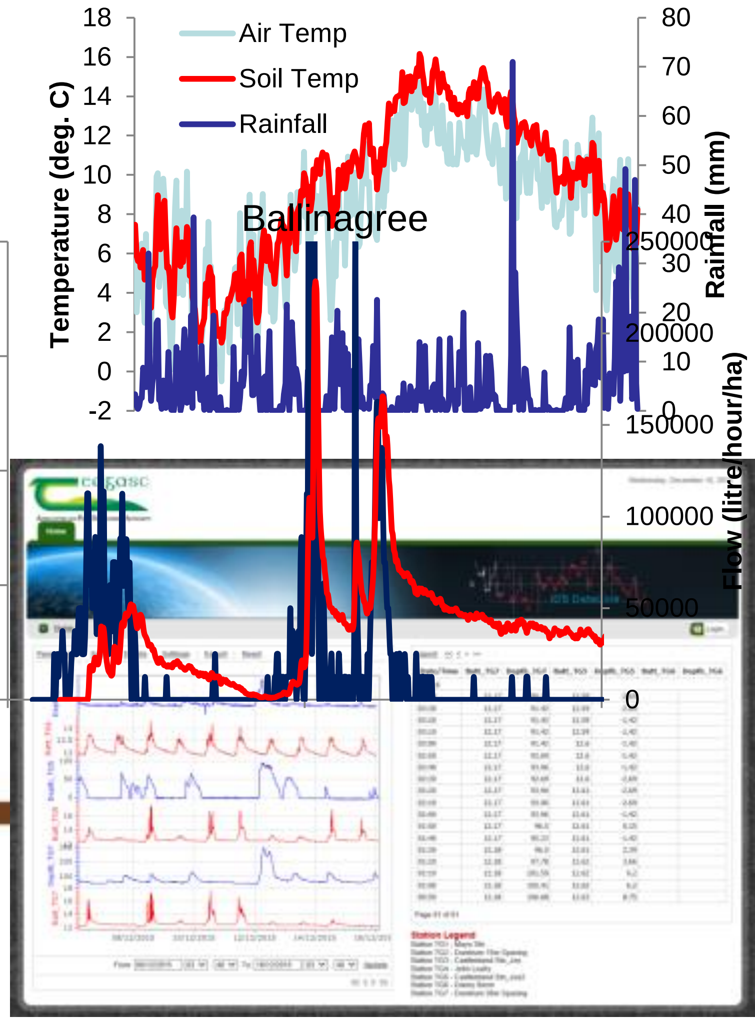


- The permeability of each horizon in test pit is scored using physical indicators (water seepage, texture, structure, etc.)
- Drainage design is based on this permeability classification
- A clear-cut methodology allows for widespread use
- **Effective drainage design can be formulated on-site where an appropriate visual assessment of soil can be made**

Monitoring drainage system performance

- Site specific land drainage systems installed on all farms
- Real time performance data is continuously collected
- Efficiency of systems quantified





Water quality/Nutrient losses

- Water samples are collected from drain outflows and groundwater wells to establish nutrient loss pathways and rates

- Soils highly variable in terms of soil chemistry and permeability

GROUP 1 Doonbeg

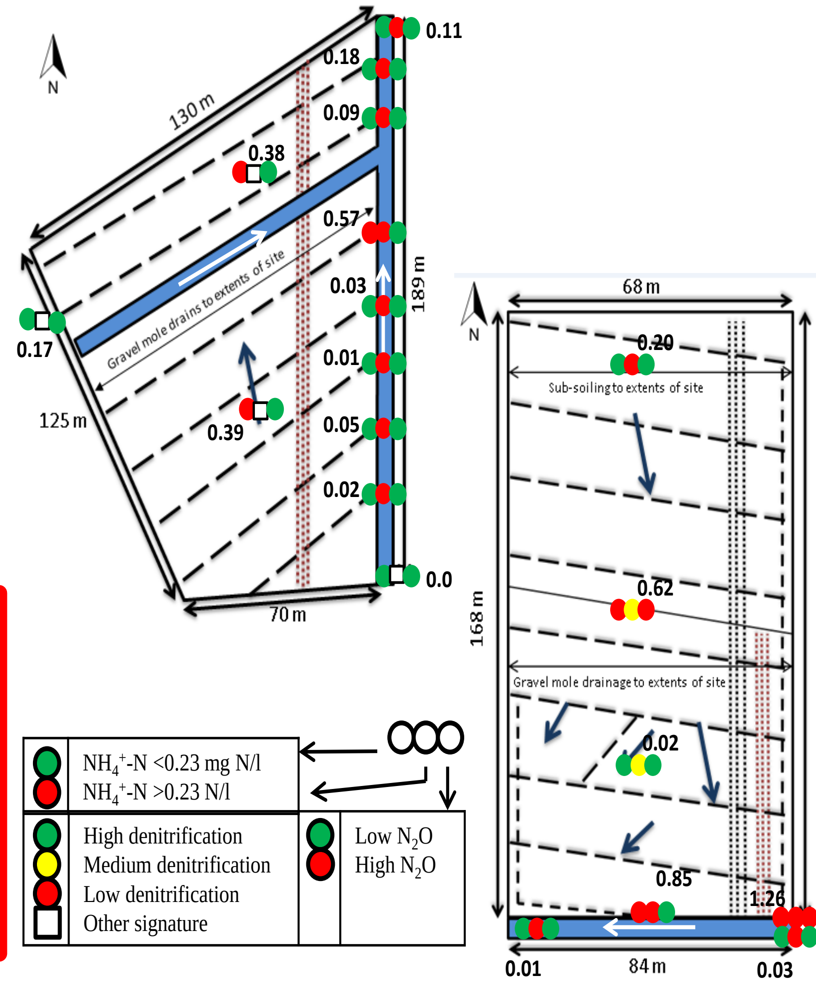
- Low contamination
- Low denitrification
- Nitrification important
- Low N_2O, high N_2

GROUP 2 Kishkeam and Rossmore

- Low contamination
- High denitrification
- Intermediate N_2O, low N_2

GROUP 3 Athea and Castleisland

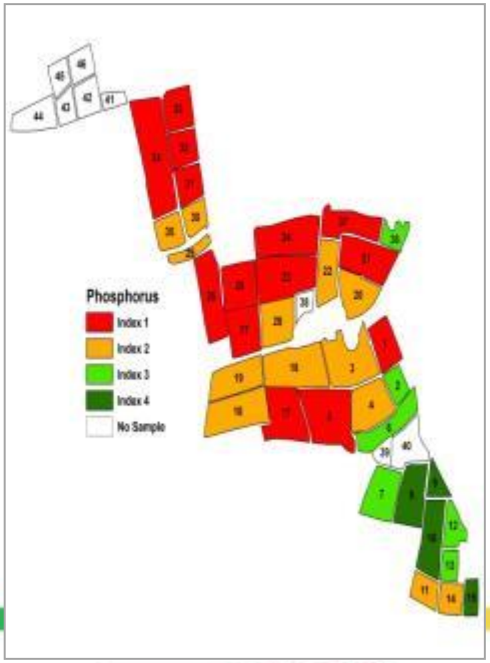
- High NH_4^+-N in GW and drainage water.
- Fate of nitrate affected by N Surplus
- Low N promotes bacteria capable of reparatory ammonification (DNRA) over denitrifers
- Low N_2O emissions

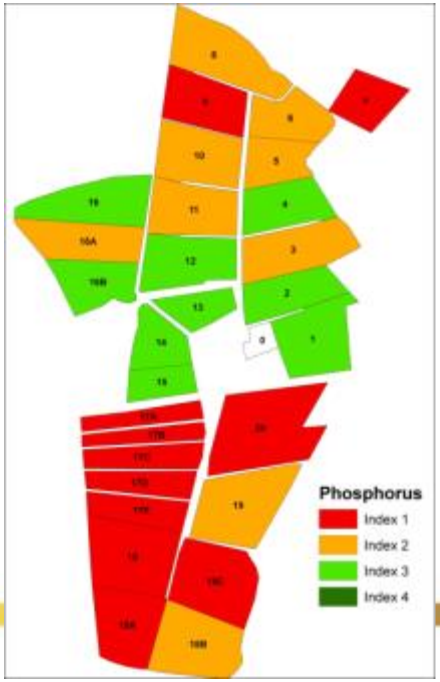


Bioreactor Needed but for Ammonium not Nitrate

Soil fertility status

- Majority of farms are severely limited by poor soil fertility status
- A soil sampling campaign has been established: **Every paddock , Every year** and all inputs are recorded on farms
- Aim to develop strategies for improving fertility on heavy soils in light of technical, financial and legislative restraints



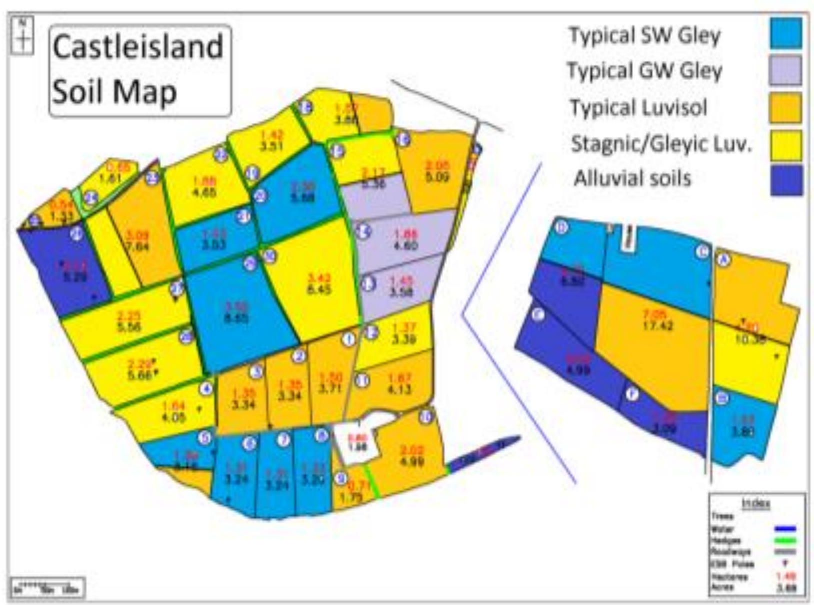


Soil Surveying/Mapping

- Soil augers (40 per farm) and test pits (4 per farm)
- Soil description and sampling
- Lab analysis of soil physical and chemical properties

- Soil type and horizon specific characterisation and soil sample archive
- Paddock scale soil maps and summary reports

- Contextualise all other data and underpin future work.



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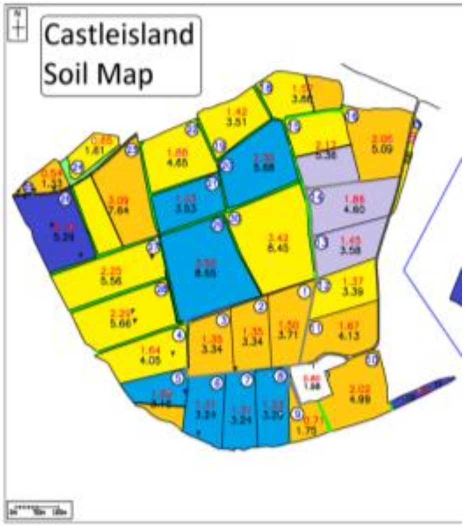
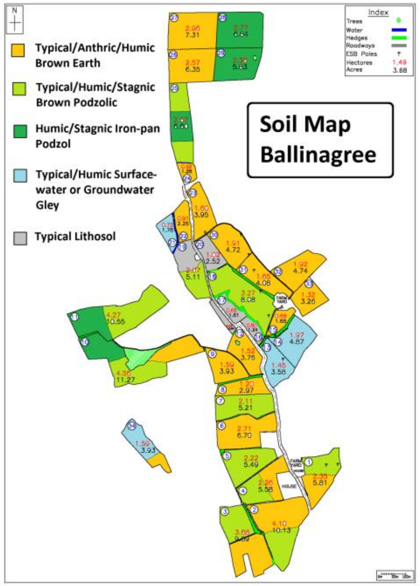
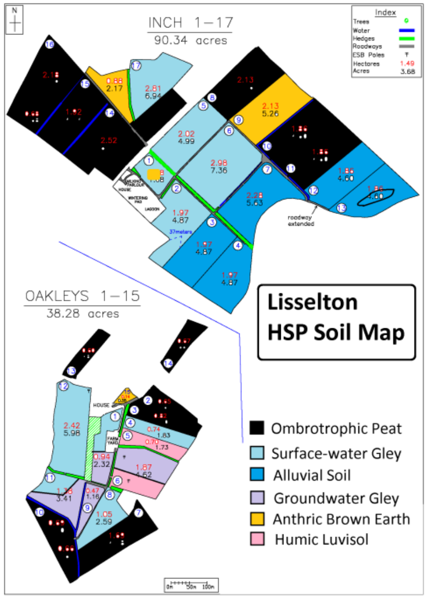
Soil Maps



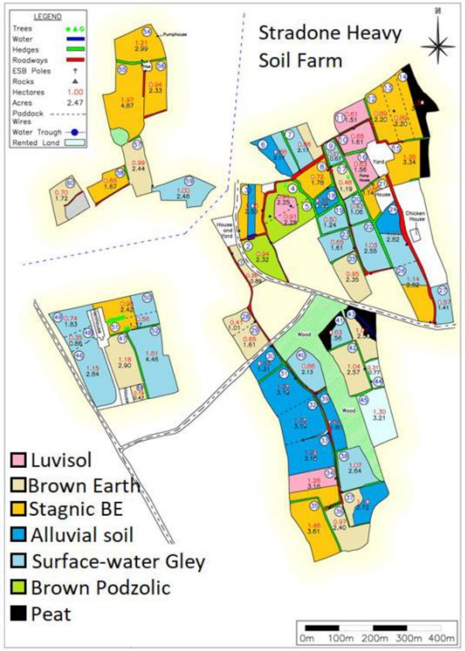
Castleisland
Soil Map



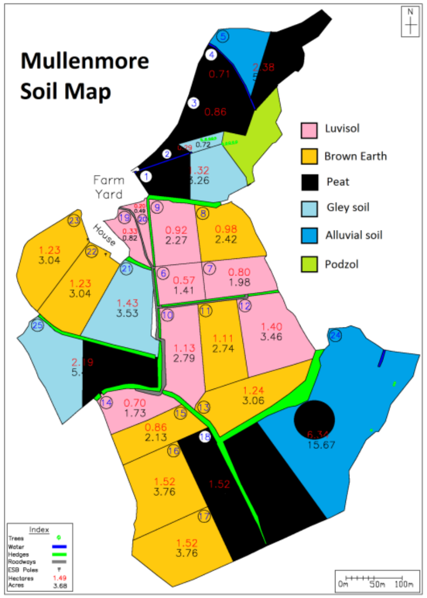
Typical/Anthric/Humic Brown Earth
Typical/Humic/Stagnic Brown Podzolic
Humic/Stagnic Iron-pan Podzol
Typical/Humic Surface-water or Groundwater Gley
Typical Lithosol
Soil Map
Ballinagree



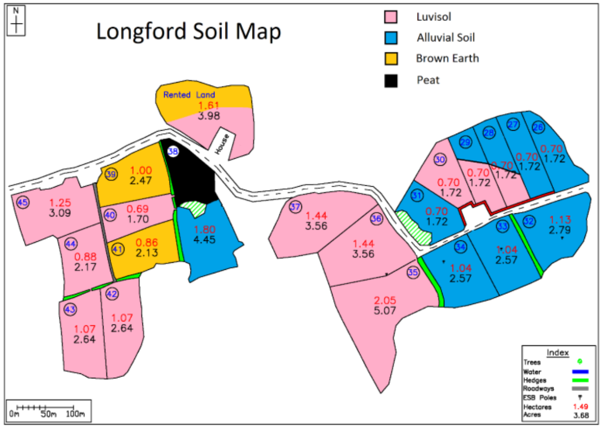
INCH 1—17
90.34 acres
OAKLEYS 1—15
38.28 acres
Lisselton
HSP Soil Map
Ombrotrophic Peat
Surface-water Gley
Alluvial Soil
Groundwater Gley
Anthric Brown Earth
Humic Luvisol



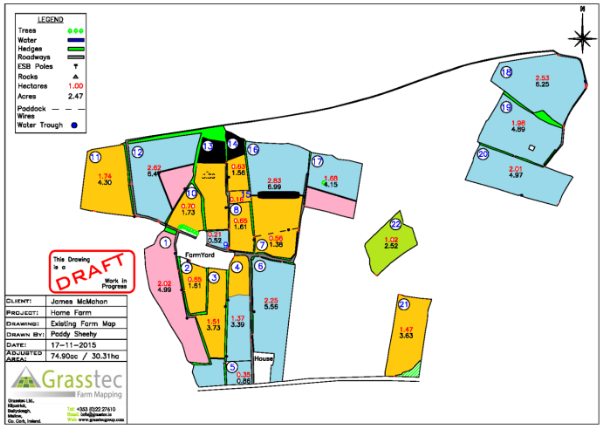
Stradone Heavy
Soil Farm
Luvisol
Brown Earth
Stagnic BE
Alluvial soil
Surface-water Gley
Brown Podzolic
Peat
0m 100m 200m 300m 400m



Mullenmore
Soil Map
Luvisol
Brown Earth
Peat
Gley soil
Alluvial soil
Podzol
Farm
Yard



Longford Soil Map
Luvisol
Alluvial Soil
Brown Earth
Peat
Rented Land

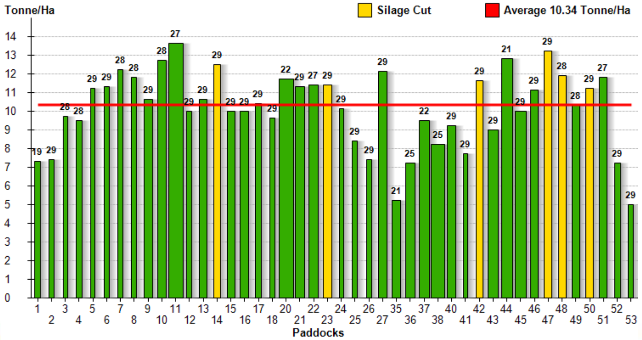


DRAFT
Grasstec

Production systems

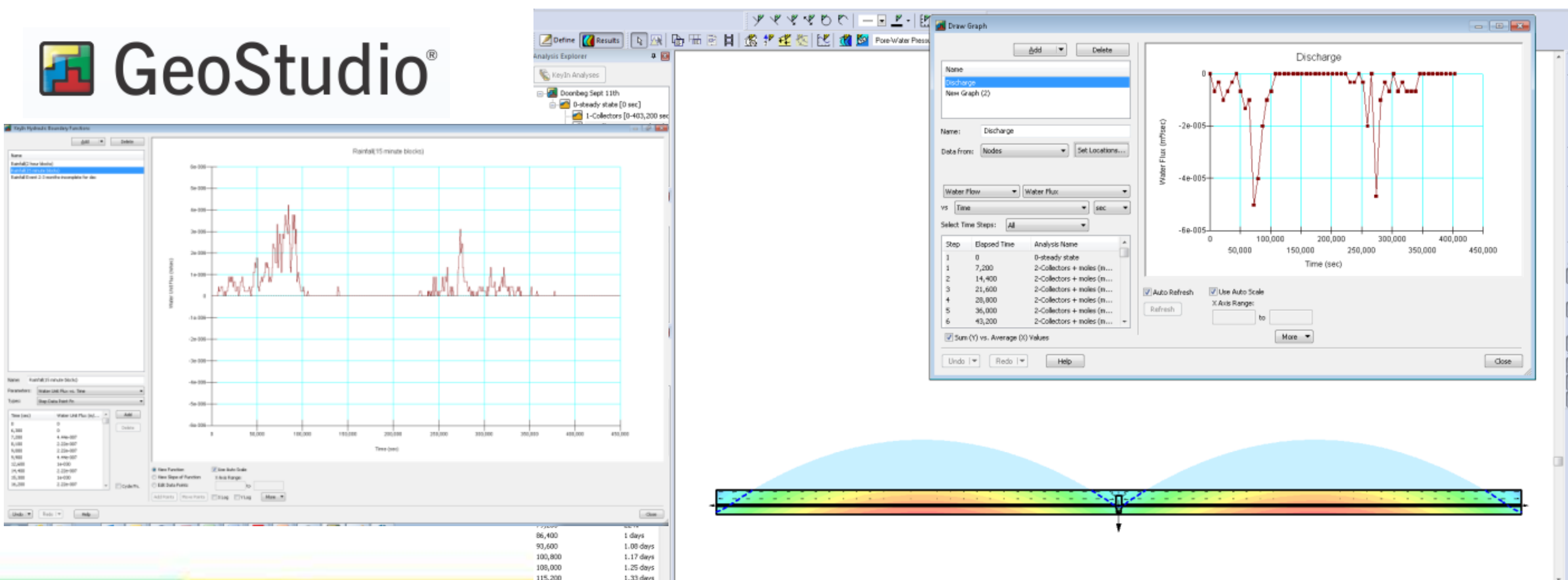
Farm production and performance on poorly drained soils

- Monitoring whole farm systems
  - **System inputs:** Feed, fertiliser, lime, slurry
  - **Management practices:** Grassland, labour, contracting
  - **System outputs:** Animal performance & productivity
  - **Financial Performance:** Profit monitor, economics



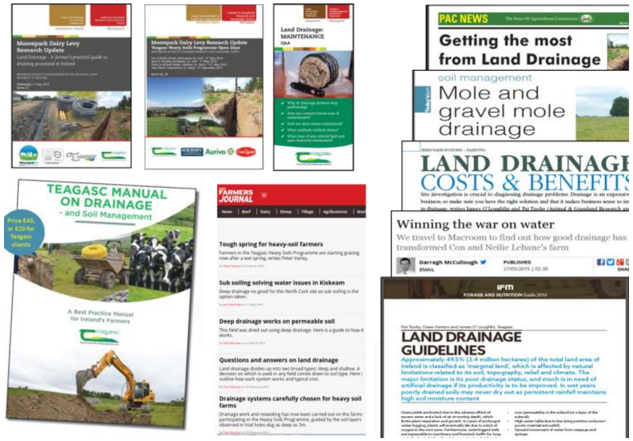
Model simulations

- Model simulations of drain performance are dependent on high resolution performance data and detailed measurement of soil
- Simulation models allow for variations in drainage design to be tested at low cost
- Scope for assessing drainage systems across a range of soil types and climates



Dissemination, Extension & Training

- The programme delivers outputs in scientific and popular press



- And through public on-farm and training events

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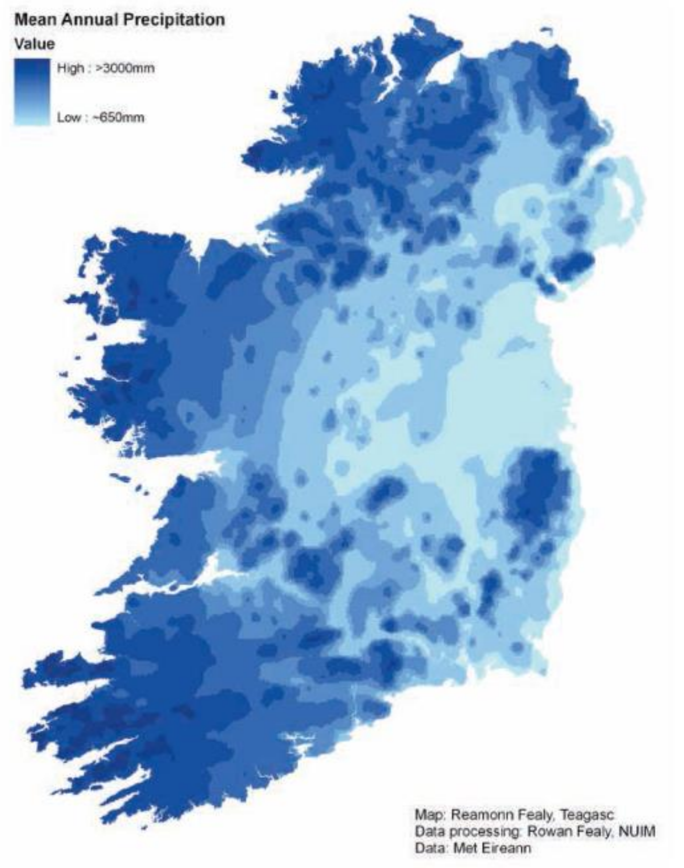
The Irish Agriculture and Food Development Authority

Soils and rainfall

- Marginal land occupies just under 50% of Irish land area
- Trafficability for machinery and livestock is a major limitation in wet conditions
- Use of such soils is curtailed due to;
  - Reduced stocking capacity and grass yields.
  - Increased susceptibility to surface damage and compaction.




20
40
60
80
1
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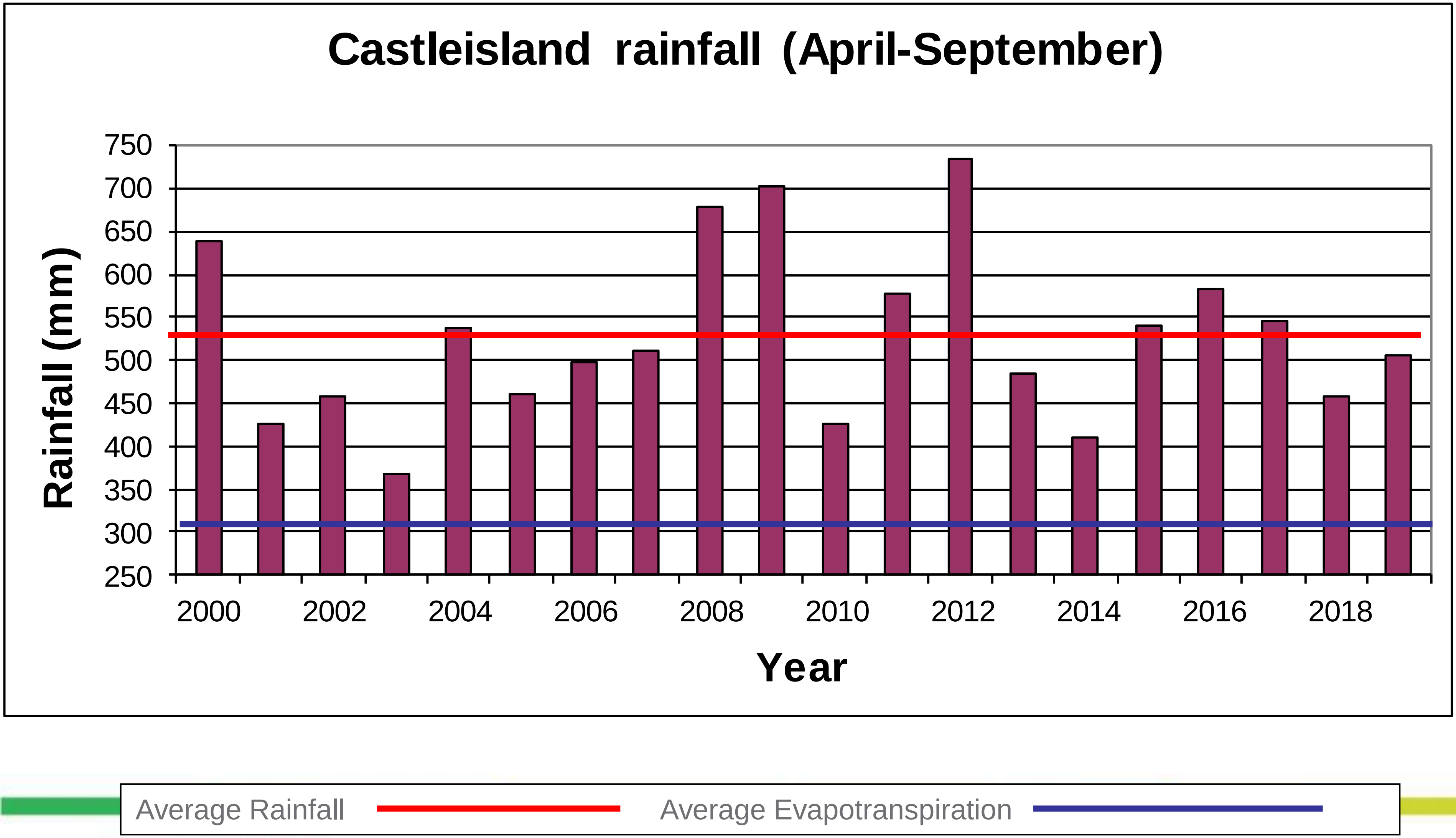

Castleisland rainfall (April-September)
750
700
650
600
550
500
450
400
350
300
250
Rainfall (mm)
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
Year
Average Rainfall
Average Evapotranspiration

HSP Farm Performance 2011 - 2018

Year	Herd Size	Stocking Rate		Herd EBI		6 week calving %
		Farm	MP	Total	Fertility	
2011	78	1.70	2.12	84	47	72
2012	85	1.71	2.27	112	73	68
2013	84	1.69	2.24	134	79	76
2014	88	1.85	2.30	150	87	74
2015	95	1.81	2.45	161	89	74
2016	100	1.85	2.56	82	35	69
2017	104	2.00	2.80	89	39	75
2018	**107**	**2.00**	**2.90**	**119**	**45**	**74**

HSP: Average Farm Performance

Year	Milk Solids (kg/ha)	Gross Output		Total Costs		Net Margin	
		(€/Ha)	(c/litre)	(€/Ha)	(c/litre)	(€/Ha)	(c/litre)
2011	850	3236	35.6	1838	20.3	1398	15.3
2012	869	3092	35.4	2143	24.7	948	10.7
2013	940	3689	40.0	2332	25.4	1357	14.6
2014	935	3725	39.0	2134	22.4	1591	16.9
2015	1091	3245	32.2	2145	21.2	1100	10.8
2016	1068	2935	28.3	1911	19.7	954	8.6
2017	1289	4508	38.4	2355	20.1	2153	18.4
2018	**1404**	**4530**	**37.6**	**2961**	**23.3**	**1571**	**12.6**

Grass Production 2018 (>22 walks)

	Date		Walks	Number Grazing	Grazing* Area (Ha)	Tonnes (DM/Ha)			
	First	Last				Grown	Spring	Summer	Autumn
Castleisland	1st Feb	30th Dec	37	8	49.7	**13.0**	0.5	7.1	5.4
Ballinagree	7th Feb	20th Nov	27	8	52.8	**11.3**	1.1	6.5	3.7
Doonbeg	12th Feb	28th Dec	37	7	43.9	**11.4**	0.3	6.7	4.4
Athea	12th Jan	30th Dec	39	7	39.3	**11.6**	0.5	6.9	4.2
Rossmore	7th Jan	20th Dec	26	8	29.5	**12.7**	0.7	7.5	4.5
Kishkeam	7th Feb	19th Nov	23	7	42	**9.2**	0.3	4.8	4.1
Listowel	1st Feb	20th Nov	24	6	31.3	**12.5**	0.6	6.6	5.3
Crossmolina	8th Mar	8th Nov	24	5	11.2	**8.9**	0.1	5.3	3.5
Stradone	24th Jan	16th Nov	36	5	37.8	**11.3**	0.3	7.1	3.9
Swanscross	22nd Mar	16th Nov	22	6	33.3	**11.2**	0.2	6.7	4.3
Average	6th Feb	2nd Dec	30	7	37.1	**11.3**	0.5	6.5	4.3

Grass Production Best Grazing Paddock 2018

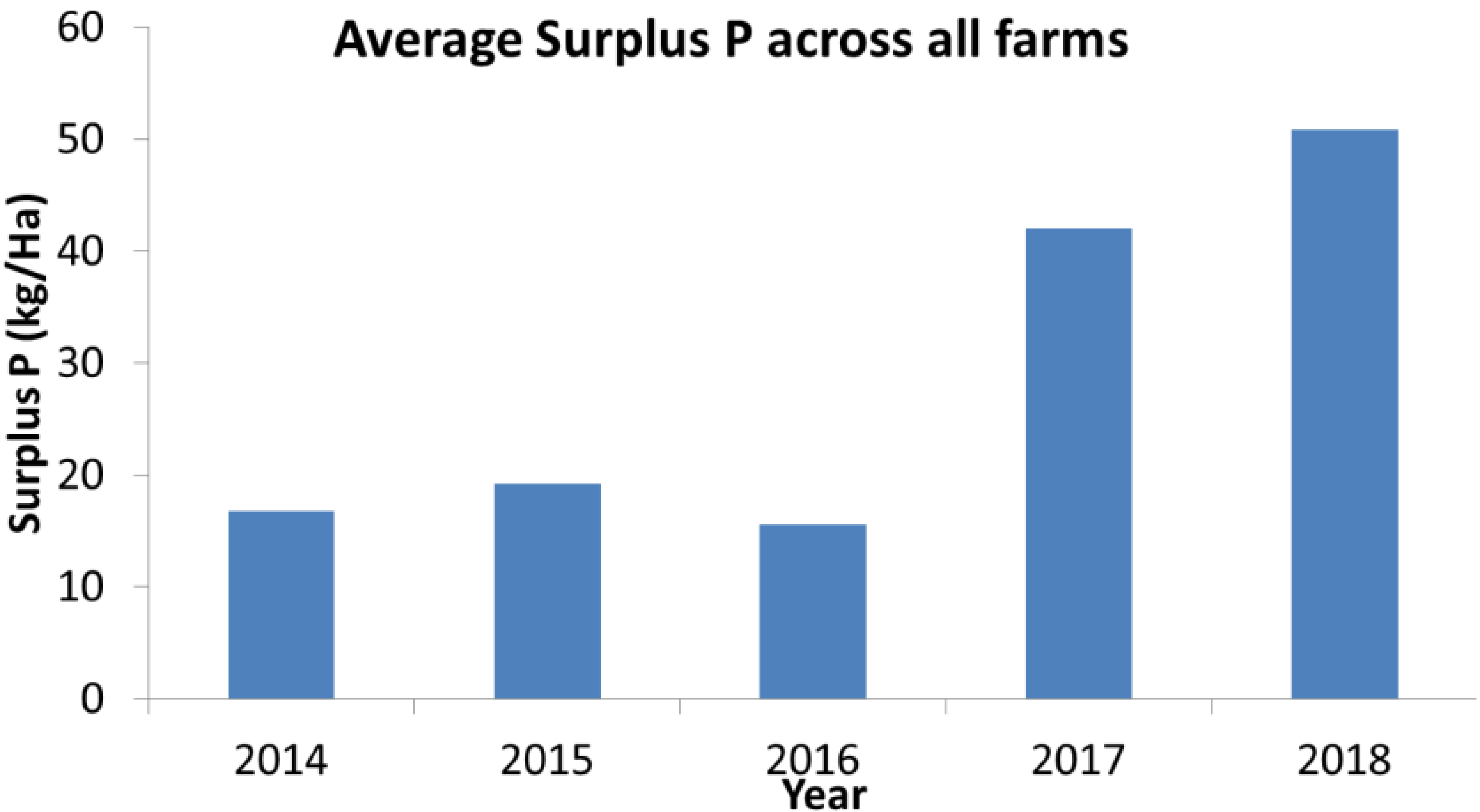
	Average	Spring	Summer	Autumn		Best Paddock			Spring	Summer	Autumn
						No.	Graz/ Silage	Growth			
Castleisland	**13.0**	0.5	7.1	5.4		11	9+1	**18.1**	2.5	9.7	5.9
Ballinagree	**11.3**	1.1	6.5	3.7		14	10	**14.0**	1.2	7.9	4.9
Doonbeg	**11.4**	0.3	6.7	4.4		3	9+2	**14.6**	0.3	9.1	5.2
Athea	**11.6**	0.5	6.9	4.2		12	7+1	**14.9**	0.6	8.6	5.7
Rossmore	**12.7**	0.7	7.5	4.5		13	9	**16.4**	0.2	10.7	5.5
Kishkeam	**9.2**	0.3	4.8	4.1		5	7+1	**11.5**	0.4	7.1	4.0
Listowel	**12.5**	0.6	6.6	4.3		3	7+1	**16.7**	1.2	8.8	6.7
Crossmolina	**8.9**	0.1	5.3	3.5		33	4+1	**12.5**	0.1	8.1	4.3
Stradone	**11.3**	0.3	7.1	3.9		31	2+3	**18.8**	0.1	10.6	8.1
Swanscross	**11.2**	0.2	6.7	4.3		17	6+1	**16.2**	0.1	8.3	7.8
Average	**11.3**	0.5	6.5	4.3			7+1	**15.1**	0.7	8.8	5.6

Soil Fertility: pH Status

Location	2013	2014	2015	2016	2017	2018
Castleisland	5.5	5.7	5.9	6.0	6.2	6.3
Doonbeg	5.8	5.8	5.7	6.1	6.1	5.8
Athea	5.5	5.8	6.2	6.5	6.6	6.6
Kishkeam	5.8	5.8	6.2	6.4	6.3	6.2
Listowel	5.7	5.5	5.9	6.0	6.0	6.0
Rossmore	5.8	5.8	6.2	6.2	6.2	6.4
Ballinagree	5.8	5.9	6.5	6.5	6.3	6.3
Crossmolina	5.4	5.6	5.7	6.1	5.9	5.8
Swanscross	--	--	6.4	6.5	6.4	6.3
Stradone	--	--	6.2	6.5	6.6	6.7
Average	5.7	5.7	6.1	6.3	6.3	6.2
Target	6.2	6.2	6.2	6.2	6.2	6.2

Soil Fertility: Phosphorus mg/l

Location	2013	2014	2015	2016	2017	2018
Castleisland	4.7	6.4	4.2	5.3	5.2	7.1
Doonbeg	4.9	5.6	5.5	4.1	5.2	6.1
Athea	3.1	4.9	3.7	3.9	4.2	8.0
Kishkeam	1.9	4.4	2.8	3.1	3.4	6.2
Listowel	5.4	9.8	6.5	5.5	5.9	7.0
Rossmore	8.5	11	10.7	10.1	8.2	7.0
Ballinagree	5.6	6.5	5.1	6.2	5.5	5.8
Crossmolina	7.6	3.4	4.4	5.8	6.2	6.6
Swanscross	--	--	6.2	5.8	5.9	5.2
Stradone	--	--	3.1	5.1	4.1	6.5
Average			5.2	5.5	5.4	6.6
Target	5.1 – 8.0	5.1 – 8.0	5.1 – 8.0	5.1 – 8.0	5.1 – 8.0	5.1 – 8.0



Total Cumulative surplus: 144 kg/ha P = ~ 1.5ppm

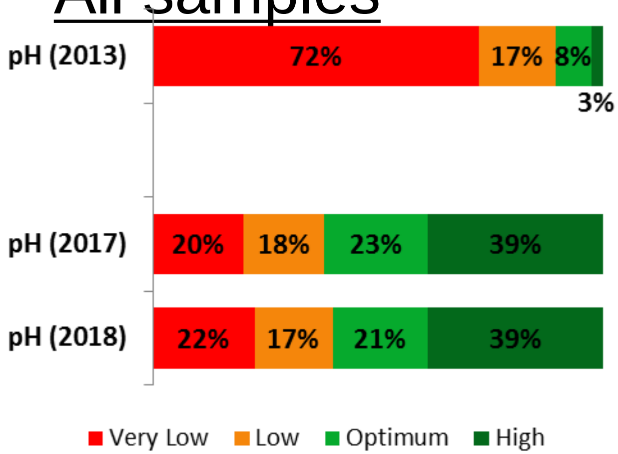
It take 70-90 kg/ha P surplus to increase soil test by 1 ppm in heavy soils

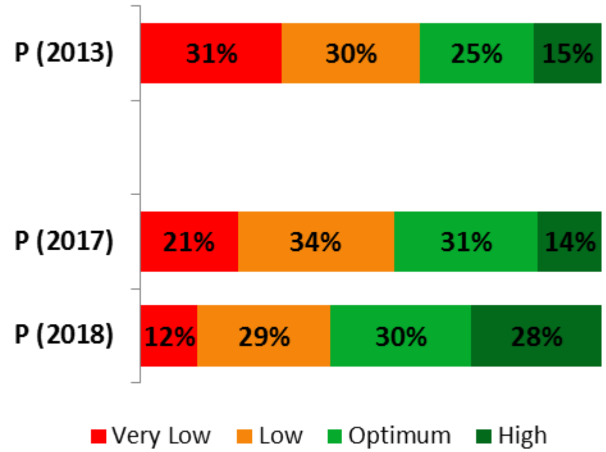
Soil Fertility: Potassium mg/l

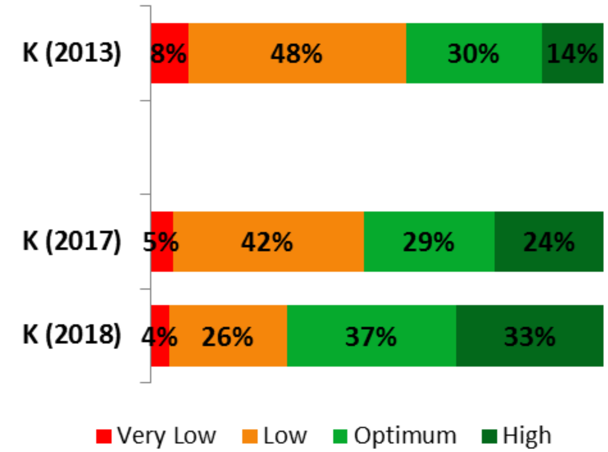
Location	2013	2014	2015	2016	2017	2018
Castleisland	94	110	87	103	109	147
Doonbeg	74	96	91	64	84	122
Athea	134	125	104	106	98	154
Kishkeam	82	112	88	86	99	142
Listowel	89	140	105	74	91	98
Rossmore	97	95	106	111	108	99
Ballinagree	144	155	115	154	145	156
Crossmolina	105	112	73	92	107	142
Swanscross	--	--	170	150	165	156
Stradone	--	--	142	153	152	145
Average	102	118	108	109	116	136
Target	101 – 150	101 – 150	101 – 150	101 – 150	101 – 150	101 – 150

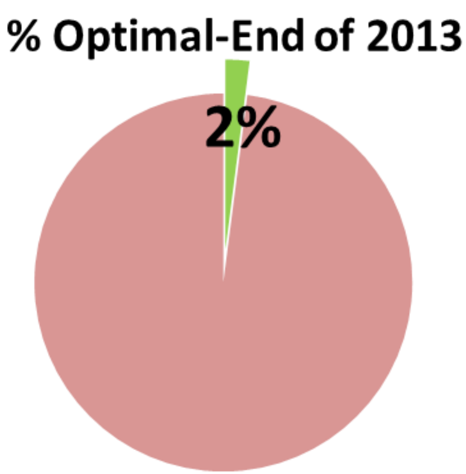
Soil Fertility: Progression

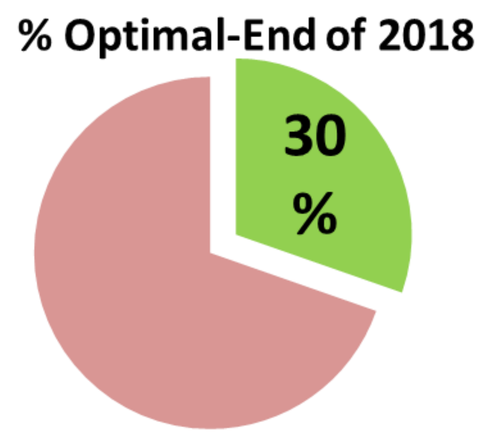
All samples



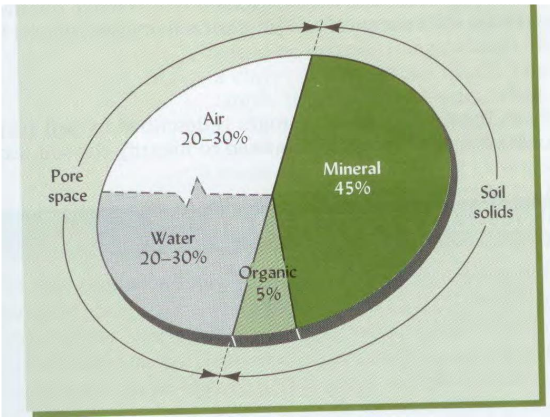


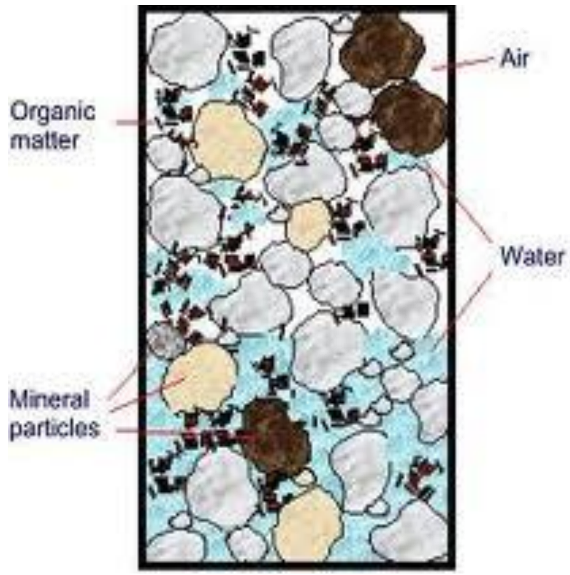


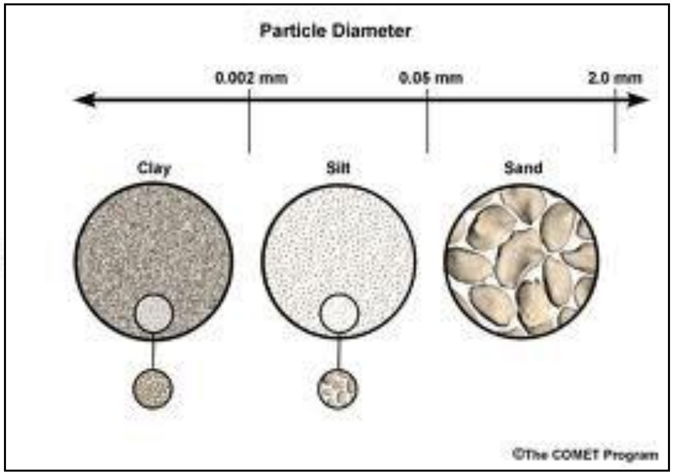




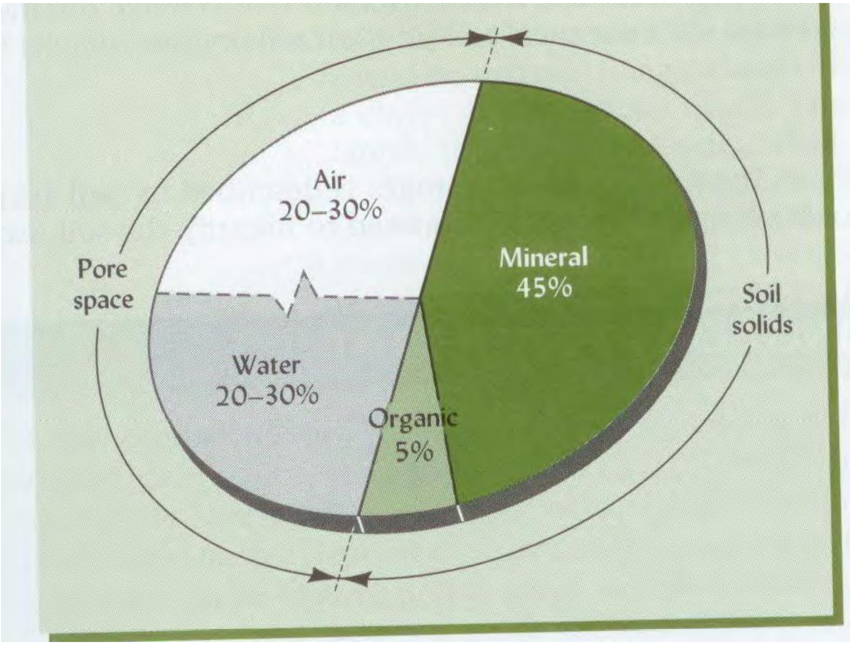
Soil Characteristics







Soil Phases



- Air and water phases occupy the pore space and are complimentary
- Pore space in a saturated soil is filled with water.
- Crops require a minimum 10 -15% air filled pore space for water and nutrient uptake

Soil Solids

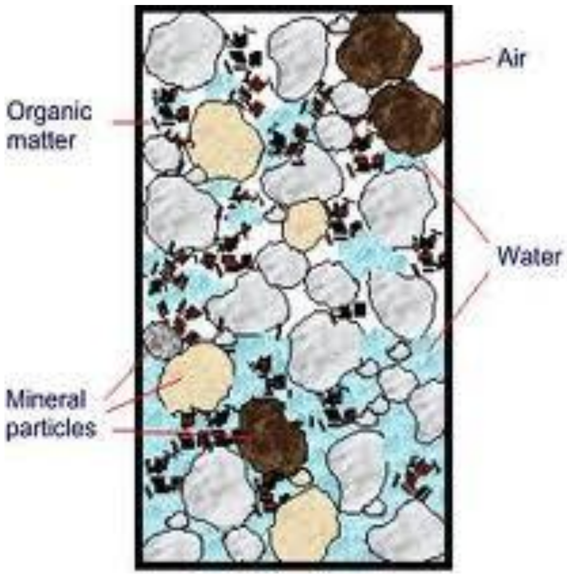
Soil solids consist of mineral and organic materials

Organic Material (<10% in mineral soils)

- Stores water and nutrients
- Binds mineral particles

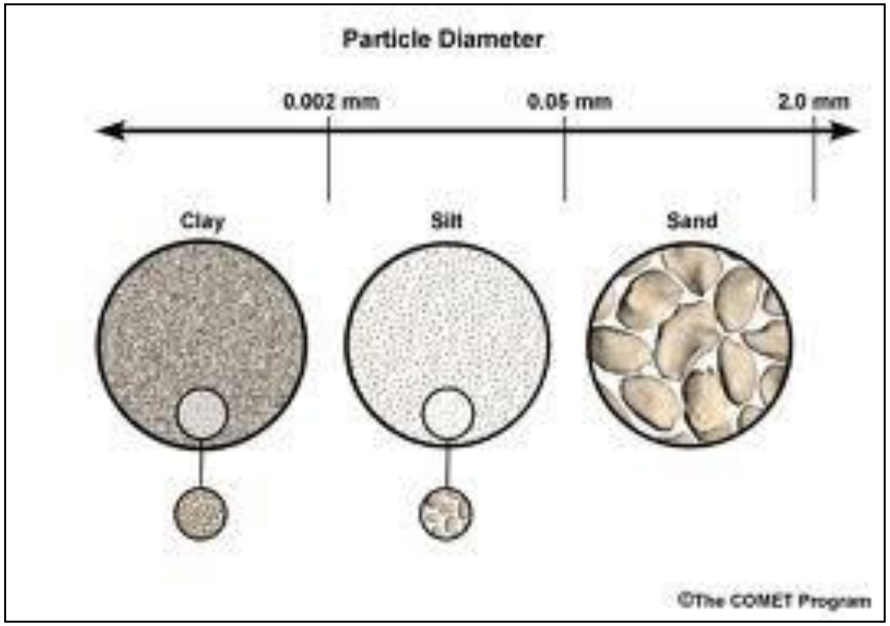
Mineral Particles

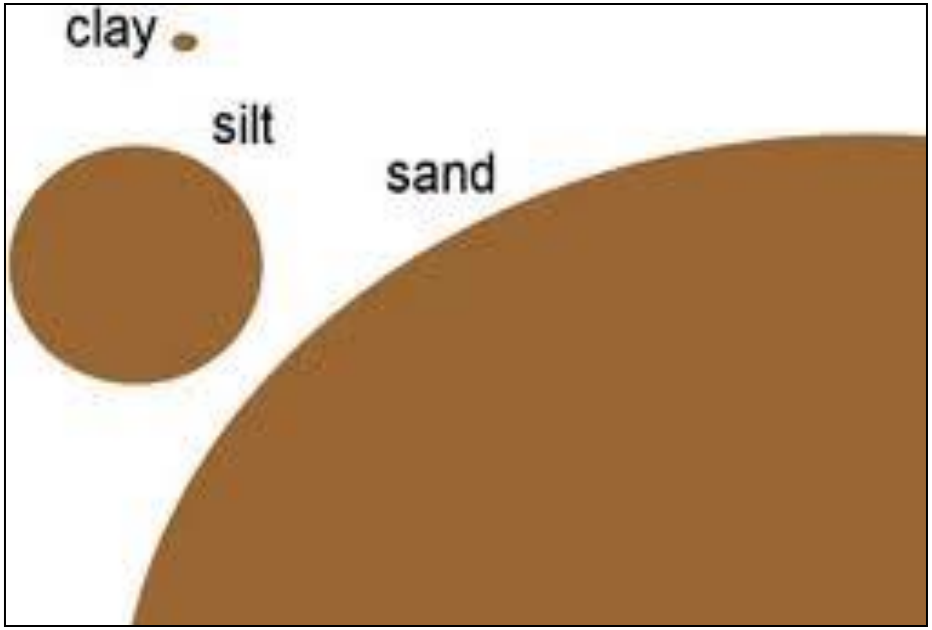
- Sand, silt and clay (plus larger particles - gravel, stones,etc.)
- Size and arrangement of solid particles bear huge influence on water movement



Soil Texture

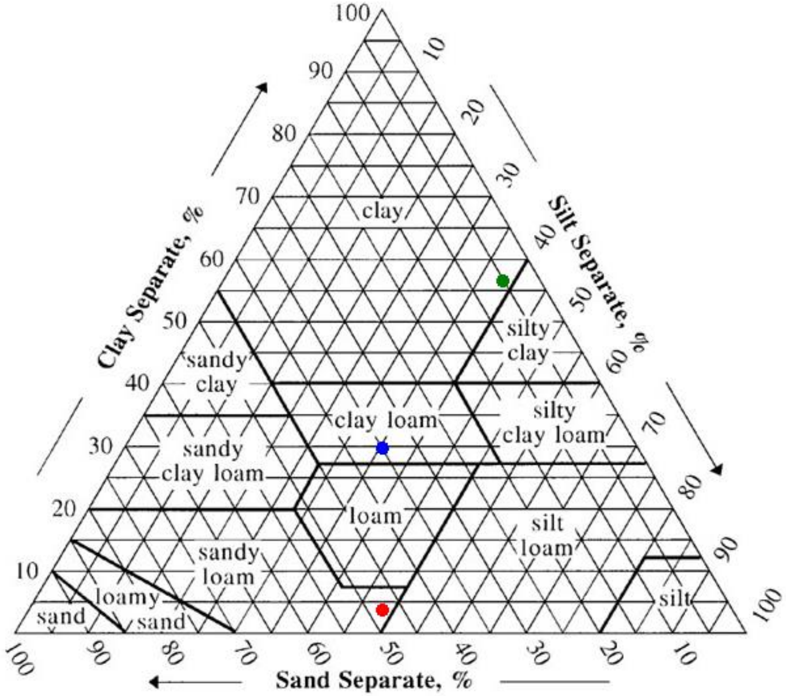
- The relative proportions of sand, silt and clay particles in a soil
- Anything bigger than 2mm is gravel/stone





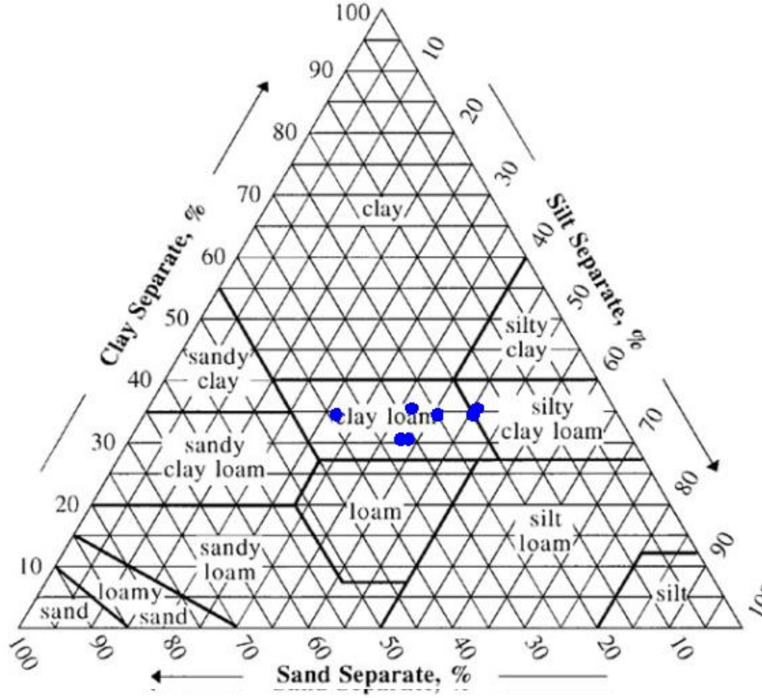
Texture Triangle

- Classification of soils into textural groups
- Classification is assigned after lab or field analysis of soil samples
- On the left the numbers correspond to the % of clay, on the right the numbers correspond to the % of silt. At the bottom of the chart are the % of sand.
- To classify a soil sample, find the intersection of the three lines that correspond to the three proportions of sand, silt and clay.



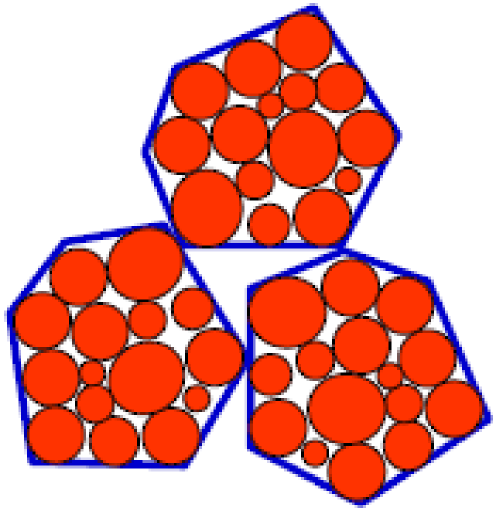
Texture Triangle

- Moorepark (RED-48% sand, 48% silt, 4% clay)
- Blue-35% sand, 35% silt, 30% clay
- Green-5% sand, 38% silt, 57% clay
- HSP farms topsoils
- HSP farms subsoils



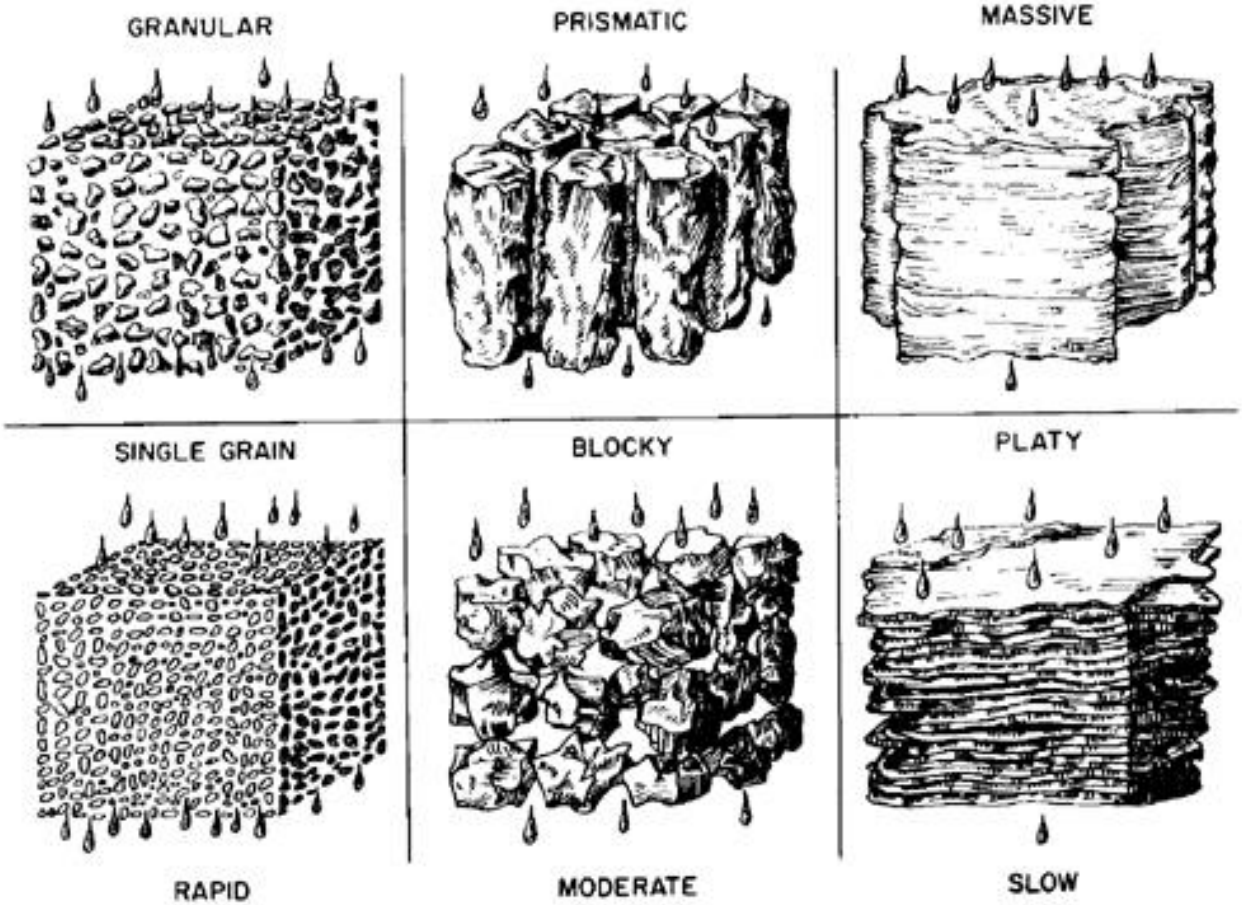
Soil Structure

- Arrangement of particles/level of cracking
- Structural development influenced by formation, texture and management.
- Greatly influences:
  - Water/Air infiltration & movement
  - Root penetration & growth



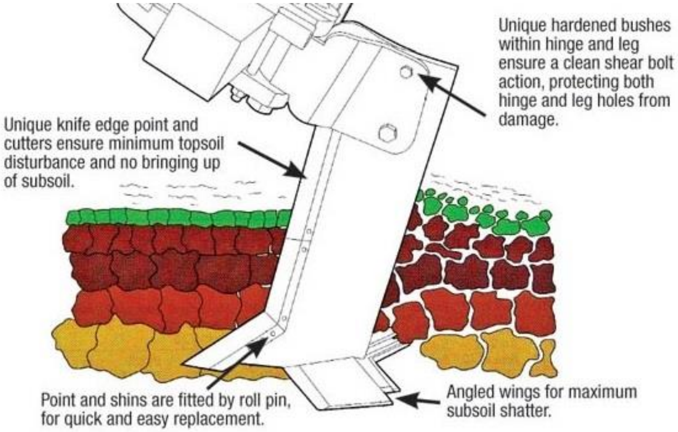
Three soil aggregates comprising many sand, silt, clay and organic particles

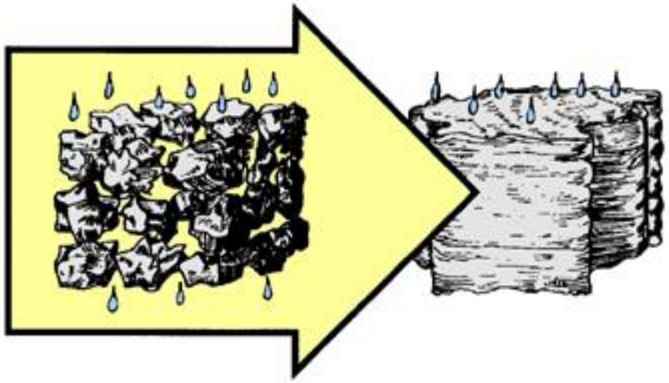
Soil Structure



Altering Soil structure

- Greatly Influenced by management
- Weathering: Wetting/drying and freezing/thawing
- Biological process's: plant roots, earthworms
- *Negative manmade changes*: excessive cultivation, untimely operations on wet soil, heavy machinery.
- *Positive manmade changes*: tilling, drainage, sub-soiling, mole ploughing etc.

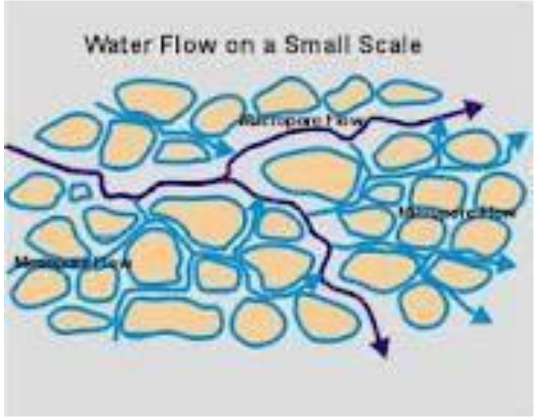




Water movement through Soil

- In free draining soils the rate of water flow through the soil will be higher than all bar very extreme rainfall rates.

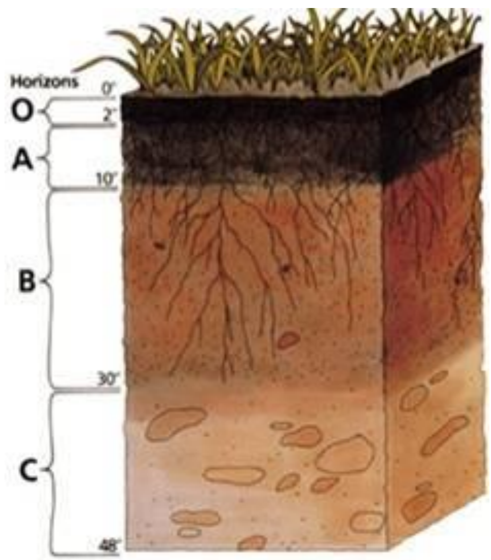
- In poorly drained soil the rate of water flow can be regularly exceeded by rainfall rate due to:
  - Low hydraulic conductivity
  - High Water table due to low lying position and poor out-fall
  - Upward movement of water from seepage and springs



Land Drainage

Definition:

"Ireland lies in the temperate zone, where the main role of drainage is the removal of excess water in the root zone of crops from surplus rainfall, while a secondary objective is to provide good trafficability for farm machinery and livestock"



Types of drainage system

- The depth and type of drain to be installed depends entirely on the interpretation soil characteristics.

- Two principle types are distinguished:

  - **Groundwater drainage system:** A network of deeply installed piped drains exploiting permeable layers

  - **Shallow Drainage system:** Where soil is heavy and infiltration of water is impeded at all depths and permeability needs to be improved

Groundwater Drainage System

- **A Groundwater drainage system is a network of field drains collecting groundwater which can move through soil layers of high permeability**
- They work by exploiting the natural capacity for movement of water at a certain depth in certain soils
- By "tapping" into this natural capacity for water movement the system works by lowering the watertable and reducing the amount of water stored in the soil

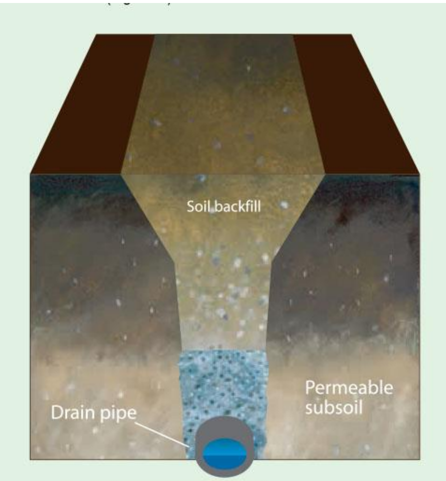
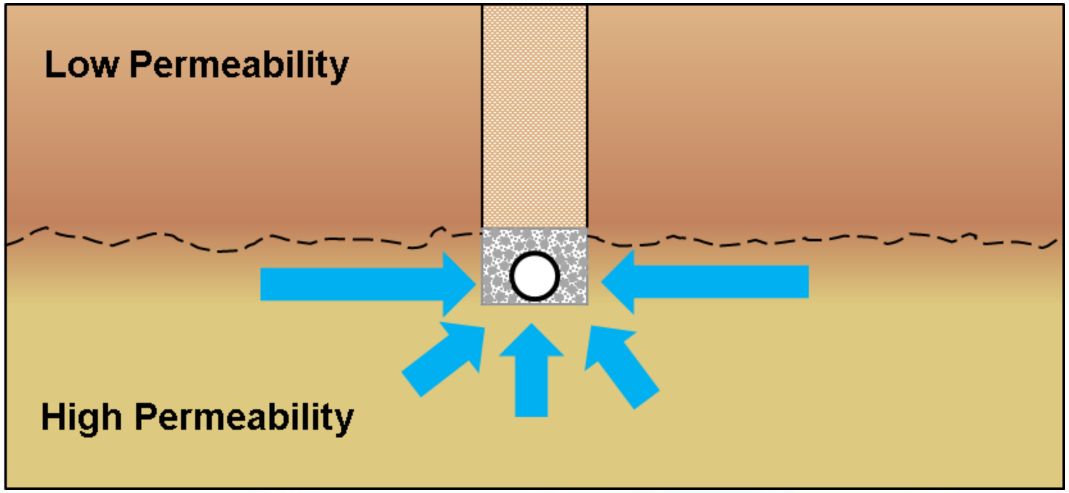


Figure 1. Connection with permeable layer.



Shallow Drainage System

- **A shallow drainage system is a network of field drains in tandem with surface disruption techniques which promote water infiltration and drainage**

- Used where soil permeability is low at all depths and aims to introduce new pathways for water movement in the soil

- Methods include: Mole drainage, gravel mole drainage, sub-soiling (pan busting) and land forming

Drainage System Materials

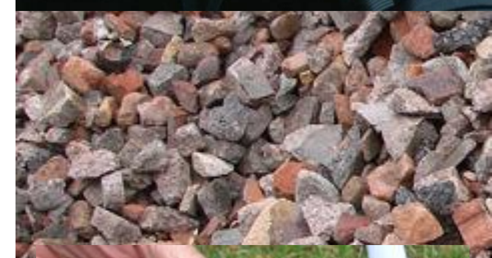
- The drainage pipe facilitates a unobstructed flow path from the field drain.

- Perforated corrugated pipe is the cheapest and most convenient

- Drainage stone has three functions
  - Hydraulic: to facilitate water flow to the pipe
  - Filter: to prevent the entry of fine particles to the pipe
  - Bedding: to provide support for the pipe and prevent collapse

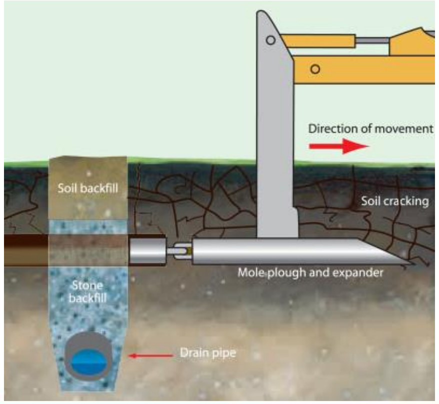
- Synthetic filters are common in other parts of the world, where creating an outlet and discharging water are enough to create gradients and remove water.

- Some Irish soils would be suited to these systems

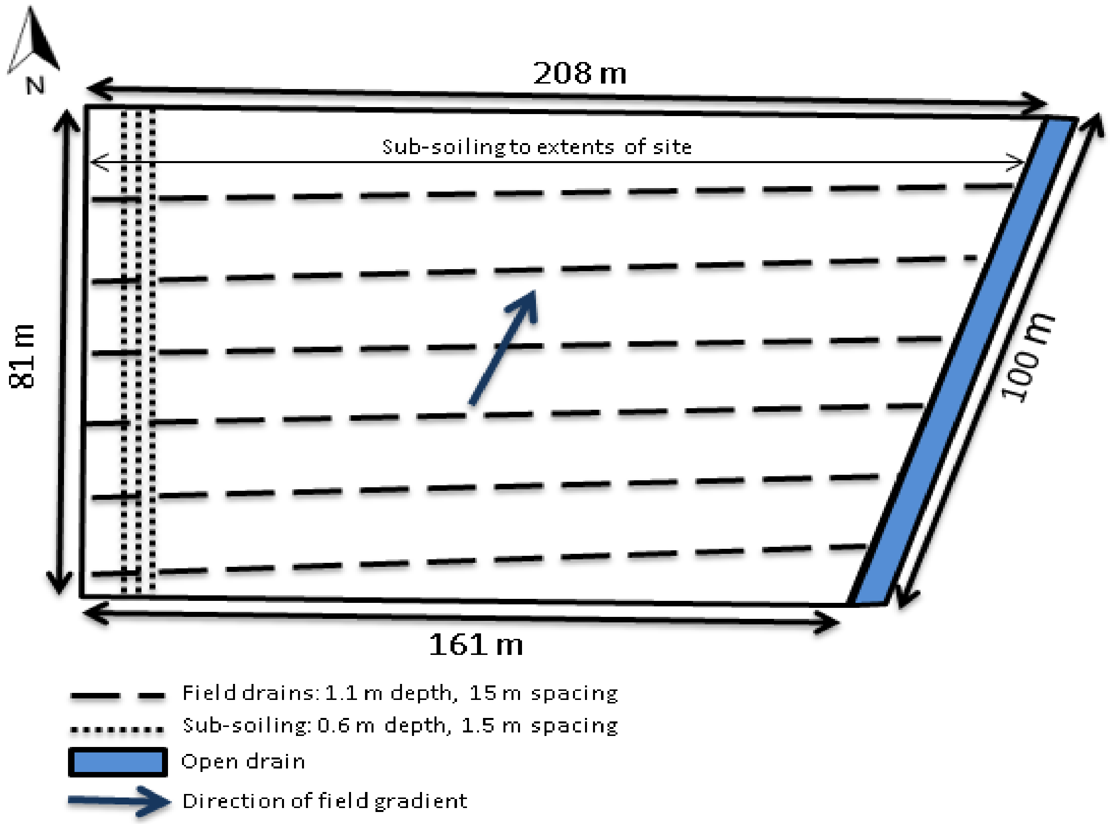


Land Drainage Design: Kishkeam Farm

Problem Diagnosis



Drainage system design

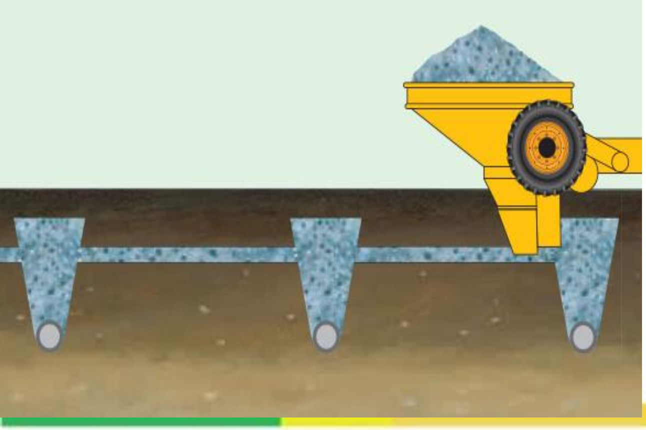


Drainage Costs: Kishkeam Farm

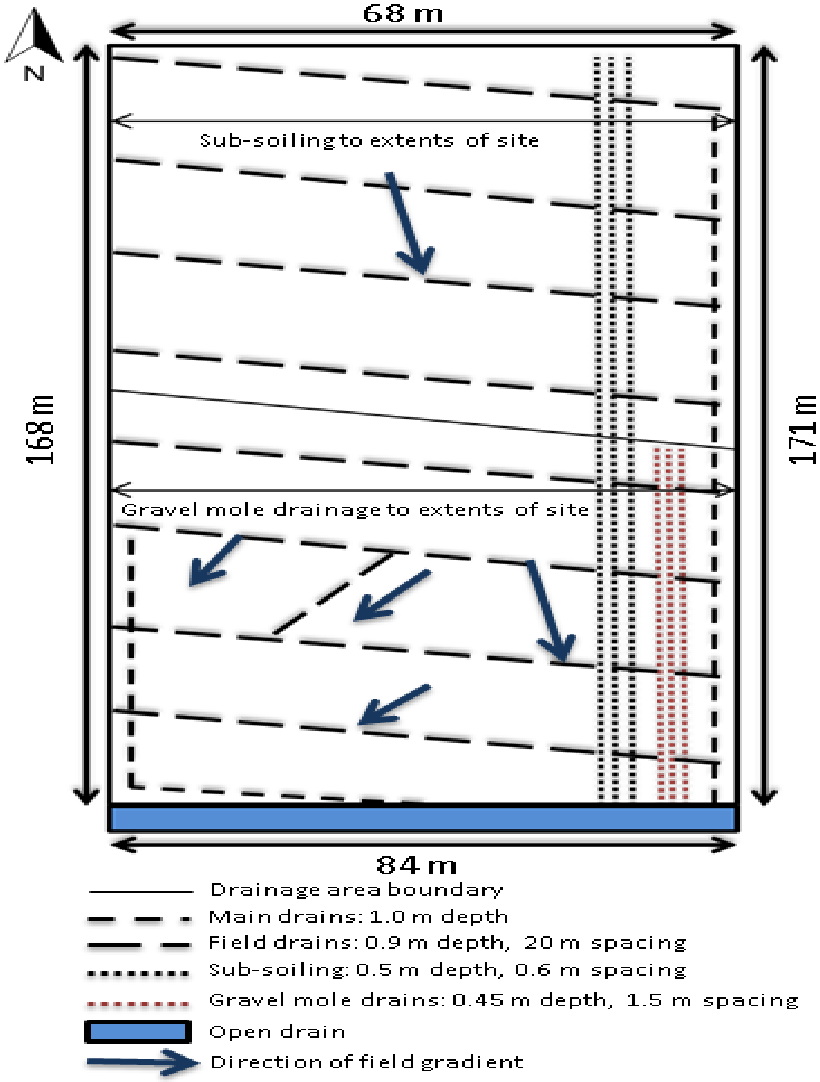
Costs	Total/ha
Drain installation @ €45/hr (36 hrs)	€1,625
Drainage pipe @ €1.03/m (566 m)	€585
Drainage stone @ €10.78/t (101 t)	€1,085
Subsoiling	€125
Drainage cost	€3,420

Land Drainage Design: Castleisland Farm

Problem Diagnosis



Drainage System Design



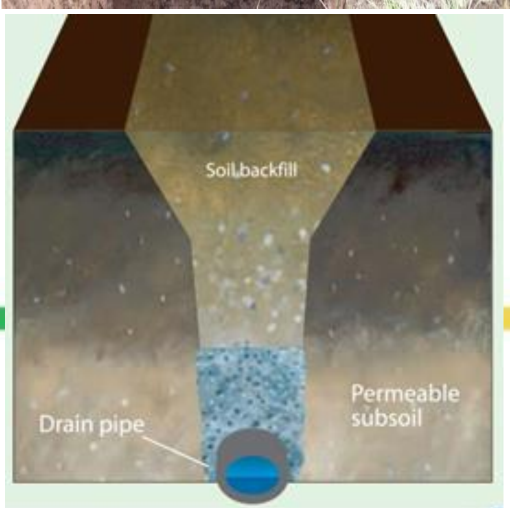
Drainage Costs: Castleisland Farm

Heavy Soils

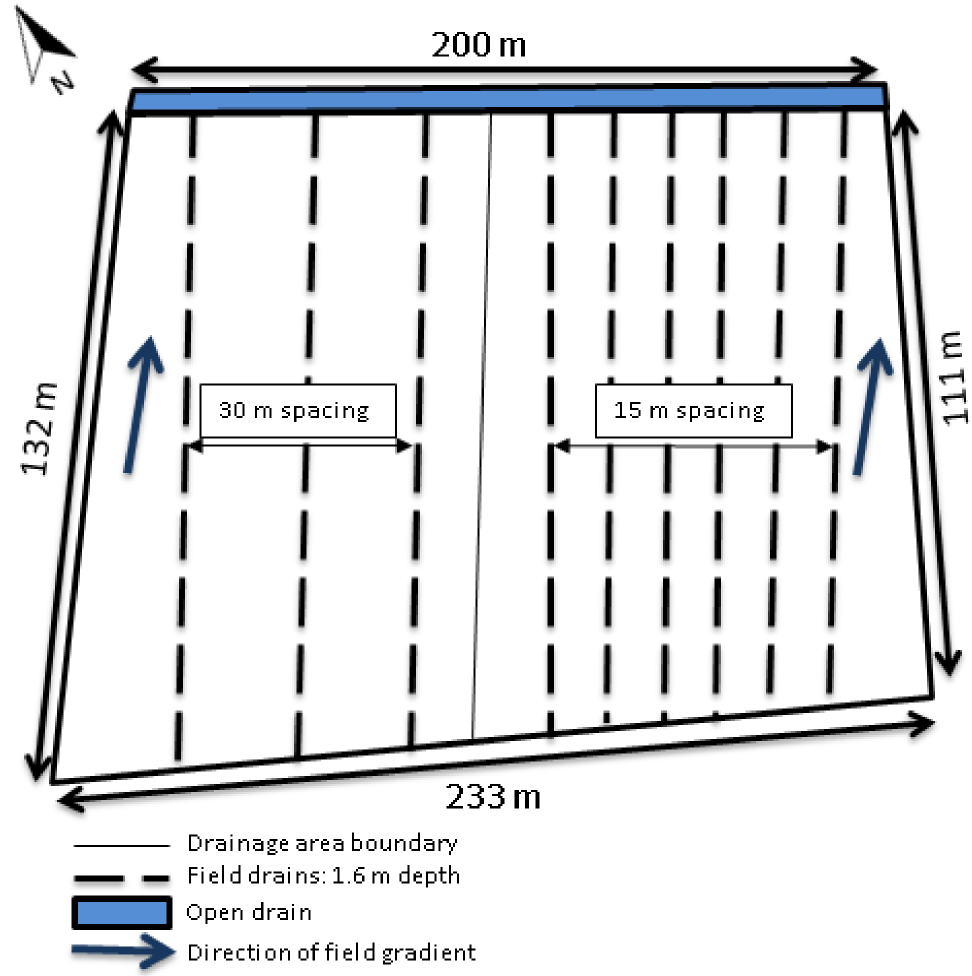
Costs	Total/ha
Drain installation @ €45/hr (40 hrs)	€1,800
Drainage pipe @ €0.93/m (677 m)	€630
Drainage stone @ €12.30/t (193 t)	€2,378
Sub-soiling	€222
Gravel mole installation	€510
Gravel mole stone @ €24/t (100t)	€2,400
Drainage cost (Subsoiling)	€5,030
Drainage cost (Gravel moling)	€7,940

Land Drainage Design: Rossmore Farm

Problem Diagnosis



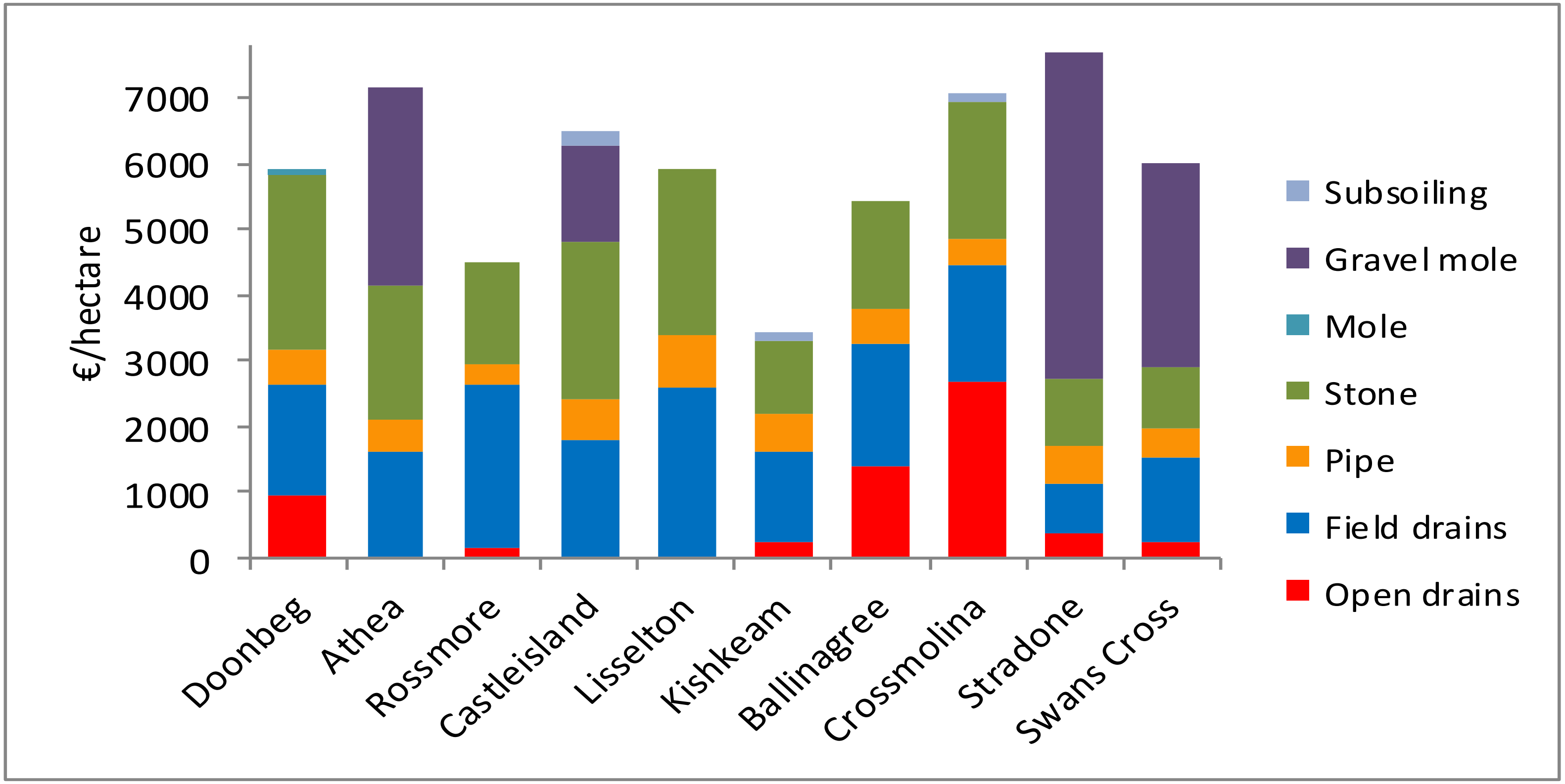
Drainage System Design



Drainage Costs: Rossmore Farm

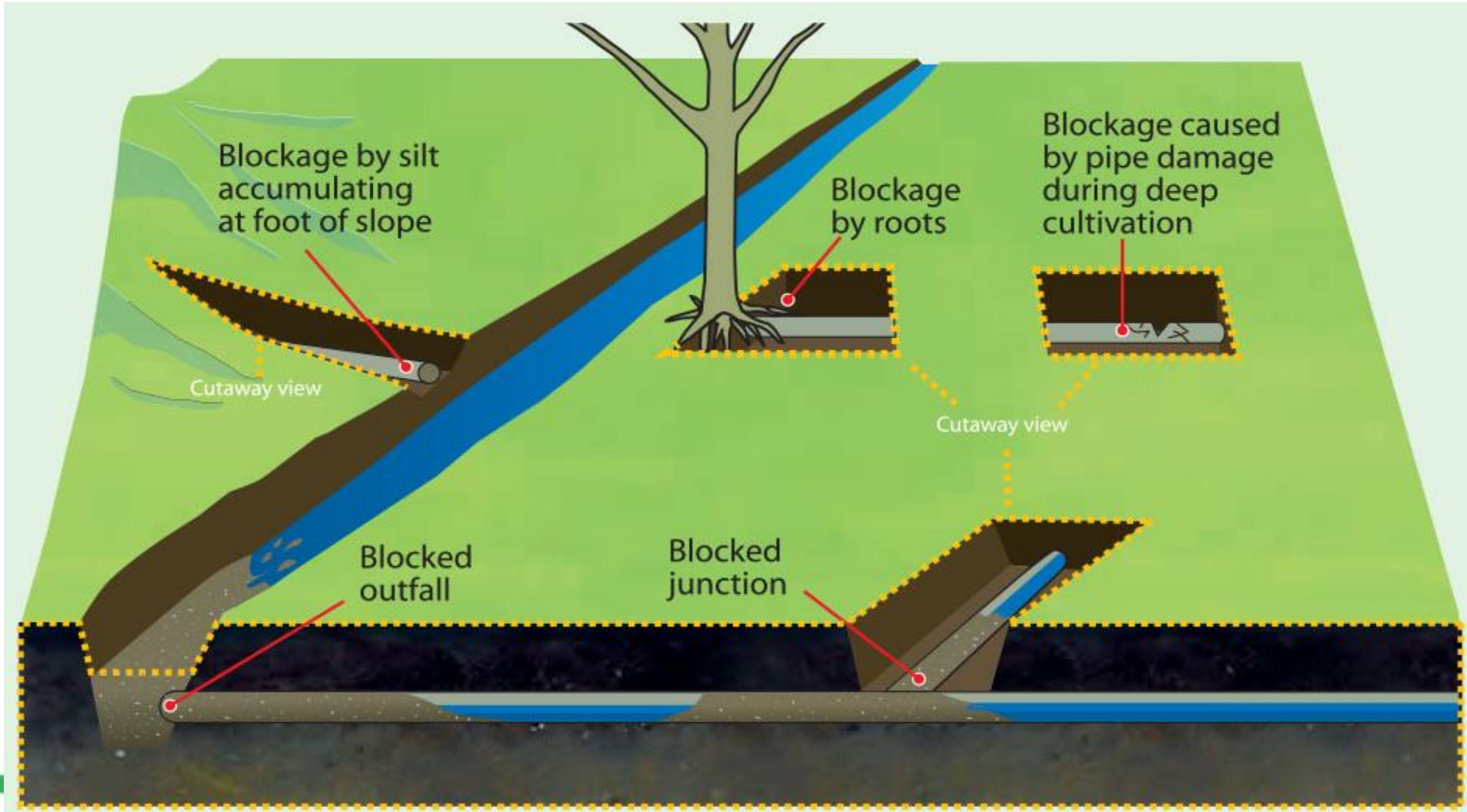
Costs	Total/ha
Drain installation @ €45/hr (55 hrs)	€2,476
Drainage pipe @ €0.70/m (429 m)	€300
Drainage stone @ €11.10/t (141 t)	€1,562
Drainage cost	€4,338

Approximate costs

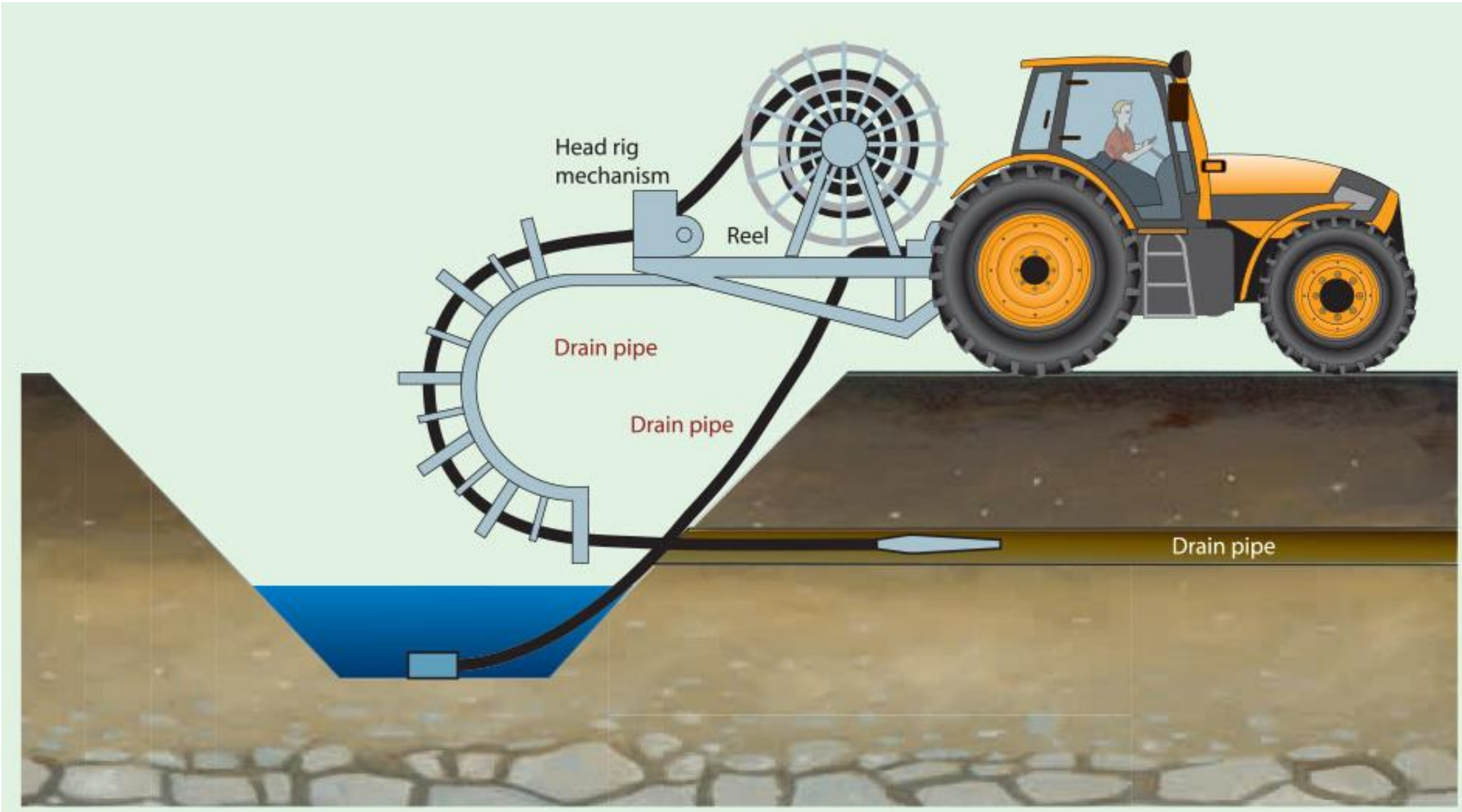


All costs included, high intensity systems. The average cost of drainage systems was €5,960/hectare (€3,420/ha to €7,690/ha)

Maintenance

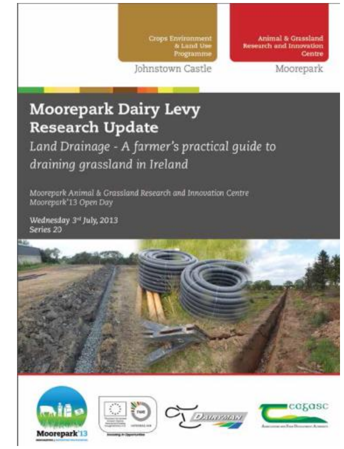


Maintenance



References

- Teagasc Land Drainage guidebook
- Heavy Soils Open Day booklets
- https://www.teagasc.ie/crops/grassland/heavy-soils/
- Teagasc Manual on Drainage and soil management



Questions