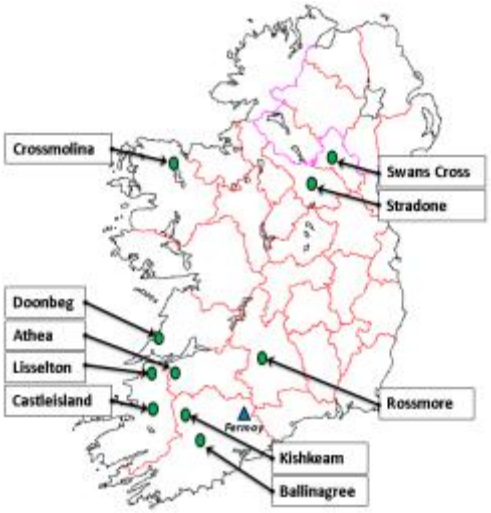
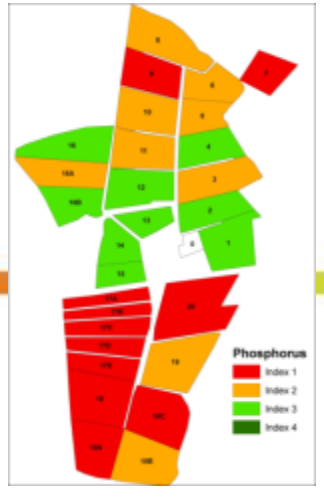
Teagasc Heavy Soils Programme Update: Tralee IT 14/11/2017

Teagasc Animal and Grassland Research and Innovation

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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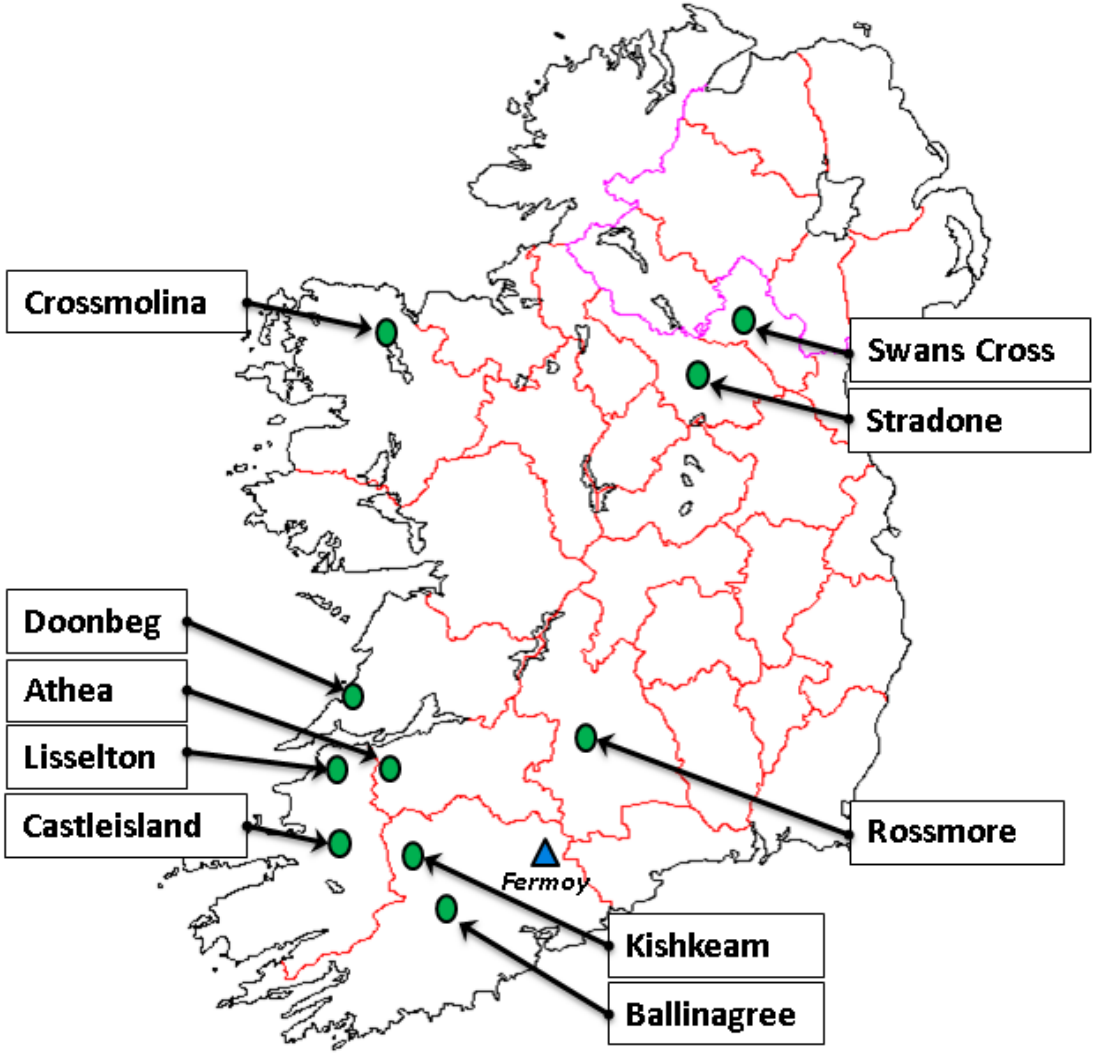
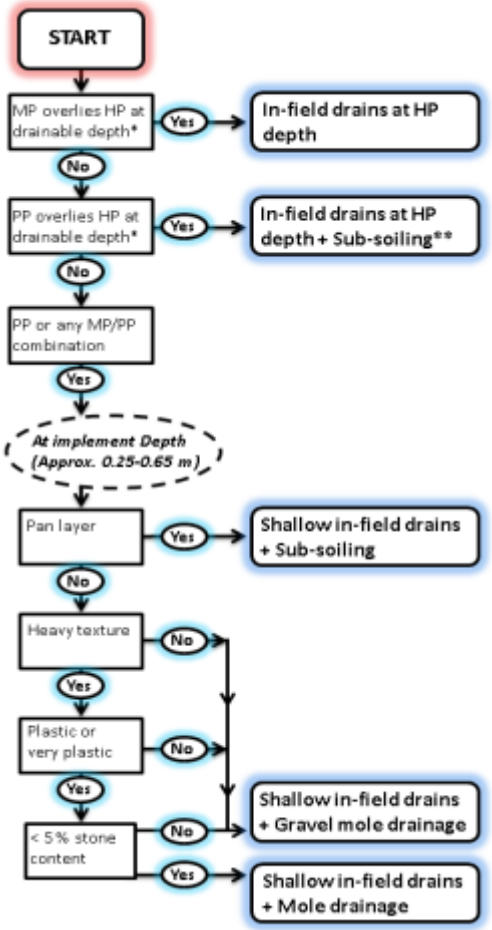
Heavy Soils Programme Farms



Land drainage system design

Development of a practical site-specific drainage design methodology

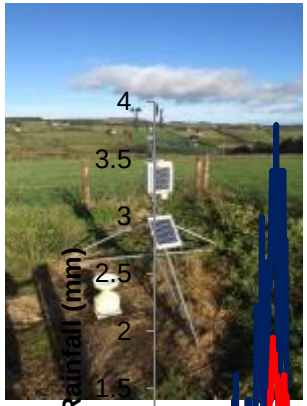


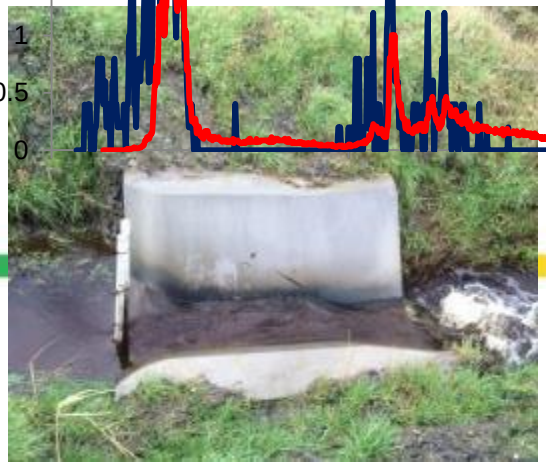



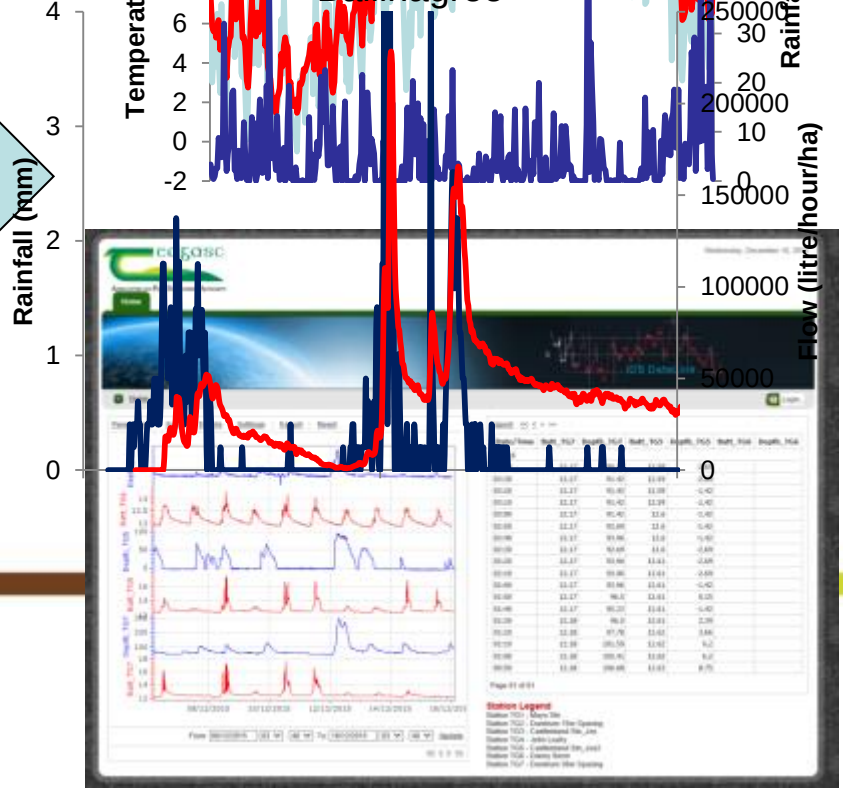
- The permeability of each horizon in test pit is scored using physical indicators (water seepage, texture, structure, etc.)
- Drainage design is based on this permeability classification
- A clear-cut methodology allows for widespread use
- **Effective drainage design can be formulated on-site where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

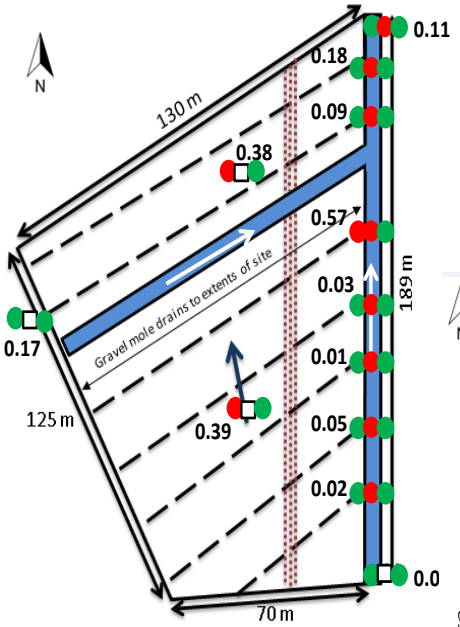
GROUP 2 Kishkeam and Rossmore

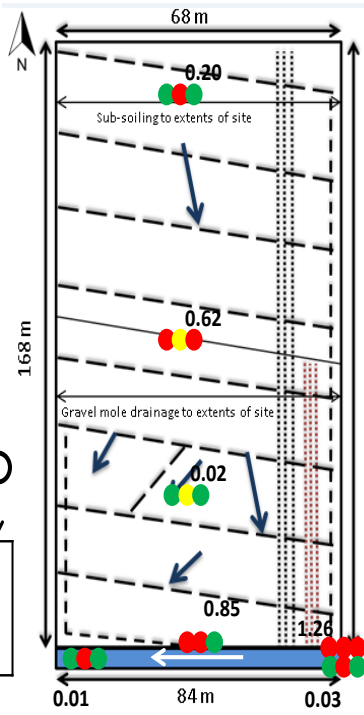
- Low contamination
- High denitrification
- Intermediate N_2O, low N_2

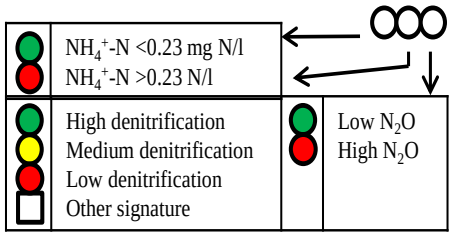
GROUP 3 Athea and Castleisland

- 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

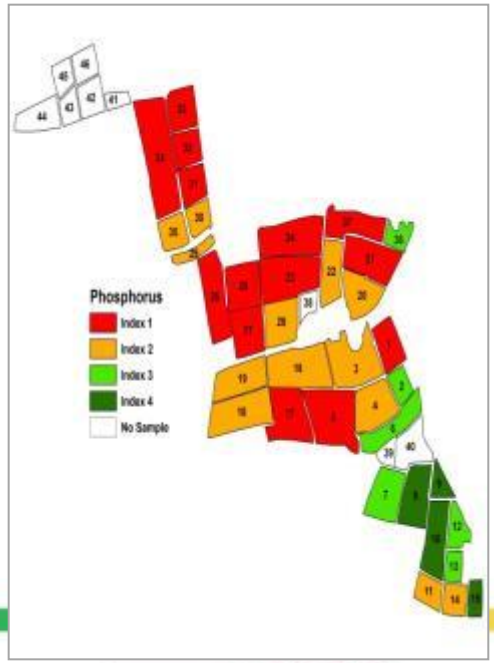


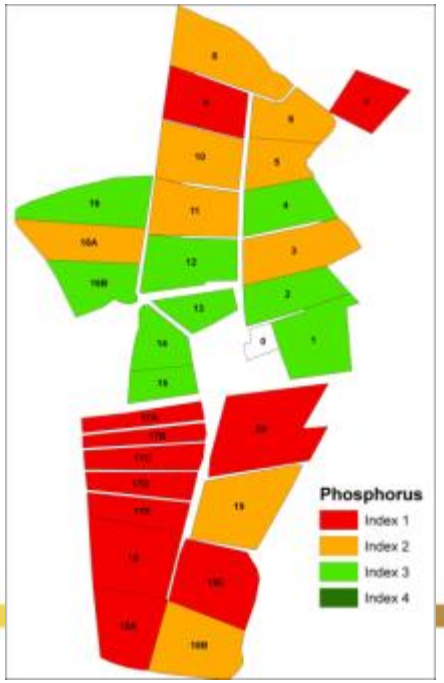




Soil fertility status

- 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





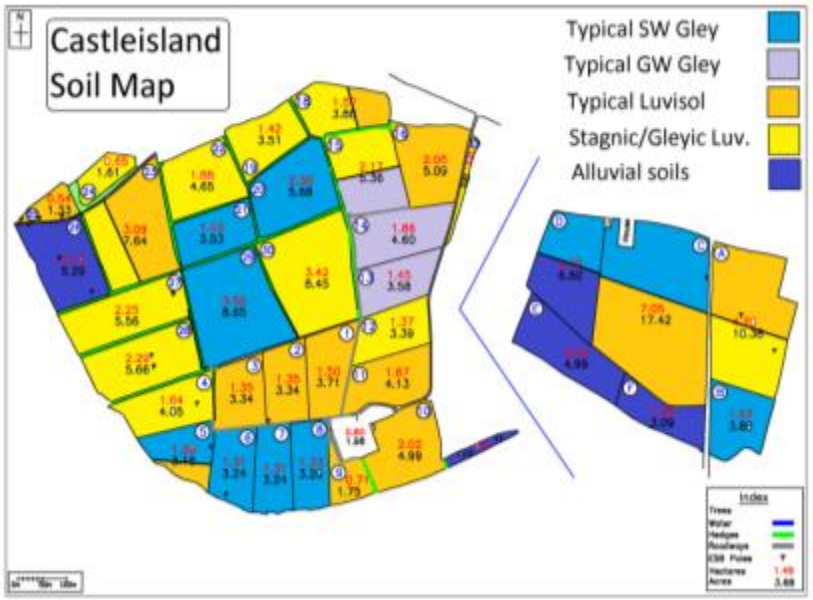
Soil Surveying/Mapping

- August 2015 – Present

- 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

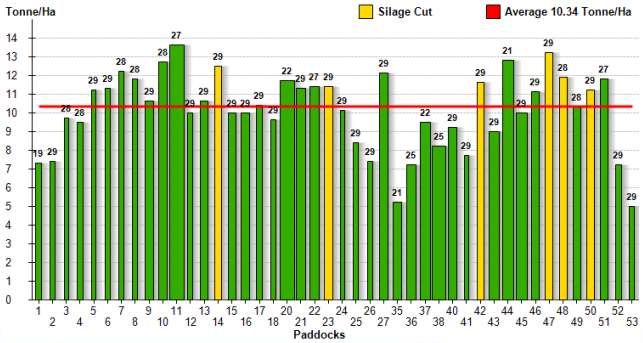
- Contextualise all other data and underpin future work.



Production systems

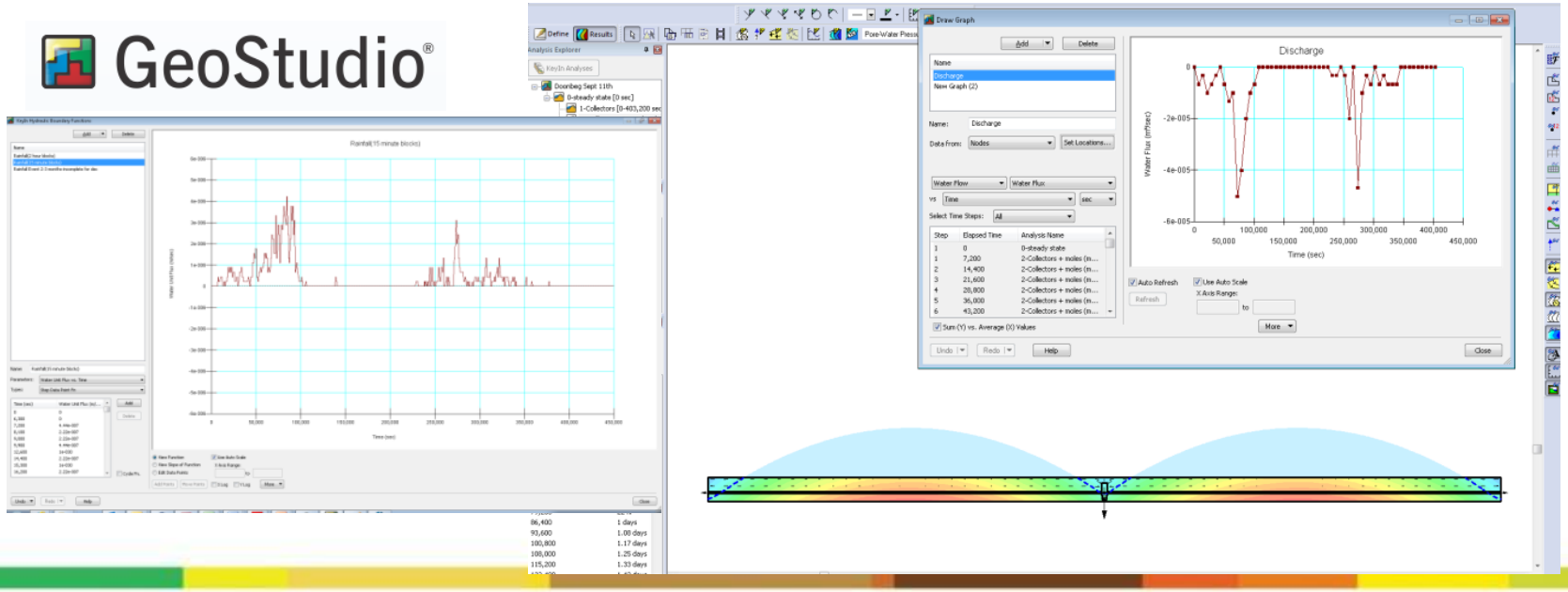
Farm production and performance on poorly drained soils

- 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



Classification of drainage system materials

Optimising the design of in-field drainage systems and their constituent materials

- Assess the drainage capacity and performance of a range of pipe/aggregate combinations
- Evaluate the performance of some other envelope materials (filters/membranes)
- Examine methods of reducing iron ochre deposition
- ***Currently recruiting!***

Dissemination & Training

Agricultural land drainage-Theory and design training course (QQI certified)

- In response to chronic lack of suitably trained personnel

- Equip participants with the ability to design land drainage systems on a range of soils types

- 8 day course Includes
  - Classroom instruction
  - Practical sessions on the identification of soils and soil characteristics
  - Field trips to a range of sites to identify drainage problems and prescribe appropriate solutions.

- Started Oct. 2016-Run Annually

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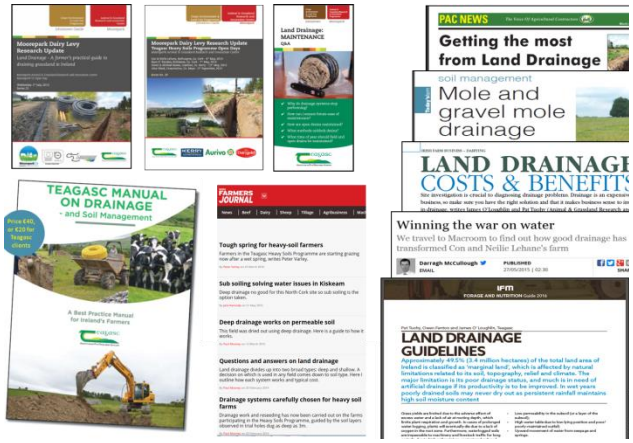
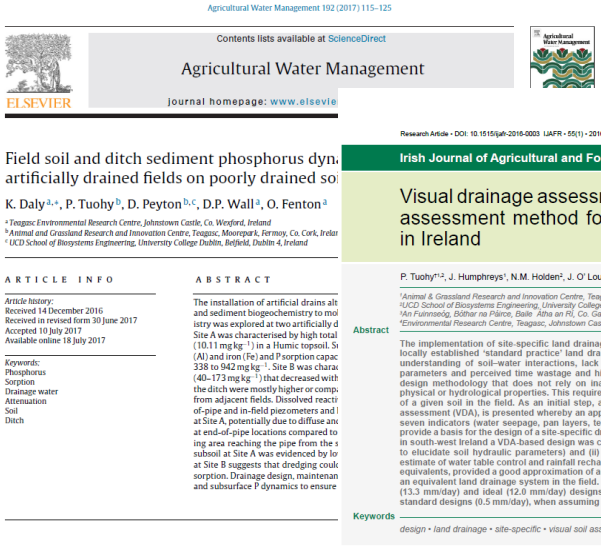
Dissemination & Training

- The programme delivers outputs in scientific and popular press

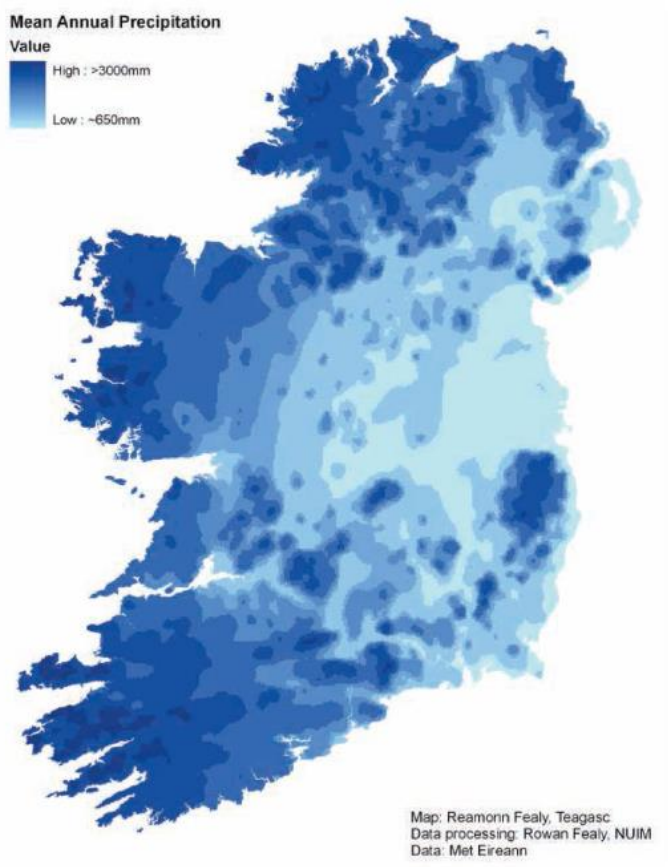




- And through public on-farm and training events

Soils and rainfall

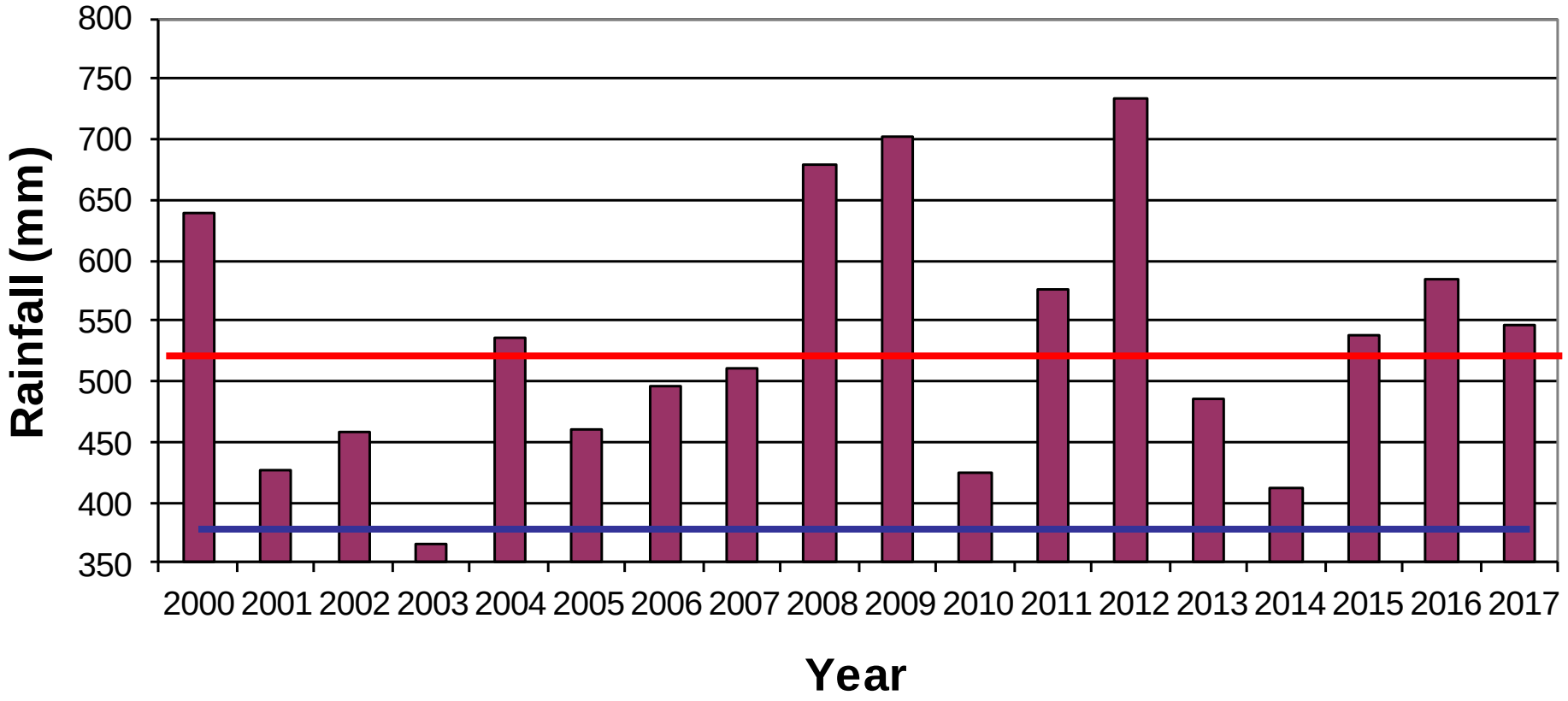
- Marginal land occupies just under 50% of Irish land area
- Trafficability for machinery and livestock is a major limitation in wet conditions
- Use of such soils is curtailed due to;
  - Reduced stocking capacity and grass yields.
  - Increased susceptibility to surface damage and compaction.



HSP Farm Performance 2011 - 2016

Year	Herd Size	Stocking Rate		Herd EBI		6 week calving %
		Farm	MP	Total	Fertility	
2011	77	1.70	2.12	84	47	72
2012	85	1.71	2.27	112	73	68
2013	83	1.69	2.24	134	79	76
2014	85	1.85	2.30	150	87	74
2015	92	1.81	2.45	161	89	74
2016	100	1.85	2.56	82	35	69

Castleisland rainfall (April-September)



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

HSP: Comparative Farm Performance 2016

Farms	Milk Solids (kg/ha)	Gross Output		Total Costs		Net Margin	
		(€/Ha)	(c/litre)	(€/Ha)	(c/litre)	(€/Ha)	(c/litre)
HSP Mean	1068	2935	28.3	1911	19.7	954	8.6
HSP Range	881 – 1430	2389 - 3703	25.8 – 31.4	1441 - 2466	14.6 – 23.9	307 - 1640	1.8 – 14.2
364 Profit monitors Mean	1015	3698	29.5	2557	20.4	1166	9.1

6 week calving %

Location	2013	2014	2015	2016
Castleisland	69	59	62	80
Doonbeg	81	78	88	86
Athea	82	80	85	88
Kishkeam	87	87	84	76
Listowel	66	68	67	81
Rossmore	72	64	69	64
Ballinagree	74	79	60	72
Swanscross	--	25	7	15
Stradone	--	45	24	58
Average	76	74	74	69

Grass Production 2016 (>15 walks)

	Date		Walks	Grazing* Area (Ha)	Tonnes (DM/Ha)			
	First	Last			Grown	Spring	Summer	Autumn
Castleisland	14th Mar	13th Nov	29	41.7	**11.6**	0.2	7.4	4.0
Ballinagree	25th Feb	7th Nov	23	44.5	**11.9**	0.4	7.4	4.1
Doonbeg	1st Feb	1st Nov	37	36.8	**12.1**	0.2	8.3	3.6
Athea	8th Mar	5th Nov	42	39.3	**11.4**	0.6	7.3	3.5
Rossmore	11th Mar	10th Nov	28	31.1	**12.7**	0.4	7.7	4.6
Kishkeam	14th Mar	Oct 28th	23	42.1	**8.6**	0.2	5.5	2.9
Listowel	24th Feb	10th Nov	22	31.3	**11.1**	0.4	7.5	3.1
Crossmolina	28th April	5th Nov	15	11.2	**7.9**	0.1	6.0	1.8
Stradone	20th Feb	9th Nov	27	29.8	**10.0**	0.3	6.4	3.3
Swanscross	26th Feb	10th Nov	15	30.3	**10.5**	0.3	6.7	3.5
Average	6th Mar	6th Nov	26	33.8	**10.7**	0.3	7.0	3.4

Grass Production Best Paddock 2016

	Average	Spring	Summer	Autumn		Best Paddock No.	Best Paddock Growth	Spring	Summer	Autumn
Castleisland	**11.6**	0.2	7.4	4.0		12	**14.4**	0	8.7	5.6
Ballinagree	**11.9**	0.4	7.4	4.1		18	**12.8**	0.5	8.6	3.8
Doonbeg	**12.1**	0.2	8.3	3.6		6	**16.9**	0.2	11.4	5.4
Athea	**11.4**	0.6	7.3	3.5		10	**13.4**	0.8	8.1	4.4
Rossmore	**12.7**	0.4	7.7	4.6		14	**14.9**	0.8	8.2	5.9
Kishkeam	**8.6**	0.2	5.5	2.9		26	**13.0**	0	8.2	4.8
Listowel	**11.1**	0.4	7.5	3.1		9	**12.7**	1.0	8.3	4.8
Stradone	**10.0**	0.3	6.4	3.3		29	**13.9**	1.0	7.8	5.2
Average	**11.2**	0.3	7.2	3.6			**14.0**	0.5	8.7	5.0

Soil Fertility: pH Status

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

Soil Fertility: Phosphorus mg/l

Location	2013	2014	2015	2016
Castleisland	4.7	6.4	4.2	6.0
Doonbeg	4.9	5.6	5.5	4.4
Athea	3.1	4.9	3.7	4.1
Kishkeam	1.9	4.4	2.8	3.0
Listowel	5.4	9.8	6.5	5.0
Rossmore	8.5	11.0	10.7	11.2
Ballinagree	5.6	6.5	5.1	6.9
Crossmolina	7.6	3.4	4.4	5.8
Swanscross	--	--	6.2	5.8
Stradone	--	--	3.1	5.1
Average	4.9	6.5	5.2	5.6
Target	5.1 – 8.0	5.1 – 8.0	5.1 – 8.0	5.1 – 8.0

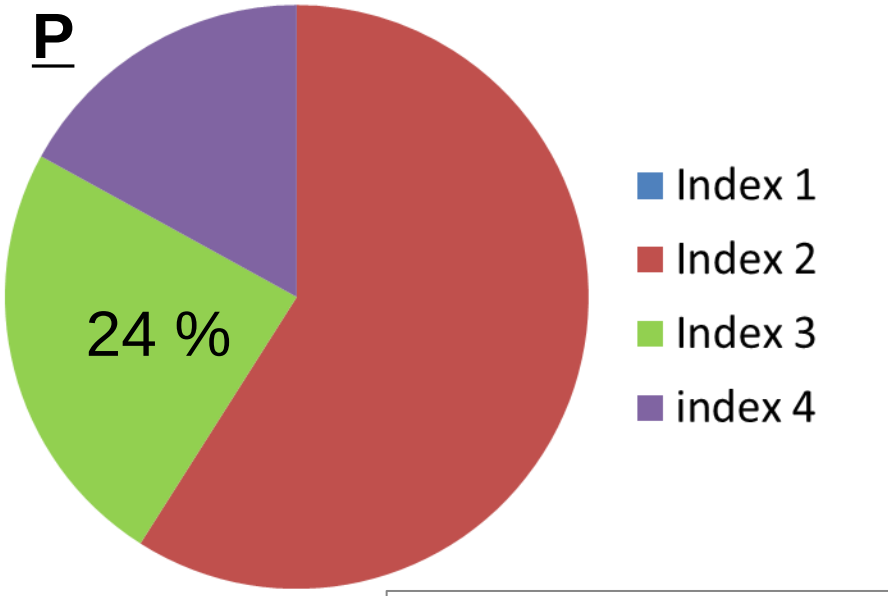
Soil Fertility: Potassium mg/l

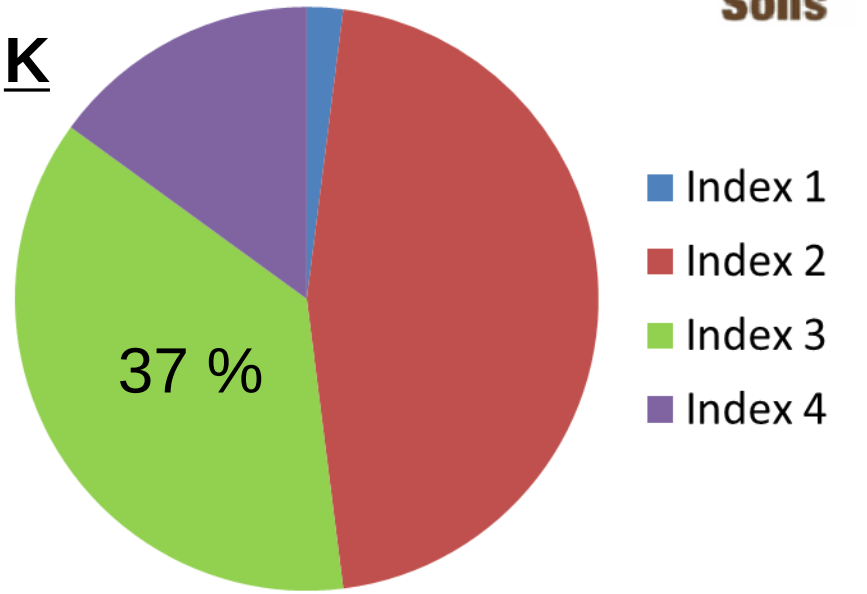
Location	2013	2014	2015	2016
Castleisland	94	110	87	115
Doonbeg	74	96	91	57
Athea	134	125	104	111
Kishkeam	82	112	88	92
Listowel	89	140	105	94
Rossmore	97	95	106	104
Ballinagree	144	155	115	147
Crossmolina	105	112	73	92
Swanscross	--	--	170	150
Stradone	--	--	142	153
Average	102	118	108	112
Target	101 – 150	101 – 150	101 – 150	101 – 150

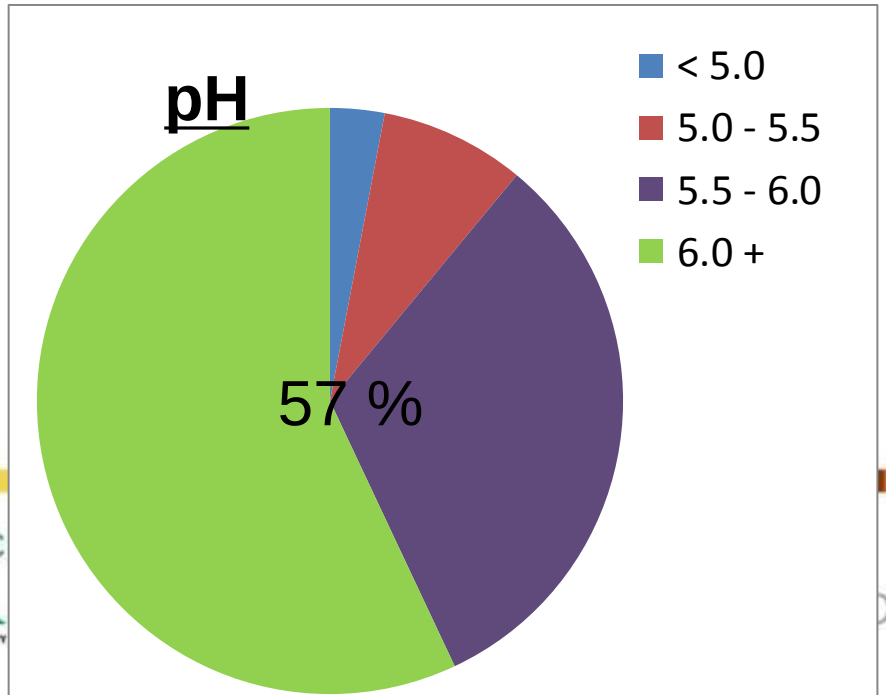
Ground cover ryegrass%

Location	2011	2012	2013	2014	2015	2016
Castleisland	34	16	26	30	31	24
Doonbeg	30	22	29	28	28	24
Athea	26	19	33	37	38	30
Kishkeam	29	17	25	27	32	25
Listowel	17	11	18	22	22	18
Rossmore	28	25	43	40	41	42
Ballinagree	32	15	27	28	26	28
Crossmolina	--	--	--	16	20	18
Stradone	--	--	--	--	39	
Swanscross	--	--	--	--	44	
Average	**28**	**18**	**29**	**29**	**32**	**26**

HSP Soil Fertility

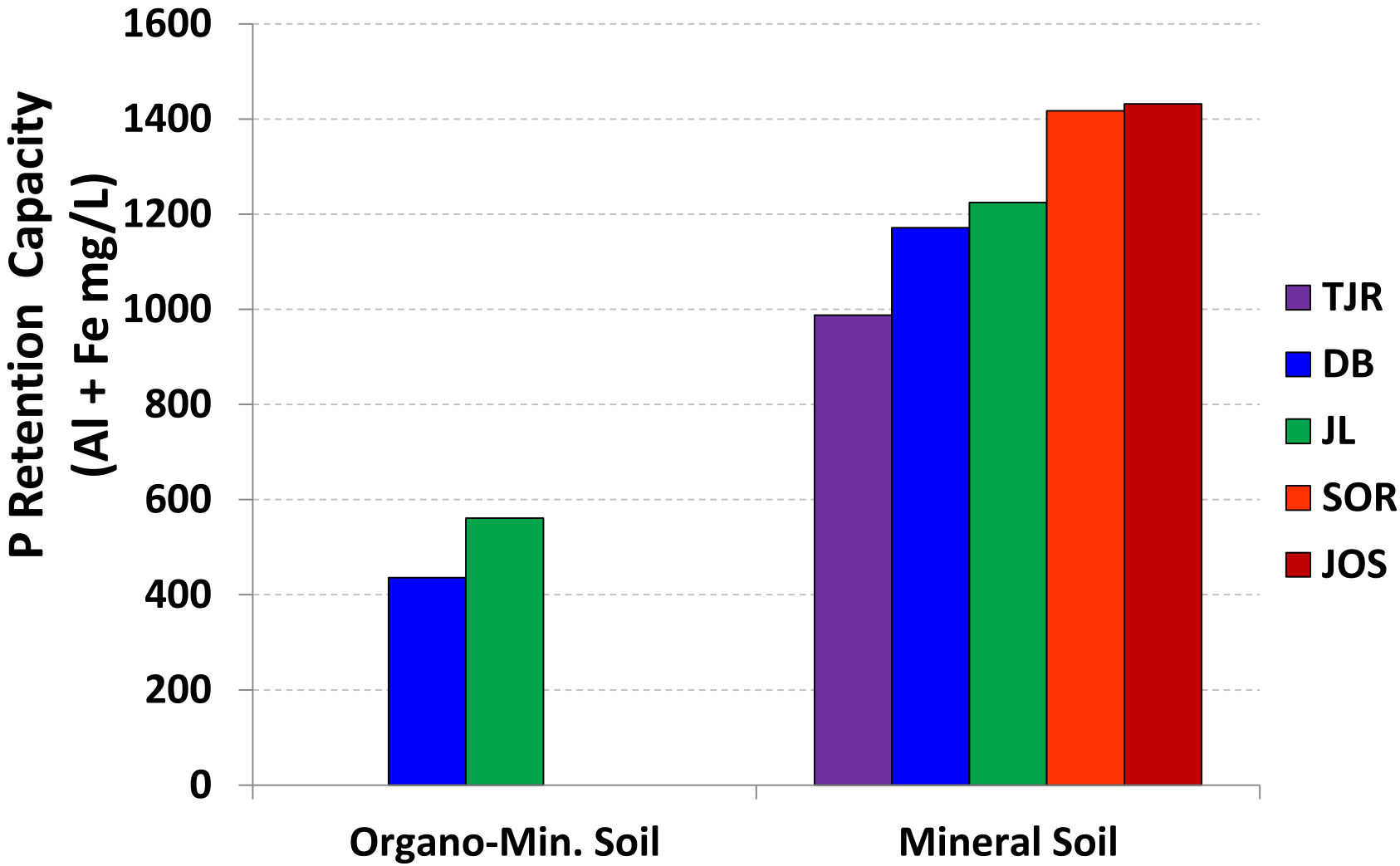






Relative Soil P Retention Capacity

(permanently fixed P)



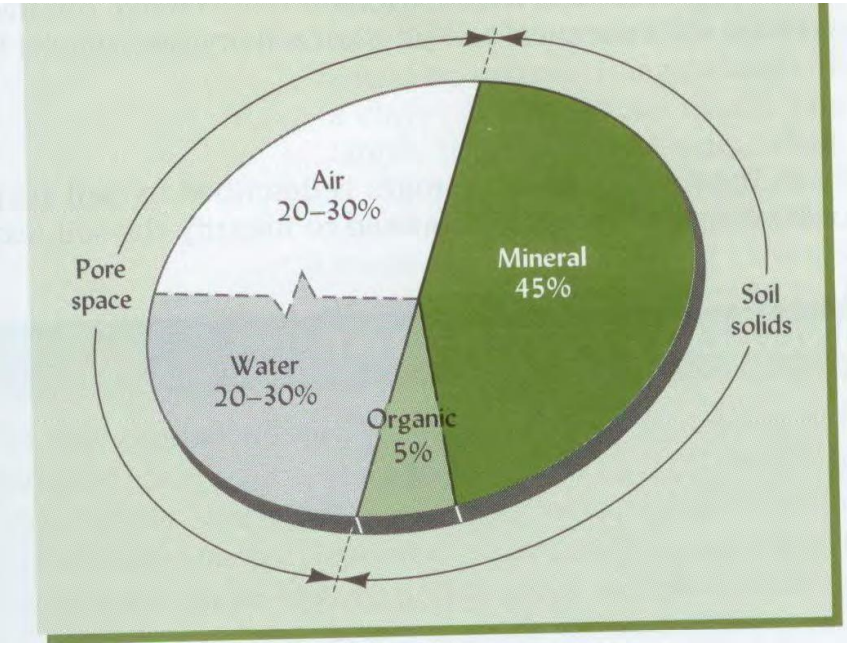
Land Drainage

Overview

- Soil Physics
  - Soil Phases
  - Soil Texture
  - Soil Structure
  - Water Movement through soil

- Land Drainage
  - Drainage investigations
  - Types of Drainage Systems
  - Drainage pipe, stone & backfill
  - Maintenance
  - Cost
  - EIA Legislation
  - References

Soil Phases



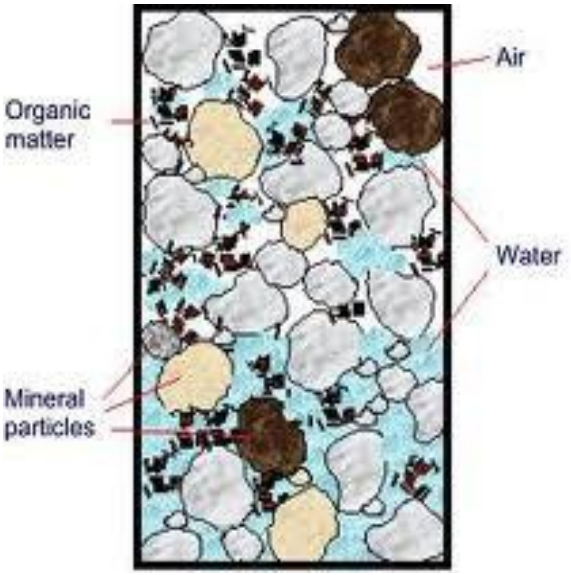
- Air and water phases occupy the pore space and are complimentary
- Pore space in a saturated soil is filled with water.
- Crops require a minimum 10 -15% air filled pore space for water and nutrient uptake

Soil Solids

Soil solids consist of mineral and organic materials

Organic Material (<10% in mineral soils)

- Stores water and nutrients
- Binds mineral particles

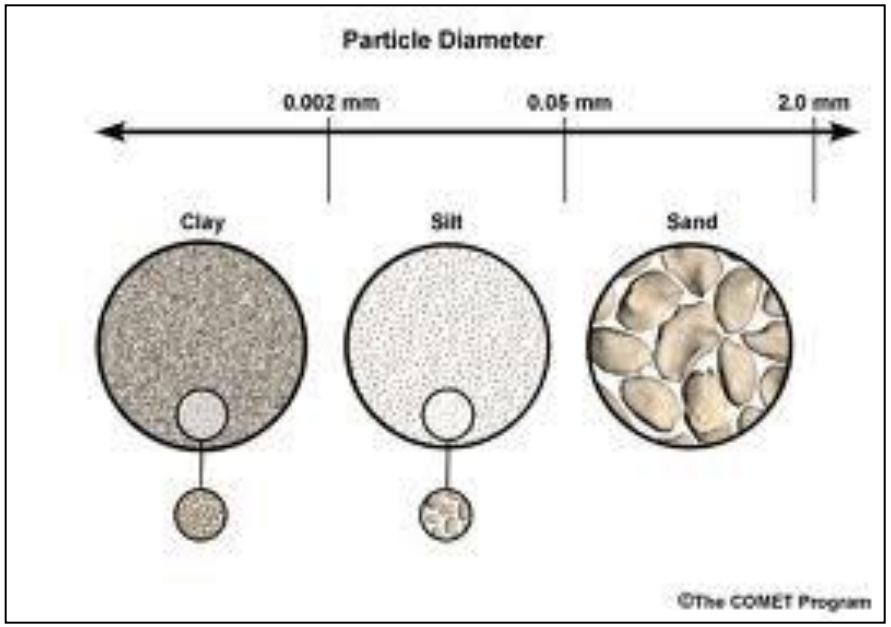


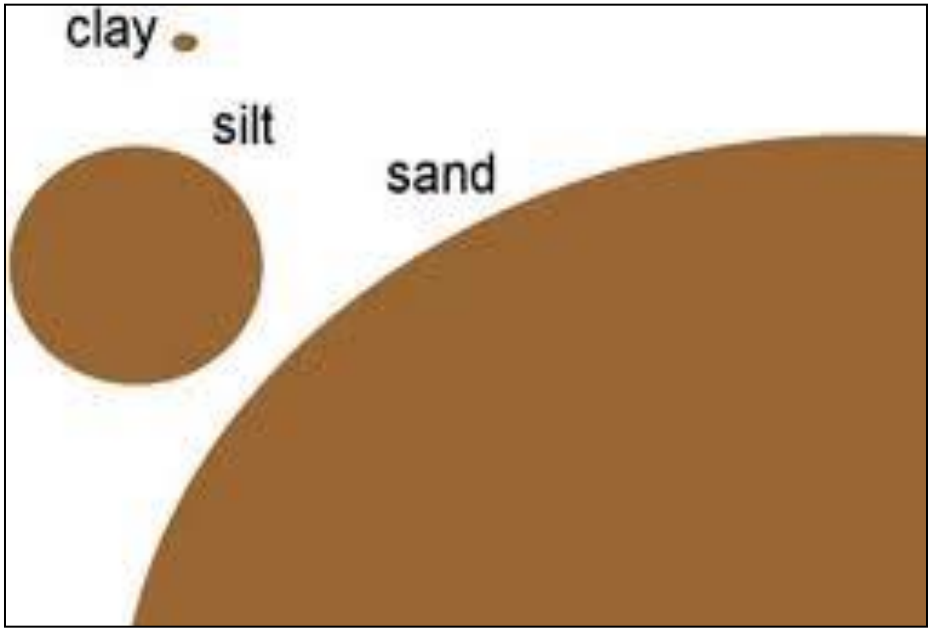
Mineral Particles

- 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





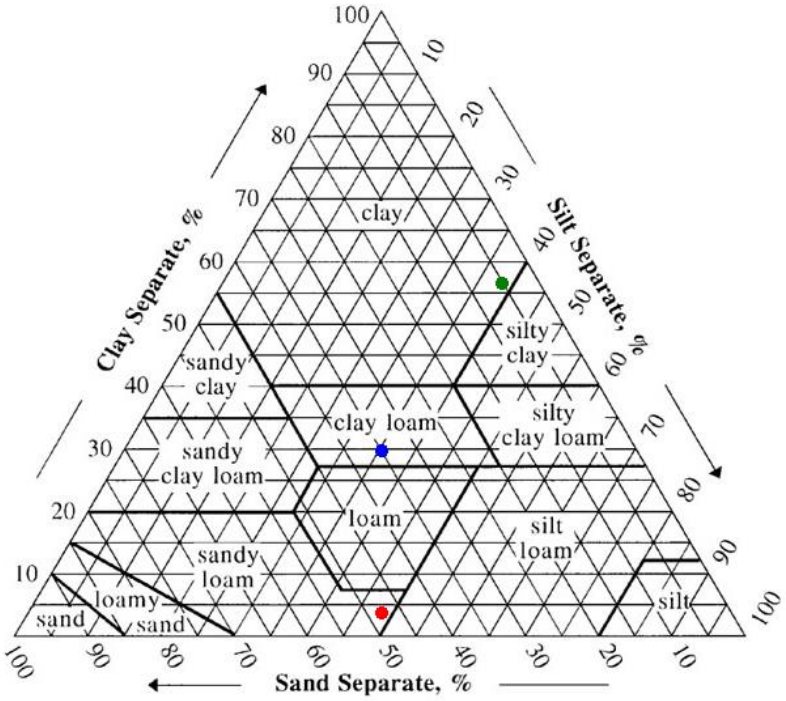
Soil Texture

- Sand: Feels gritty, large enough to be seen with the naked eye
- Silt: Feels smooth/floury, Individual grains not visible.
- Clay: Feels sticky & cohesive, resists breaking, mouldable
- Estimating soil texture by feel: http://www.ksre.ksu.edu/library/crpsl2/mf2852.pdf

Property	Rating associated with soil particles		
	Sand	Silt	Clay
Drainage Rate	High	Slow to medium	Very slow
Water holding capacity	Low	Medium to high	High
Compactability	Low	Medium	High
Warm-up in spring	Rapid	Moderate	Slow

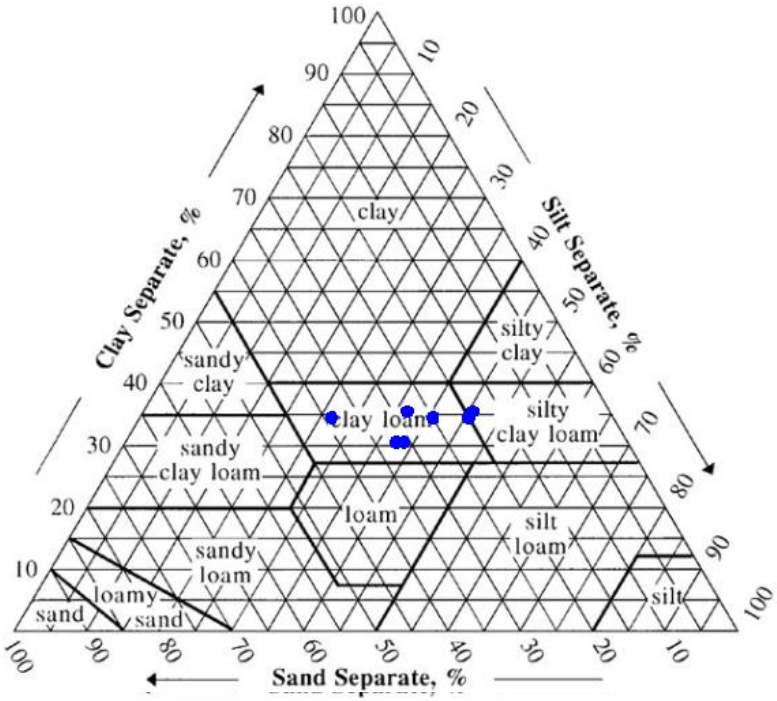
Texture Triangle

- 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.



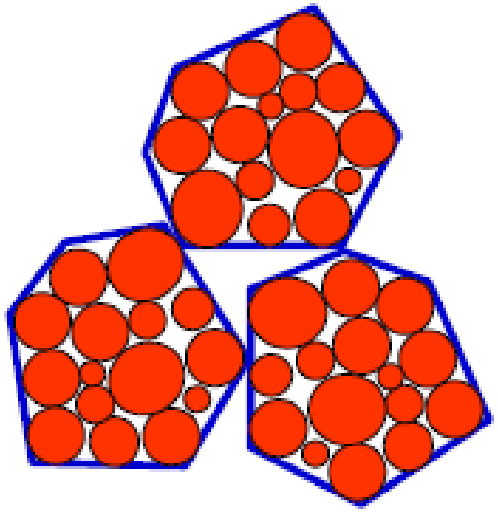
Texture Triangle

- 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



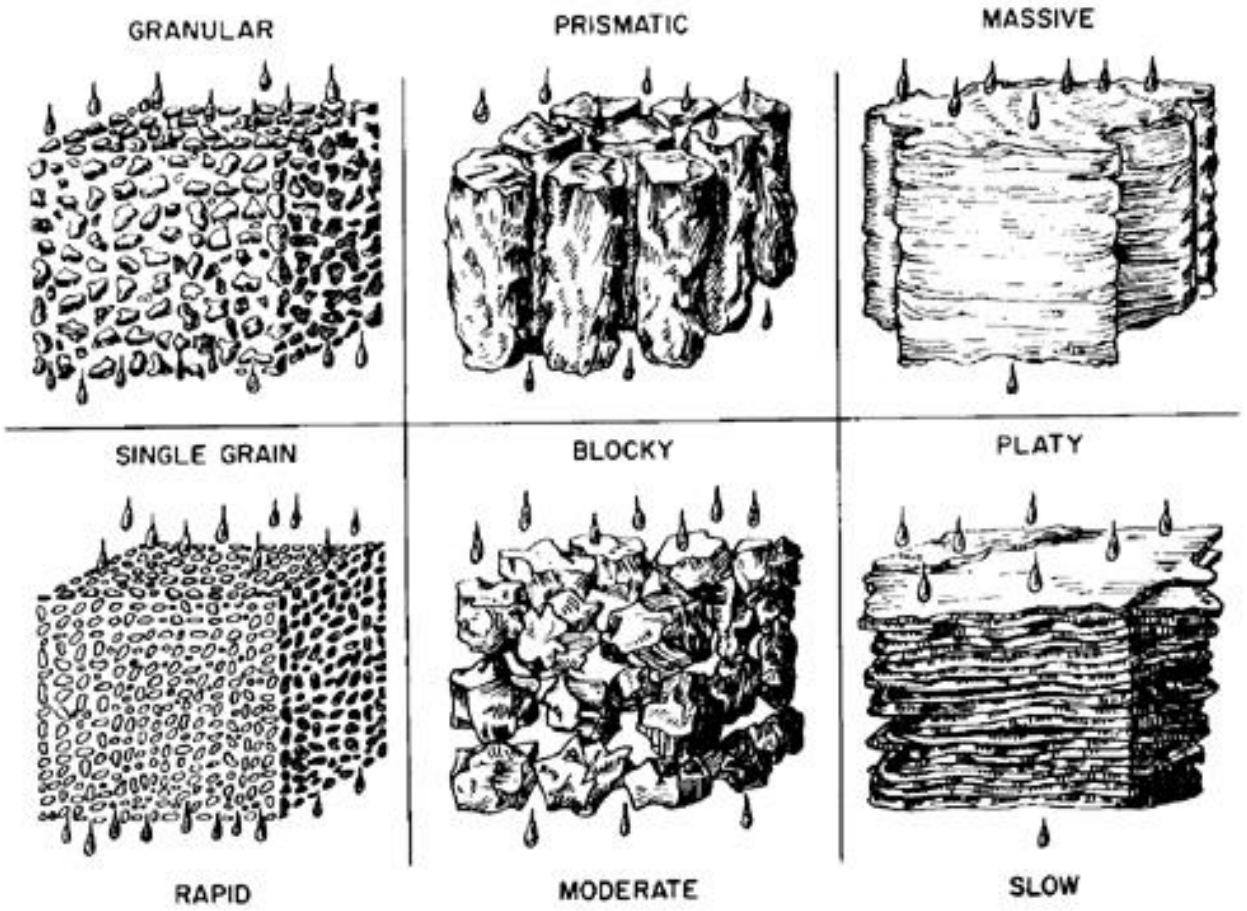
Soil Structure

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



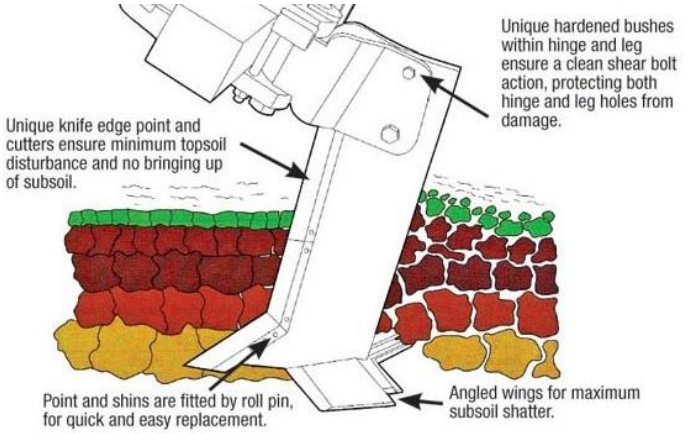
Three soil aggregates comprising many sand, silt, clay and organic particles

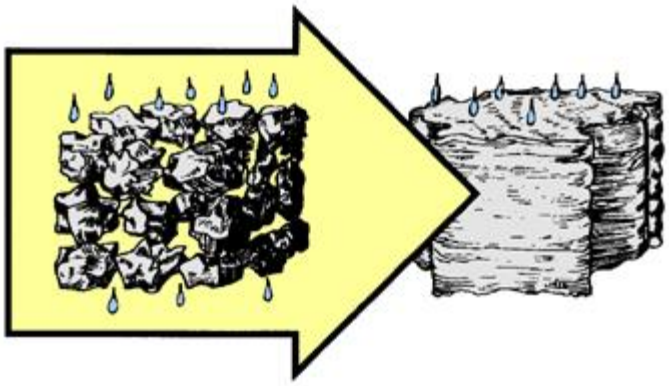
Soil Structure



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

- Hydraulic conductivity: The rate at which water moves through the soil pores.
- Dependent on texture, structure and porosity
- **This property varies enormously.**

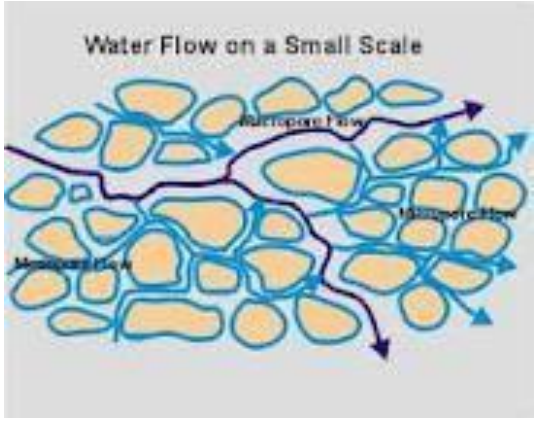
Hydraulic Conductivity Values	metres/day
Coarse Gravelly Sand	10 - 50
Medium Sand	1 - 5
Sandy Loam/Fine Sand	1 - 3
Loam/clay loam/clay, well structured	0.5 - 2.0
Very fine sandy loam	0.2 - 0.5
Clay loam/clay, poorly structured	0.02 - 0.2
Dense clay, not cracked and no biopores	< 0.002

Smedema & Rycroft, 1983

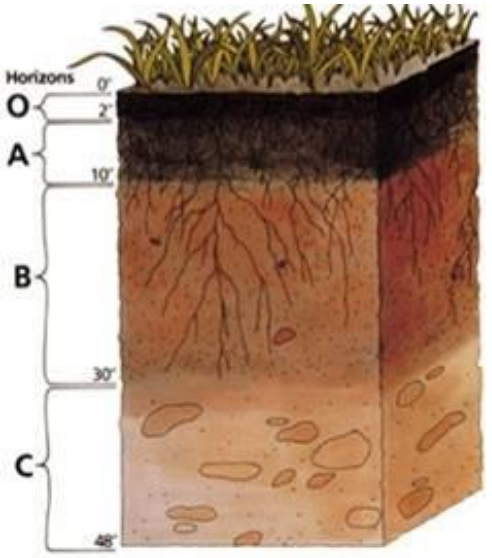
Water movement through Soil

- 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



Drainage Investigations



- **When planning a drainage system an investigation into the causes of poor drainage must first be undertaken**
- No “one size fits all” solution
- A number of test pits (at least 2.5m deep) should be dug within the area to be drained
- As the test pits are dug the faces of the pits are observed, soil type (texture and structure) should be established (varying with depth) and rate of water seepage (if any) recorded.
- **Are there layers impeding or permitting water movement ?**

Types of drainage system

- The depth and type of drain to be installed depends entirely on the interpretation of the test pits.
- 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
- Often heavy textured soils overlie soils of much higher permeability (**poorer sub-soils closer to the surface and more permeable layers underneath**)

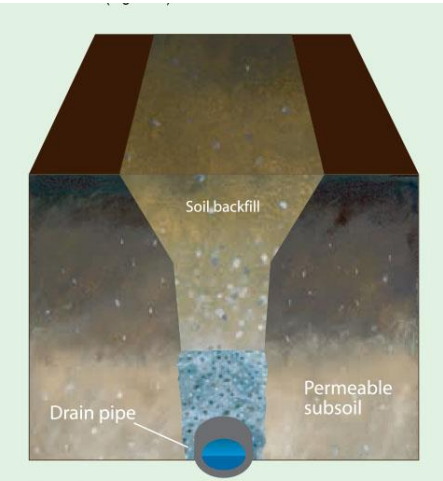
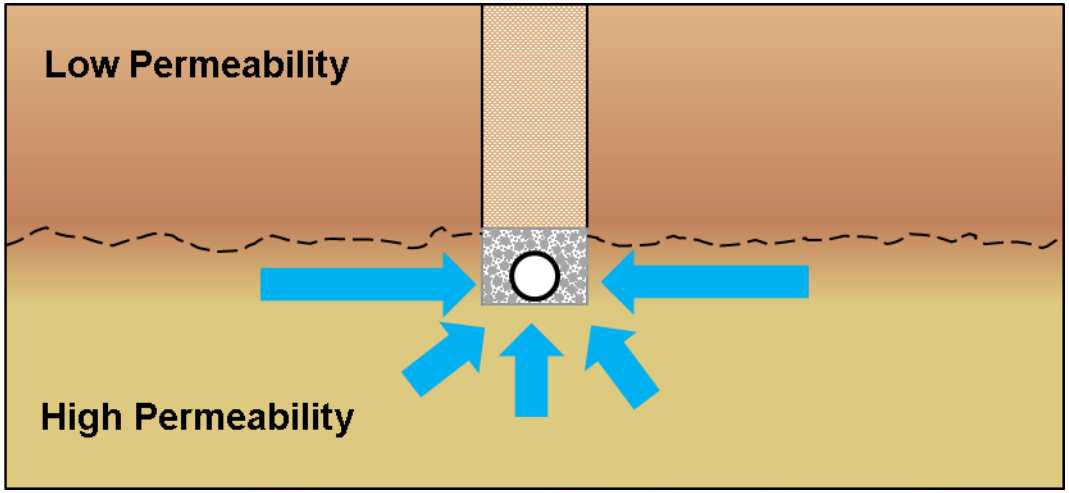
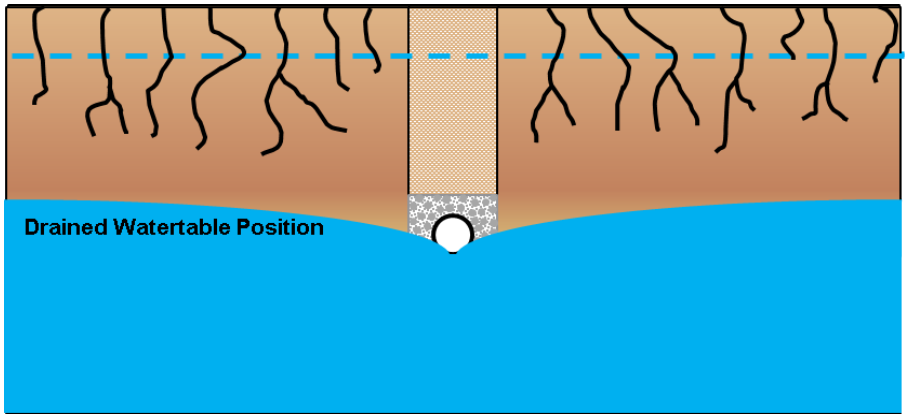


Figure 1. Connection with permeable layer.



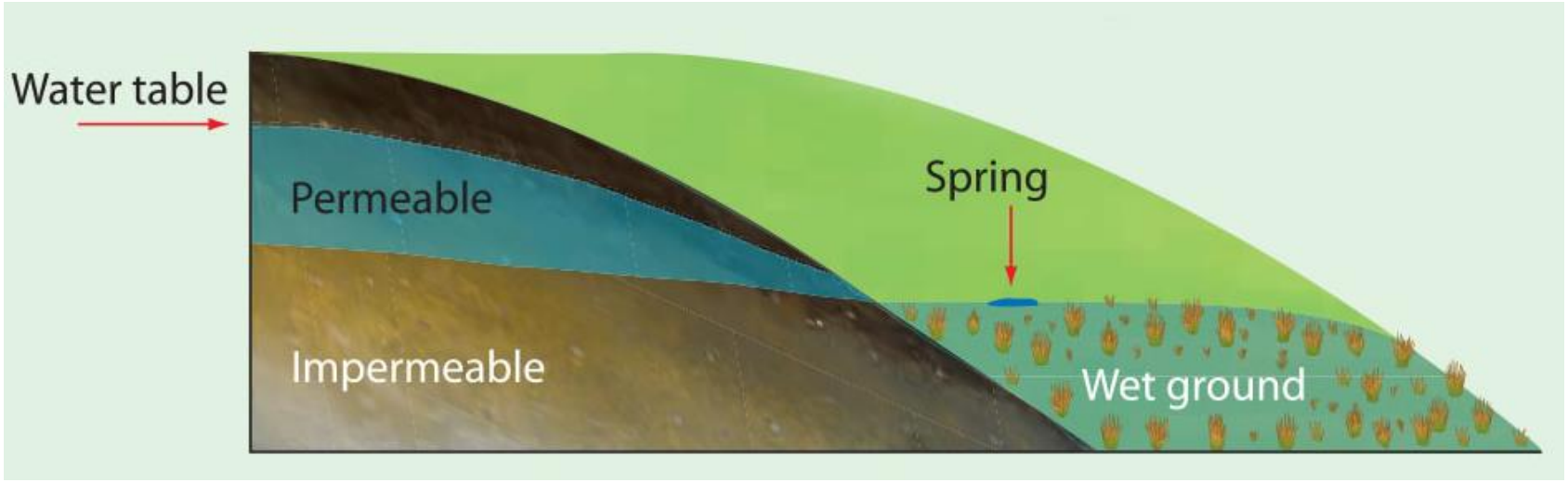
Groundwater Drainage System

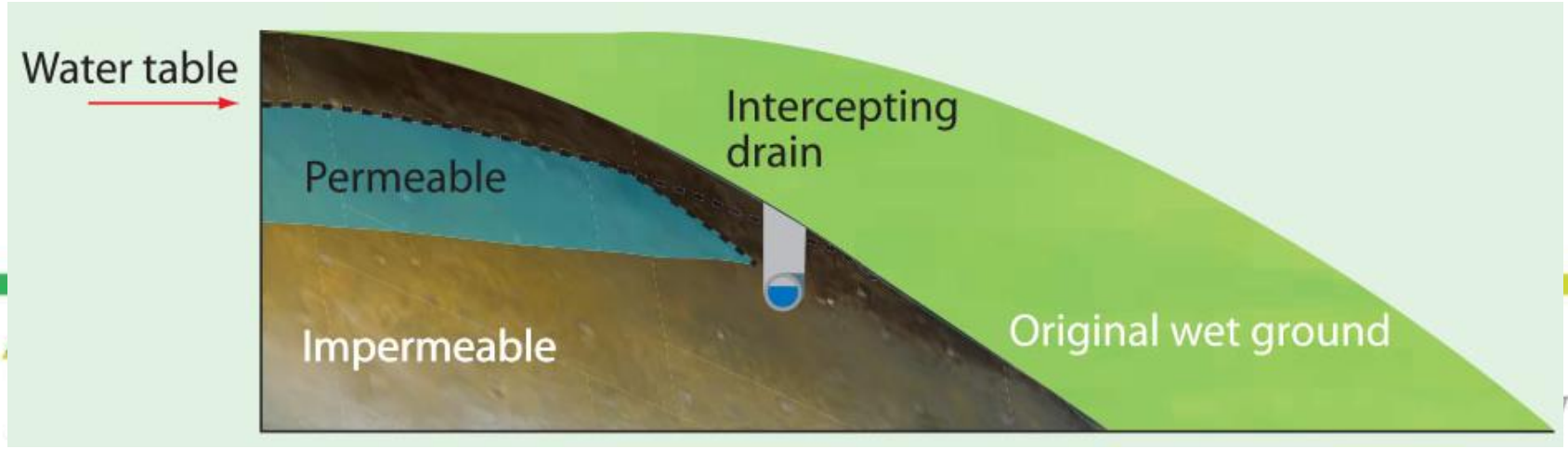
- By “tapping” into this natural capacity for water movement the system works by lowering the watertable and reducing the amount of water stored in the soil
- When it rains water can now infiltrate through the soil. Water storage is reduced so capacity is increased
- By controlling the water table,natural (cracking, root penetration) or artificial (sub-soiling/ripping) improvements in permeability in the shallower layers can occur



Groundwater Drainage System

- Groundwater seepage and springs

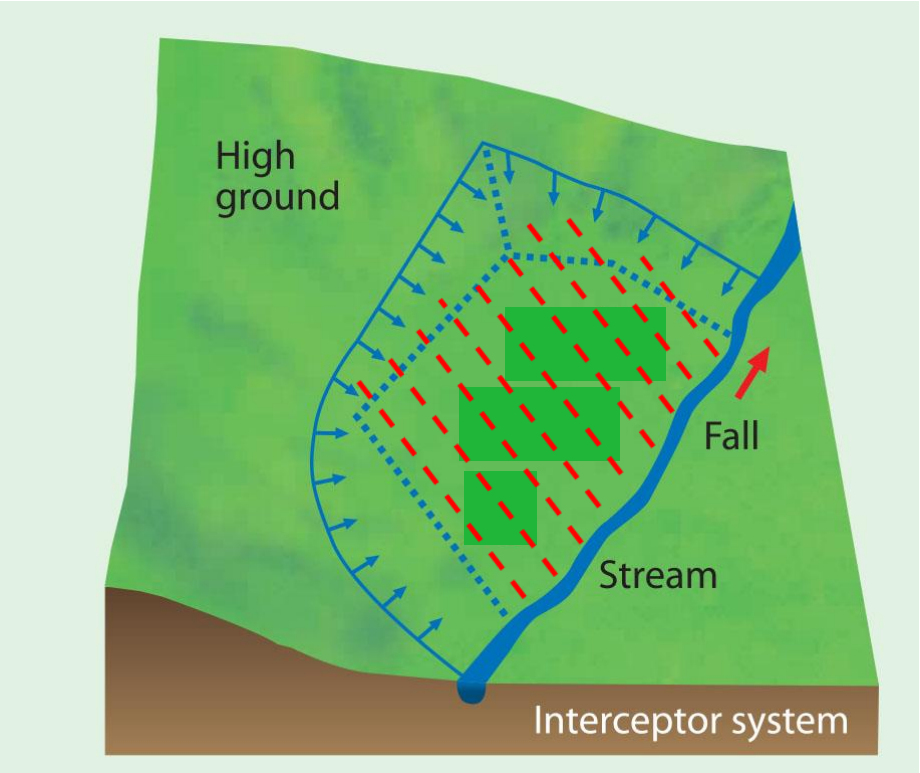




Groundwater Interceptor Drains

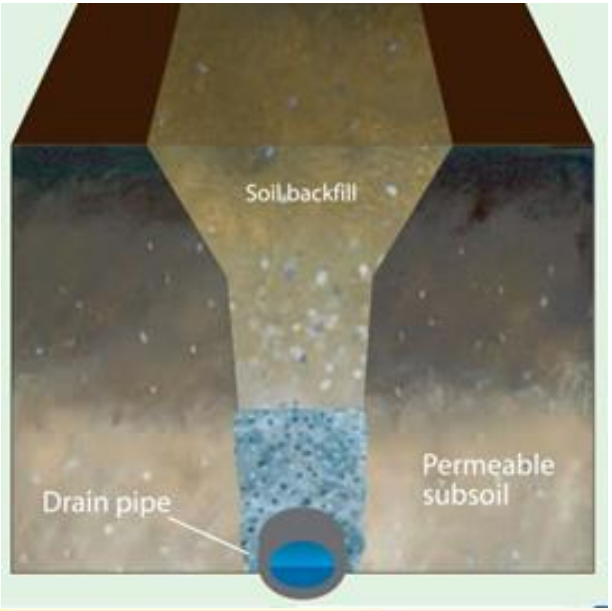
- Groundwater interceptor drains are used to prevent water breakout on sloped land

- A well placed system of interceptors can be cheaper and more effective than drainage works on low-level land



Backfilling groundwater drains

- Drainage stone should:
  - be filled to a **minimum depth of 30 cm** from the drain bottom
  - provide connectivity with layer of high permeability
  - be **clean** aggregate (10-40 mm / 0.4 -1.5 inch)



Shallow Drainage System

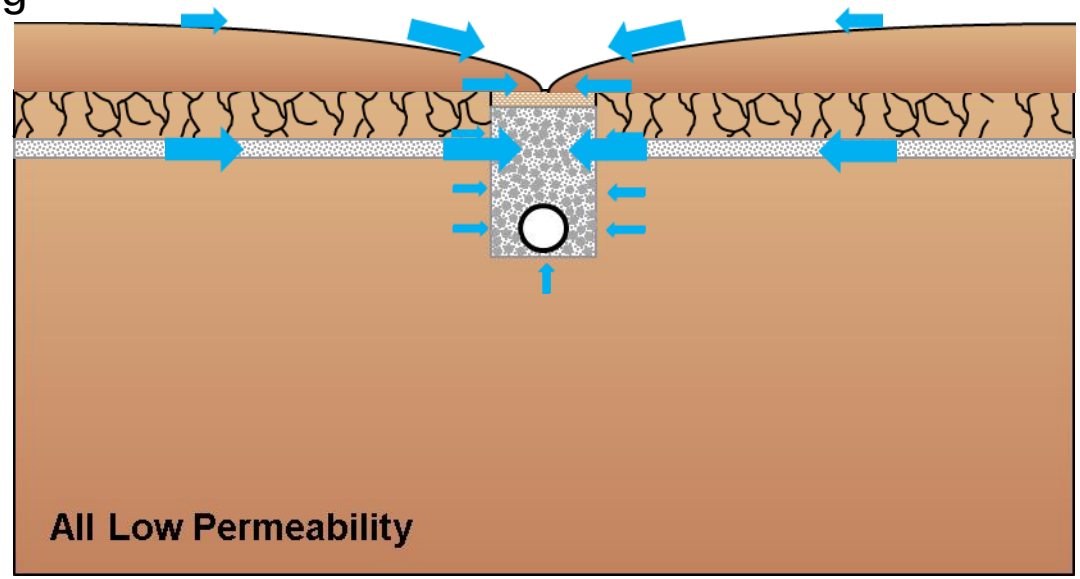
- **Where no inflow of water to test pit**
- NO permeable layer to be exploited
- Drainage must incorporate a soil disruption technique in tandem with collector drains.
- The aim of such a system is to improve soil structure and permeability

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



Mole Drainage

- Mole drainage comprises closely spaced (1-2 m) shallow **unlined** channels in **cohesive high clay content, stone-free soils**
- They are installed with a tractor mounted mole plough (adjustable depth to 60cm)
- The mole plough creates a channel and new pathways for water movement by fracturing and cracking the soil

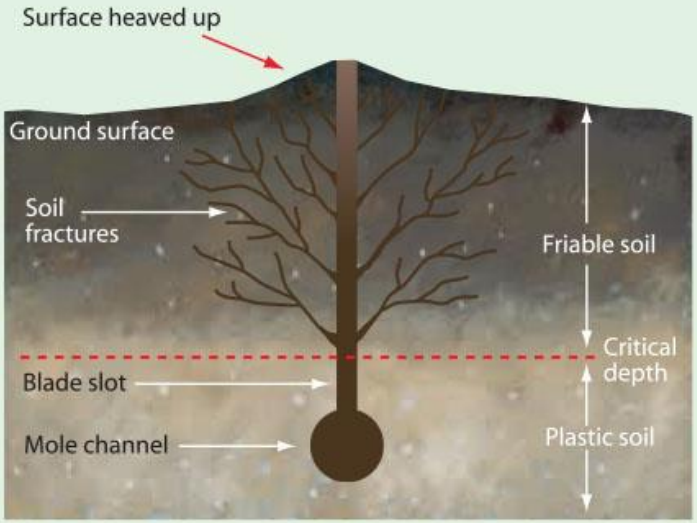


Figure 3. Mole drain showing surface heave.

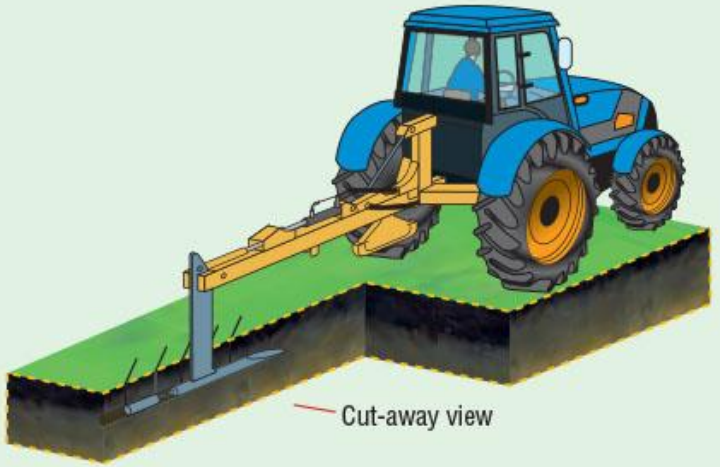


Figure 1. Installation of a mole drain.

Mole Drainage

Mole Drainage

- Mole foot creates a channel, expander finishes and solidifies channel walls
- Cracks radiate from tip of nose to the soil surface
- Surface water moves through these cracks and leg slot to mole channel
- Channels are tied in with collector drains at right angles

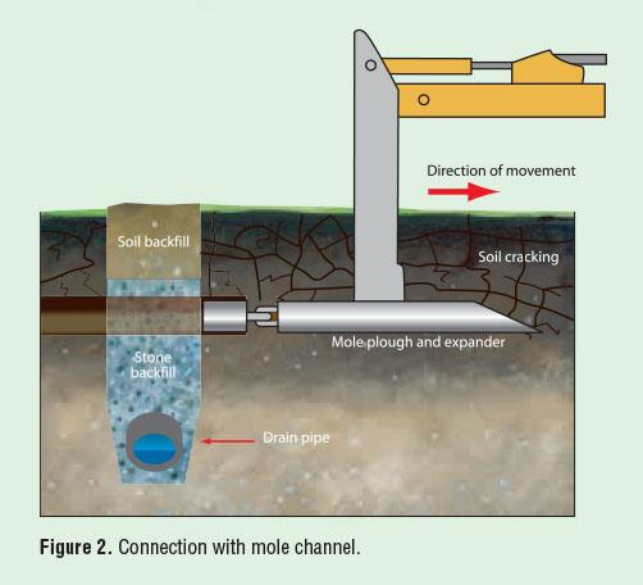


Figure 2. Connection with mole channel.

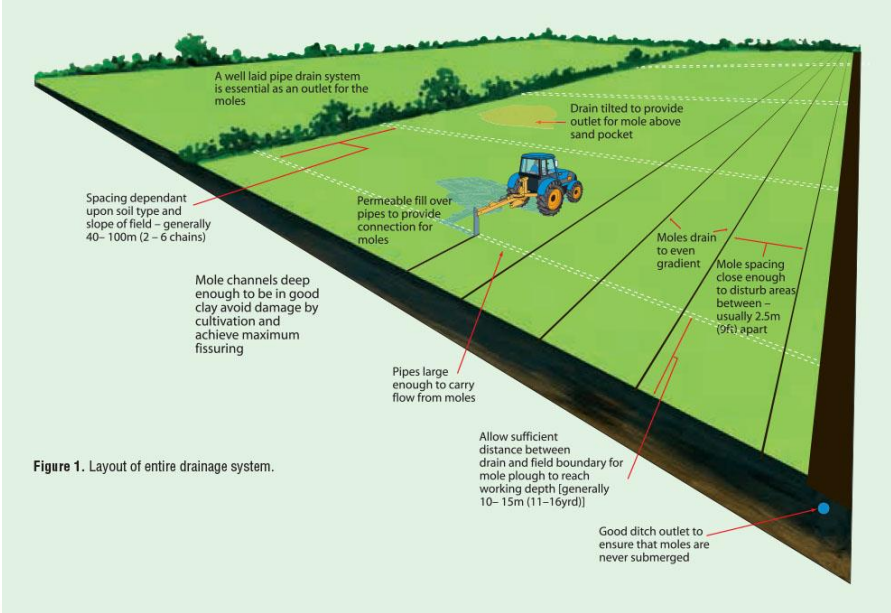


Figure 1. Layout of entire drainage system.

Gravel Mole Drainage

- Many soils require closely spaced drainage channels and soil loosening but cannot support unlined channels (texture, stone content etc.)

- Gravel mole drainage offers an alternative where the mole channel and leg slot are **filled with gravel** to provide stability

- They are installed with a tractor mounted gravel mole plough

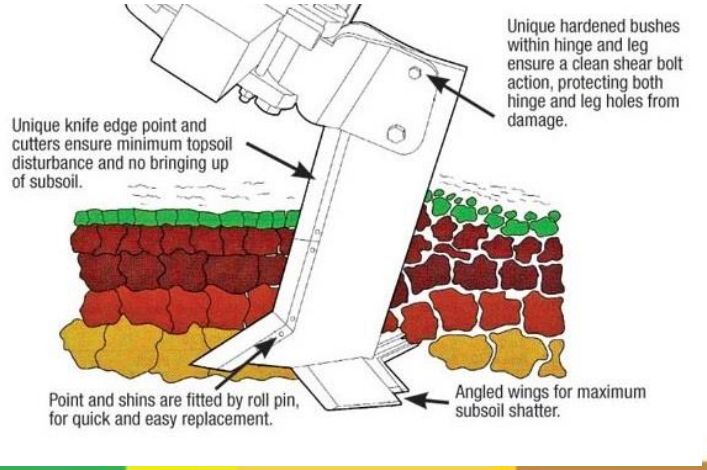
Sub-soiling (Pan-busting)

- Closely related
  - **Sub-soiling:** Refers to general soil loosening
  - **Pan-busting:** Refers to the breaking of a distinct pan or cemented layer

- No attempt to from a stable channel, soil “shattering” is the main aim.

- Generally not effective unless a shallow impermeable layer is broken or used to supplement collector drains

- Limited lifespan



Sub-soiling (Pan-busting)

The success of shallow systems!

- **Soil Type:** Will mole drains survive? Will sub-soiling have a worthwhile effect? Etc.

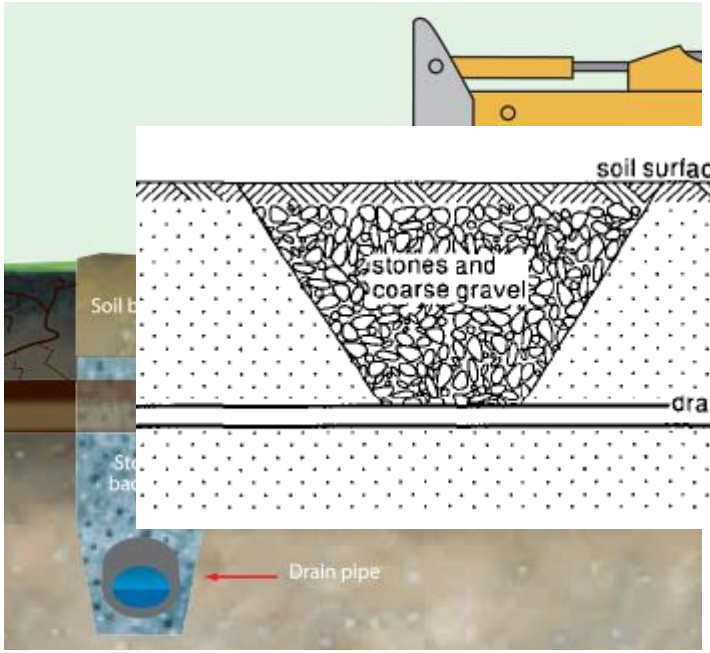
- **Timing:** Level of cracking in soils will be dependent on moisture content (weather)
  - Cracking/Shattering and surface traction will be maximised in dry conditions
  - In wet conditions the desired shattering will be replaced my “smearing”
  - Cleaning open drains and installation of collectors can be done in advance and shallow techniques installed when the opportunity arises

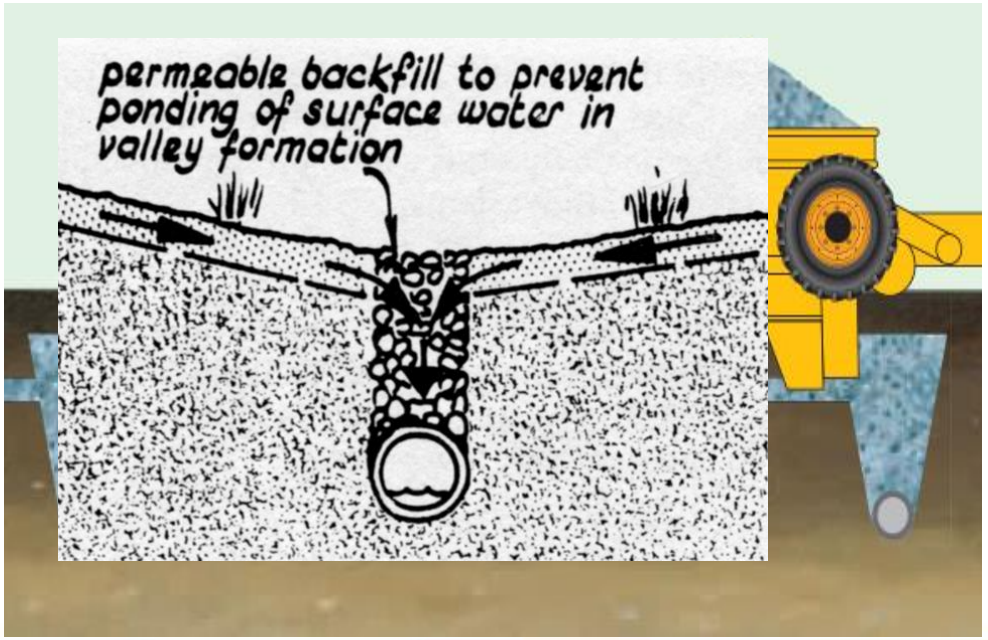
- **Equipment:** Implements used must be in good order and fit for purpose
  - Must be able to reach the desired depth
  - And create the desired effect
  - Sufficient power and traction should be available to provide an even pull

- **Capacity:** Dependent on local rainfall
  - Capacity is improved by increasing disturbance (reducing spacing,+ subsoiling)
  - Reducing spacing of collector drains
  - Isolating the site from surrounding areas (open drains)

Backfilling collector drains

- Drainage stone should:
  - fill the trench to within 25 cm of ground surface
  - provide connectivity with mole channels and topsoil
  - be **clean** aggregate (10-40 mm / 0.4 -1.5 inch)



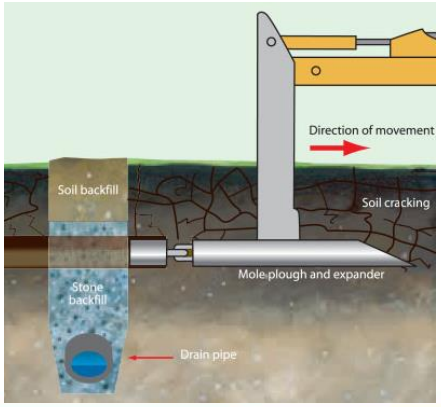


Drainage pipe and stone

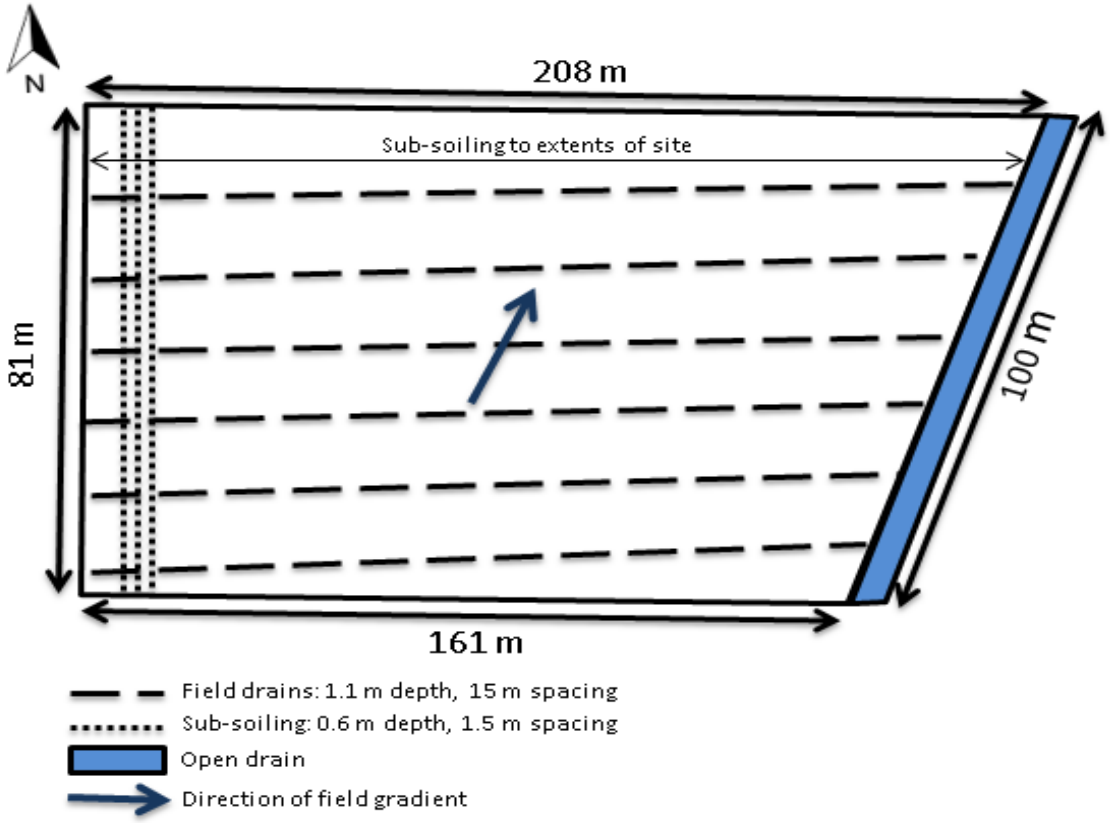
- The drainage pipe facilitates a unobstructed flow path from the field drain.
- Only short drain lengths (less than 30 m) are capable of operating at full efficiency without a pipe. (also allows maintenance)
- Perforated corrugated pipe is the cheapest and most convenient
- Drainage stone has three 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
- Stone backfill should be **clean** aggregate (5-40 mm)

Land Drainage Design: Kishkeam Farm

Problem Diagnosis



Drainage system design

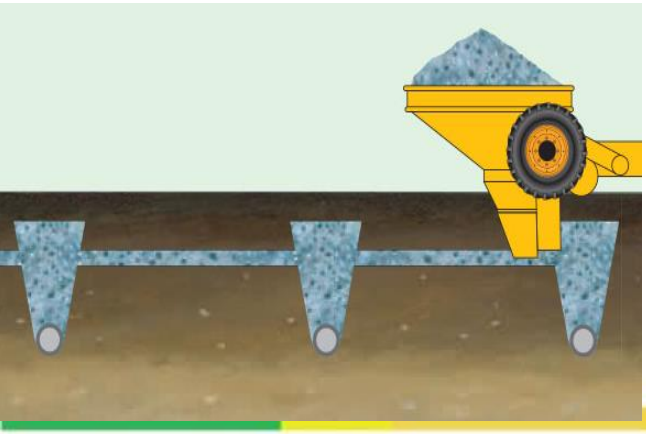


Drainage Costs: Kishkeam Farm

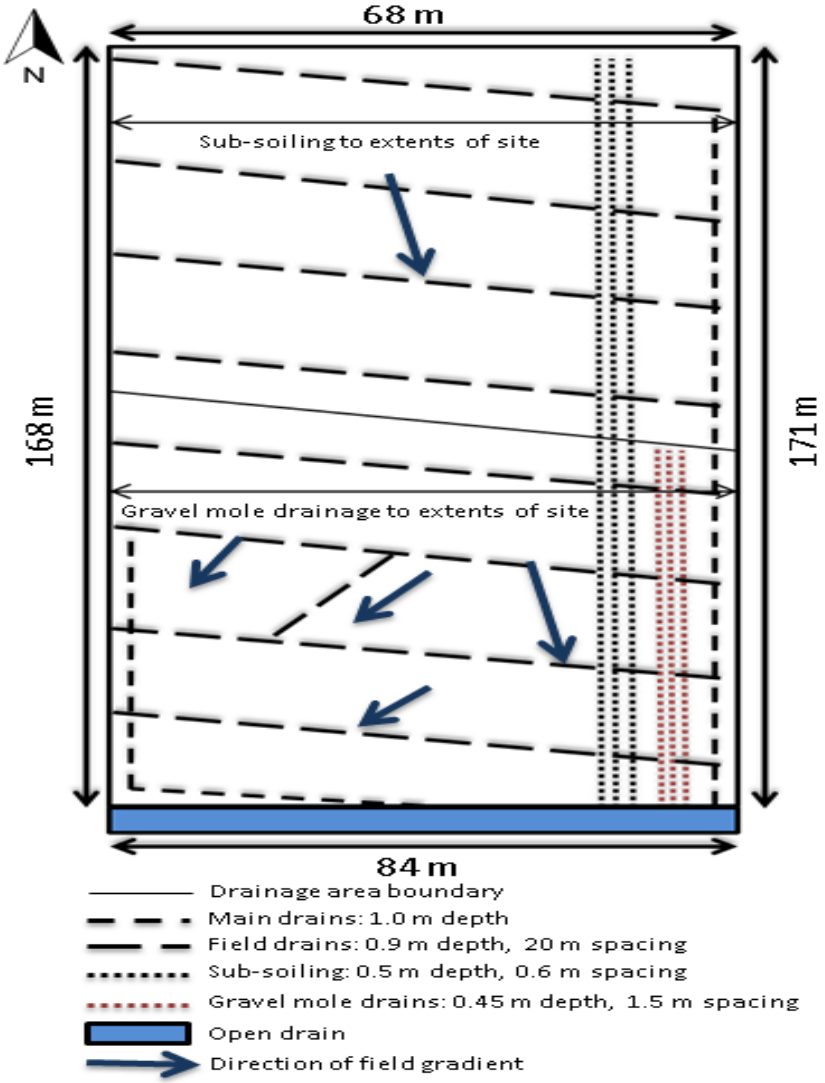
Costs	Total/ha
Drain installation @ €45/hr (36 hrs)	€1,625
Drainage pipe @ €1.03/m (566 m)	€585
Drainage stone @ €10.78/t (101 t)	€1,085
Subsoiling	€125
Drainage cost	**€3,420**

Land Drainage Design: Castleisland Farm

Problem Diagnosis



Drainage System Design



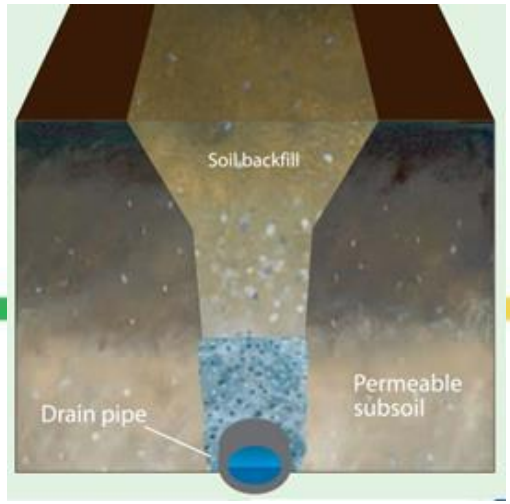
Drainage Costs: Castleisland Farm

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

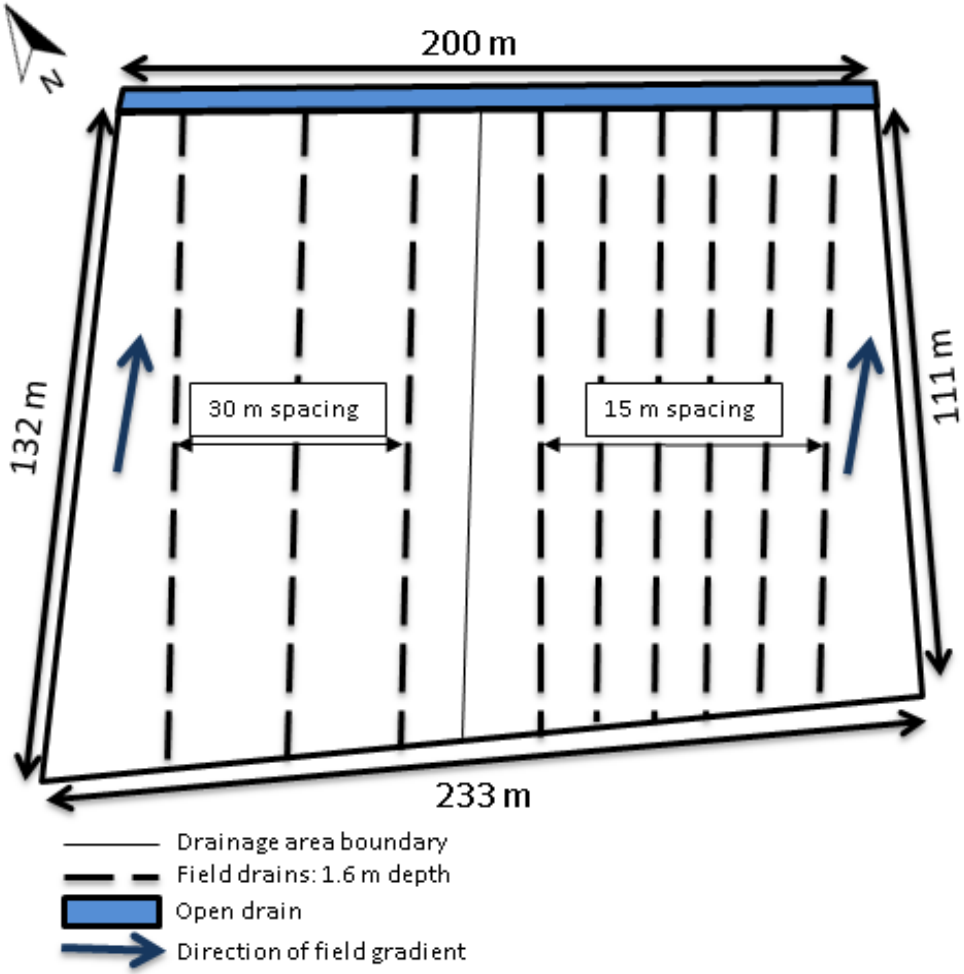
Land Drainage Design: Rossmore Farm

Heavy Soils

Problem Diagnosis



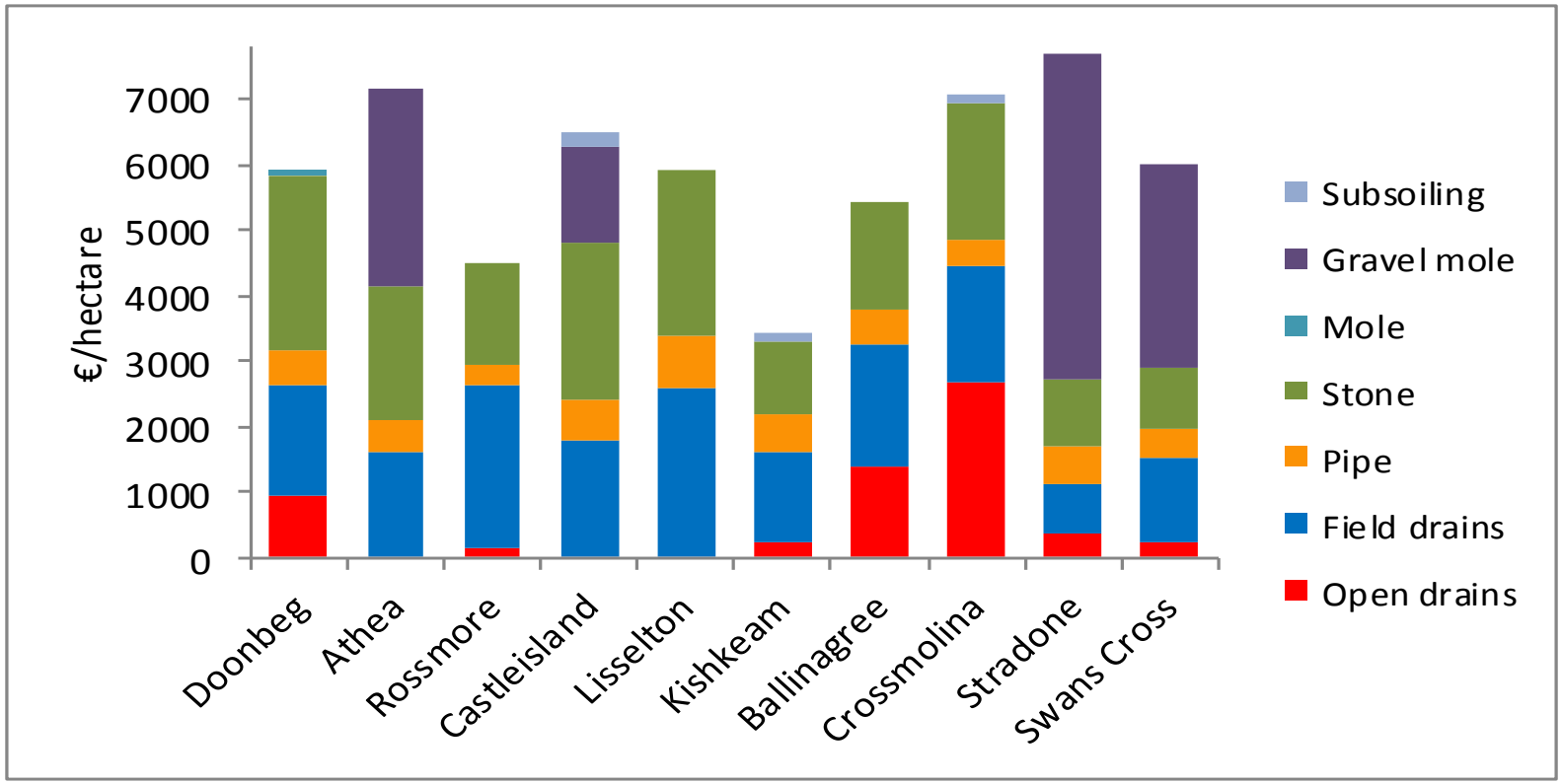
Drainage System Design



Drainage Costs: Rossmore Farm

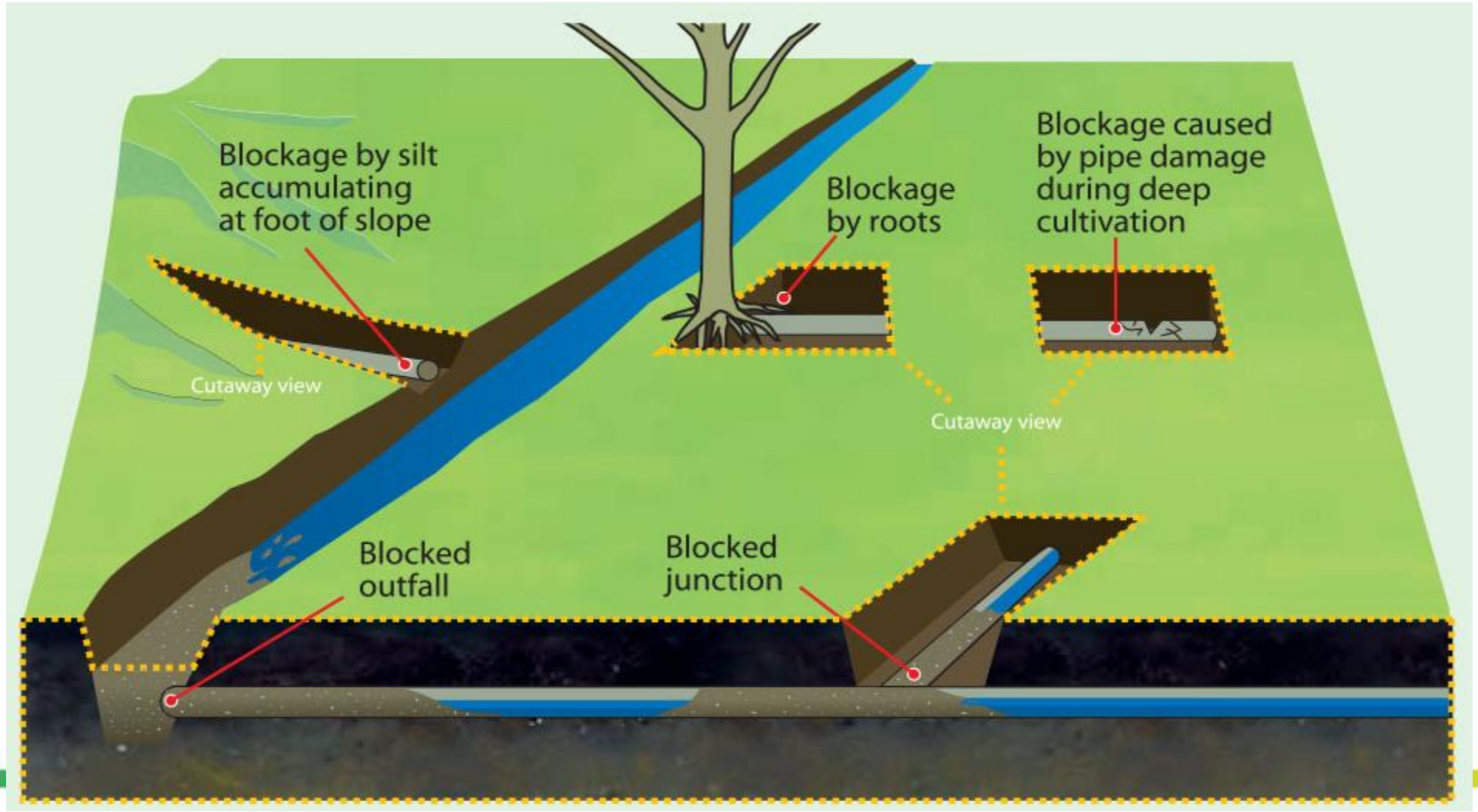
Costs	Total/ha
Drain installation @ €45/hr (55 hrs)	€2,476
Drainage pipe @ €0.70/m (429 m)	€300
Drainage stone @ €11.10/t (141 t)	€1,562
Drainage cost	**€4,338**

Approximate costs

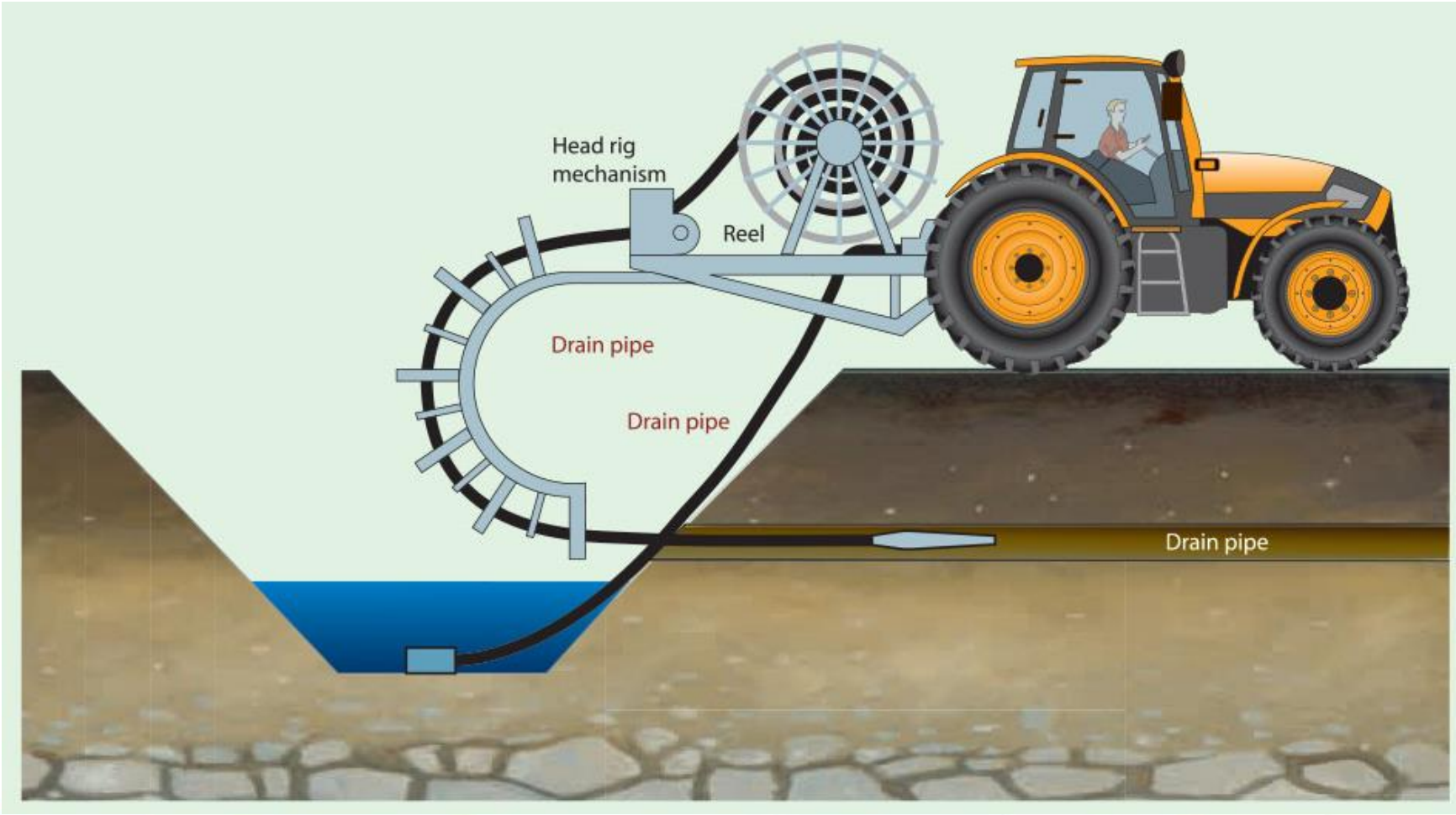


All costs included, high intensity systems. The average cost of drainage systems was €5,960/hectare (€3,420/ha to €7,690/ha)

Maintenance



Maintenance



EIA Legislation

Land drainage works on lands used for agriculture is covered by the EIA (Agriculture) Regulations and is controlled by DAFM. Such drainage works include the following:

- Installing open drains
- Installing field drains (not open) such as field drains using plastic pipe with drainage stone or field drains with drainage stone only or mole drains (no pipe or drainage stone) or gravel filled mole drains (no pipe but filled with gravel)
- Opening of a short distance of watercourse

Subsoiling is not covered by the Regulations. Cleaning of open drains and adjacent levelling of spoil from such cleaning operations is also exempt.

http://www.agriculture.gov.ie

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