

*SusCoRiDa Environmental Measurements Workshop*  
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# Making measurements of nitrogen and phosphorus leaching

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Sustainable futures for the Costa Rica dairy  
sector: optimising environmental and  
economic outcomes (*SusCoRiDa*)

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ROTHAMSTED  
RESEARCH

# Content

- Context
- UK legislation for diffuse water pollution
- Measurement approach
- Installation of porous cups (theory)
- Installation of porous cups (practical)

# Context

- Excess nitrogen (N) and phosphorus (P) applications are at risk of loss to watercourses, resulting in reduced water quality **→** eutrophication
- Sources of N and P:
  - Fertilisers
  - Livestock manure
  - Urine/dung from grazing livestock



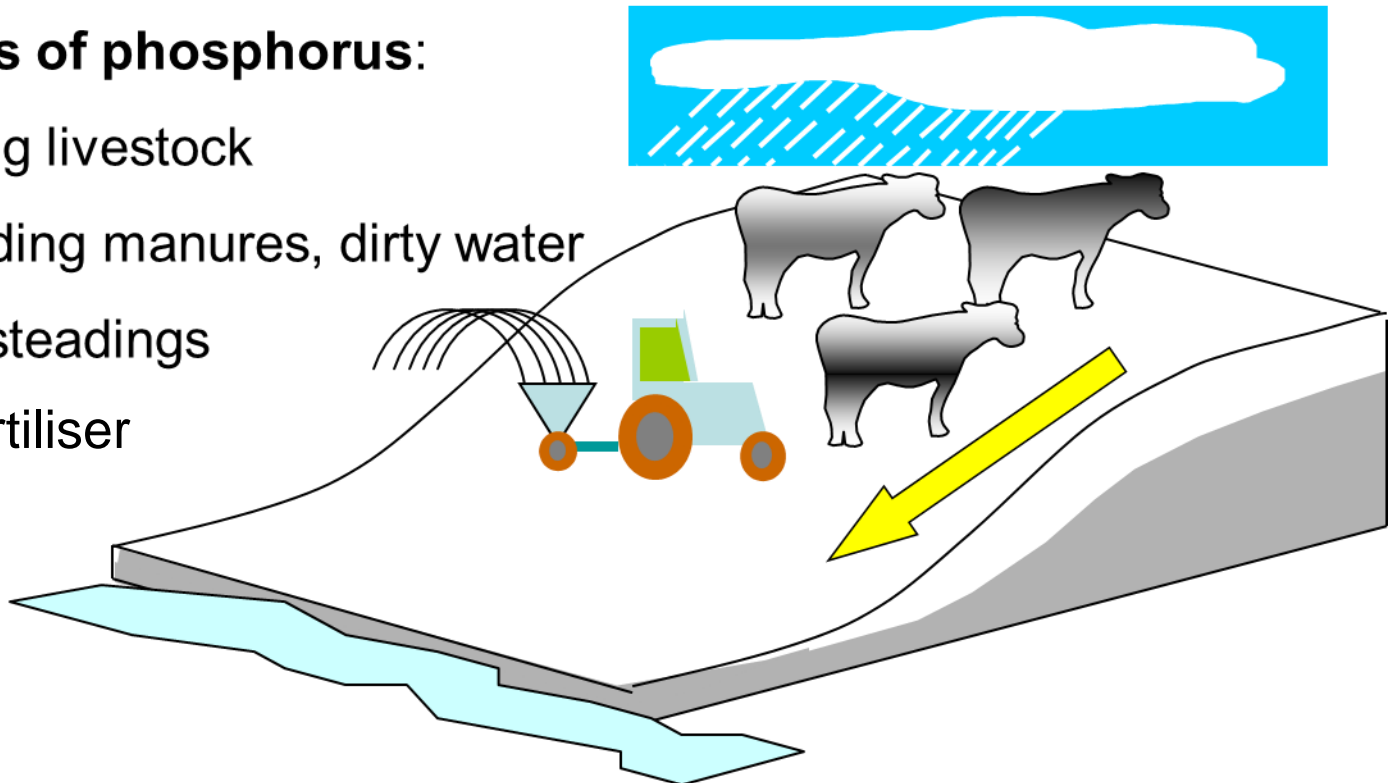
Extreme example of eutrophication:  
Tauhu Lake, China (2010)

# Phosphorus losses

- Phosphorus accumulation tends to occur in soil in fields near livestock housing and dairy because manure applications are spread on fields nearby storage facilities
- Phosphorus transfer tends to be associated with mobilisation and overland flow, but leaching will occur in some soils

## Sources of phosphorus:

- Grazing livestock
- Spreading manures, dirty water
- Farm steadings
- P Fertiliser



# Nitrate leaching

- Nitrate leaching occurs in soils that receive:
  - high / repeated manure application (especially high available N content manures, e.g. cattle/pig slurry, poultry manure, digestate)
  - high fertiliser nitrogen application rates at times of low crop demand
  - AND where there is 'effective drainage', piston flow vertically through the soil profile
- Leaching occurs if nitrate is below the rooting depth of crops in freely draining soils (lighter textured)

# UK Legislation / policy

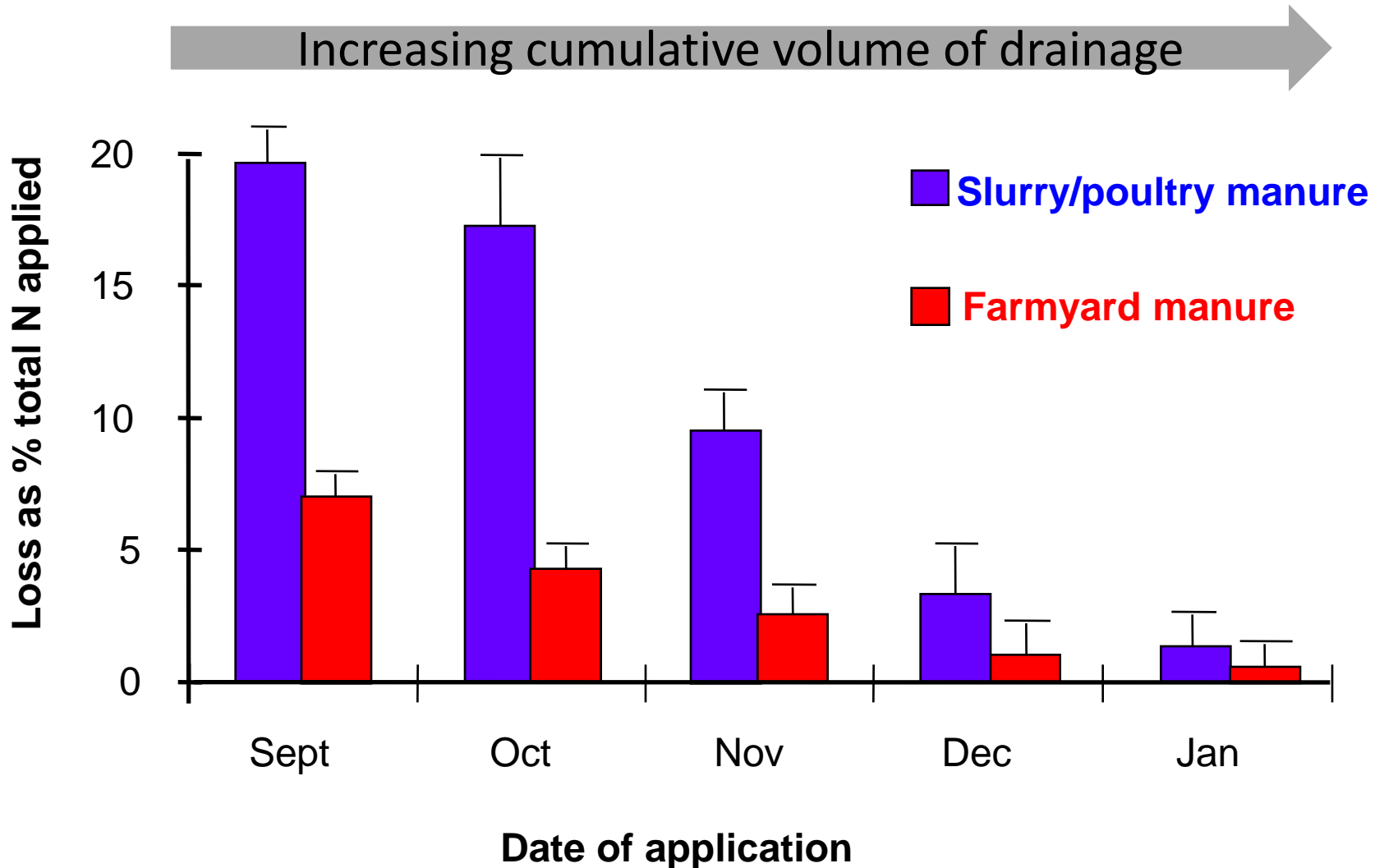
## DIFFUSE WATER POLLUTION

- **EU Water Framework Directive** (2000/60/EC) enhance the status and prevent deterioration of aquatic ecosystems – **nitrogen forms and phosphorus**
- **Freshwater Fish Directive** (2006/44/EC) to protect fresh water bodies suitable for sustaining fish populations – **ammonia and ammonium**
- **EU Nitrates Directive(91/676/EEC)**

Is designed to protect waters against nitrate pollution from agricultural sources



# UK nitrate leaching example: losses following manure applications to *free draining* arable soils

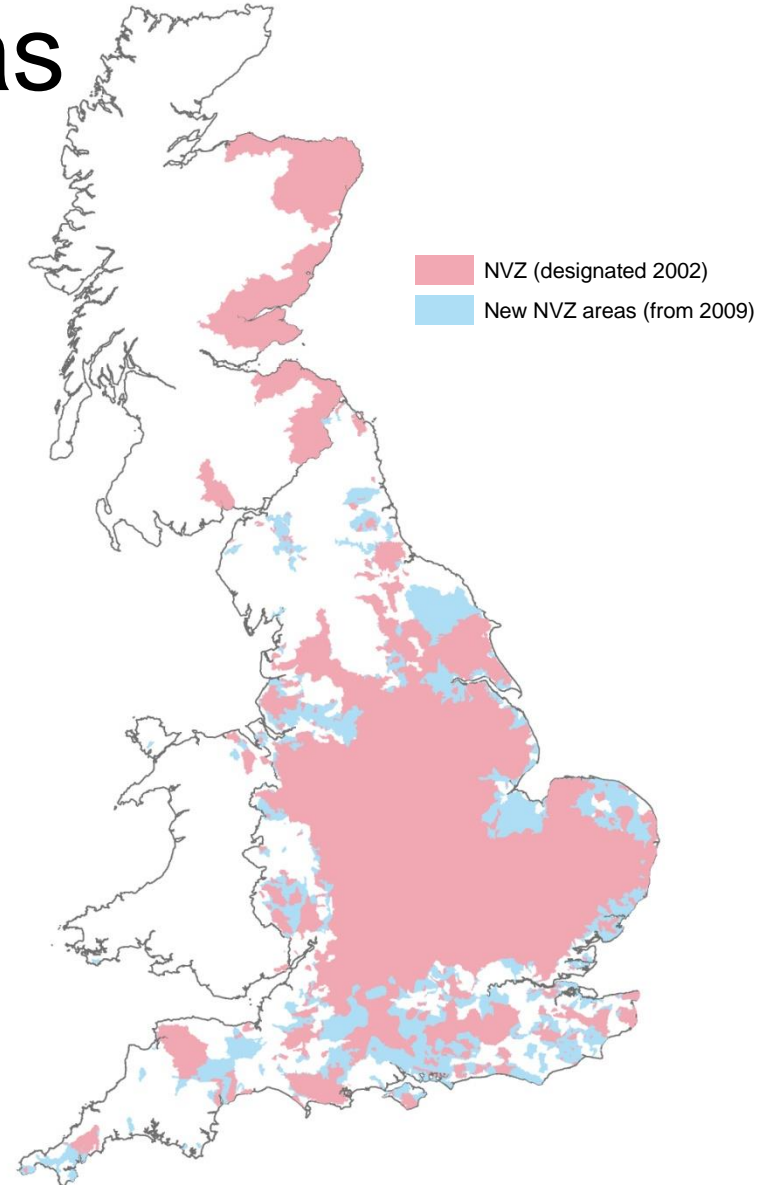


# Nitrate Vulnerable Zones designated areas

- 1996; 8% of land
- 2002; 55% of land
- *2008; 68% of land in  
England*  
14% (Scotland)  
4% (Wales)

**Designations are being revised**

100% Northern Ireland

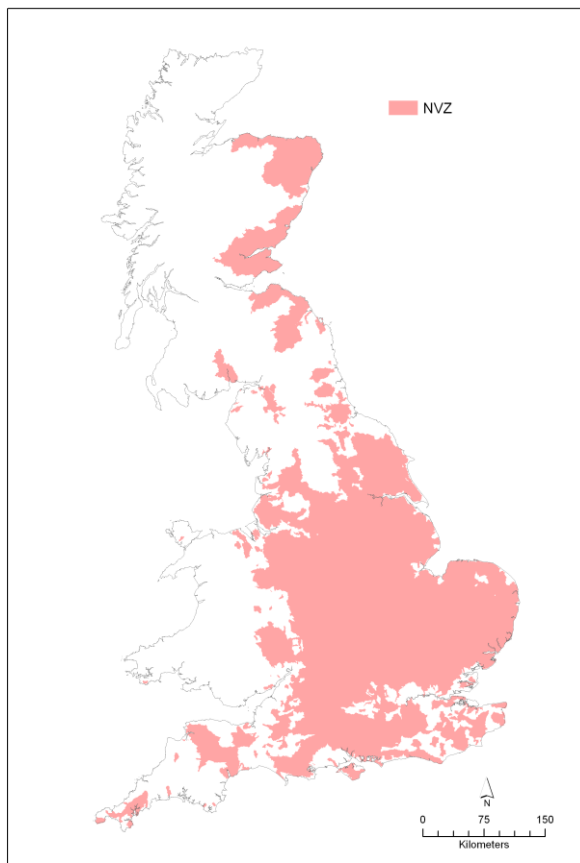




# The EC Nitrates Directive

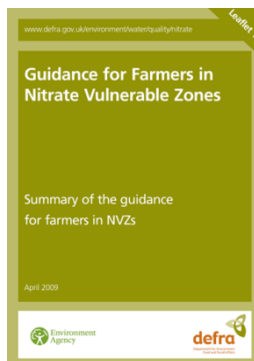
- Action is needed where:
  - ‘*surface or groundwaters contain, or could contain, more than 50 mg/litre of nitrate*’
  - ‘*inland, marine or coastal waters are, or could become, eutrophic*’
- The objective of the Directive will be achieved if the majority of water sampling points have either
  - low and stable nitrate levels
  - high nitrate levels or with a sustained downward trend

# Nitrate Vulnerable Zone Action Programme



## Action plan

- N max limit (farm and field)
- Limited stocking rates
- Closed periods when high available N content manures cannot be spread
- Slurry storage requirements
- Record keeping
- Manure management plan



# N Max (limit of N application)

Crop	N-max limit (kg/ha)	Standard crop yield (t/ha)
Autumn or early winter-sown wheat	220	8
Spring-sown wheat	180	7
Winter barley	180	6.5
Spring barley	150	5.5
Winter oilseed rape	250	3.5
Sugar beet	120	-
Potatoes	270	-
Forage maize	150	-
Field beans	0	-
Peas	0	-
Grass	300	-
Asparagus, carrots, radishes, etc	180	-
Celery, courgettes, etc	280	-
Beetroot, brussels sprouts, etc	370	-

# • The Livestock Manure N Farm Limit

(Guidance leaflet 5)



• *The amount of livestock manure applied to land each year, including by the animals themselves, shall not exceed 170 kg N/ha.* (Derogation to 250 kg N/ha)

• Calculate the farm manure N capacity and manure N loading (area of farm, standard N production figures, manure imports/exports)

• Calculations must be shown

**Stocking rate limit: 170 kg N/ha = 1.7 cows/ha. 250 kg N/ha = 2.5 cows/ha**

# Closed spreading periods



- *For manufactured nitrogen fertilisers*

<b>Grassland</b>	<b>Tillage land</b>
<b>15 September to 15 January</b>	<b>1 September to 15 January</b>

- Application is allowed to *specified crops* that have a crop N requirement during the closed period. Conditions apply.
- Application to other crops during the closed period is allowed with written advice from a FACTS qualified adviser
- Solution fertilisers are allowed if there is a P or K requirement and no practical alternative

# Closed periods: **organic manures**

- Organic manures with a high readily available N content (>30% of total N)  
e.g. slurry, poultry manure, liquid digested sludge

<b>Grassland</b>	
<b>Sandy or shallow soils</b>	<b>All other soils</b>
<b>1 Sept – 31 Dec (4 months)</b>	<b>15 Oct - 31 Jan (3 months)</b>

<b>Tillage land</b>	
<b>Sandy or shallow soils</b>	<b>All other soils</b>
<b>1 Aug – 31 Dec* (5 months)</b>	<b>1 Oct – 31 Jan (3.5 months)</b>

**\*On sandy or shallow soils, application is permitted between 1 August and 15 September provided a crop is sown on or before 15 September**

# • Storage of organic manures

(Guidance leaflet 4)



- 6 months storage capacity for pig slurry and poultry manure; 5 months storage for cattle slurry
- Excludes Dirty Water
- Use standard values of excreta production, ave. rainfall, washings
- Can deduct, exports, mechanically separated solids
- Calculations must be shown **Significant investment required**

# How to reduce slurry volume?



- Remove clean roof water
  - Cover fouled yards
  - Organise yard drainage
- Change to a solid manure system
- Slurry separation





# Storage options for solid manures

- Poultry manure and solid manures (e.g. FYM)
  - livestock house / roofed building
  - at a suitable temporary field site
  - on an impermeable surface, run-off collection and containment

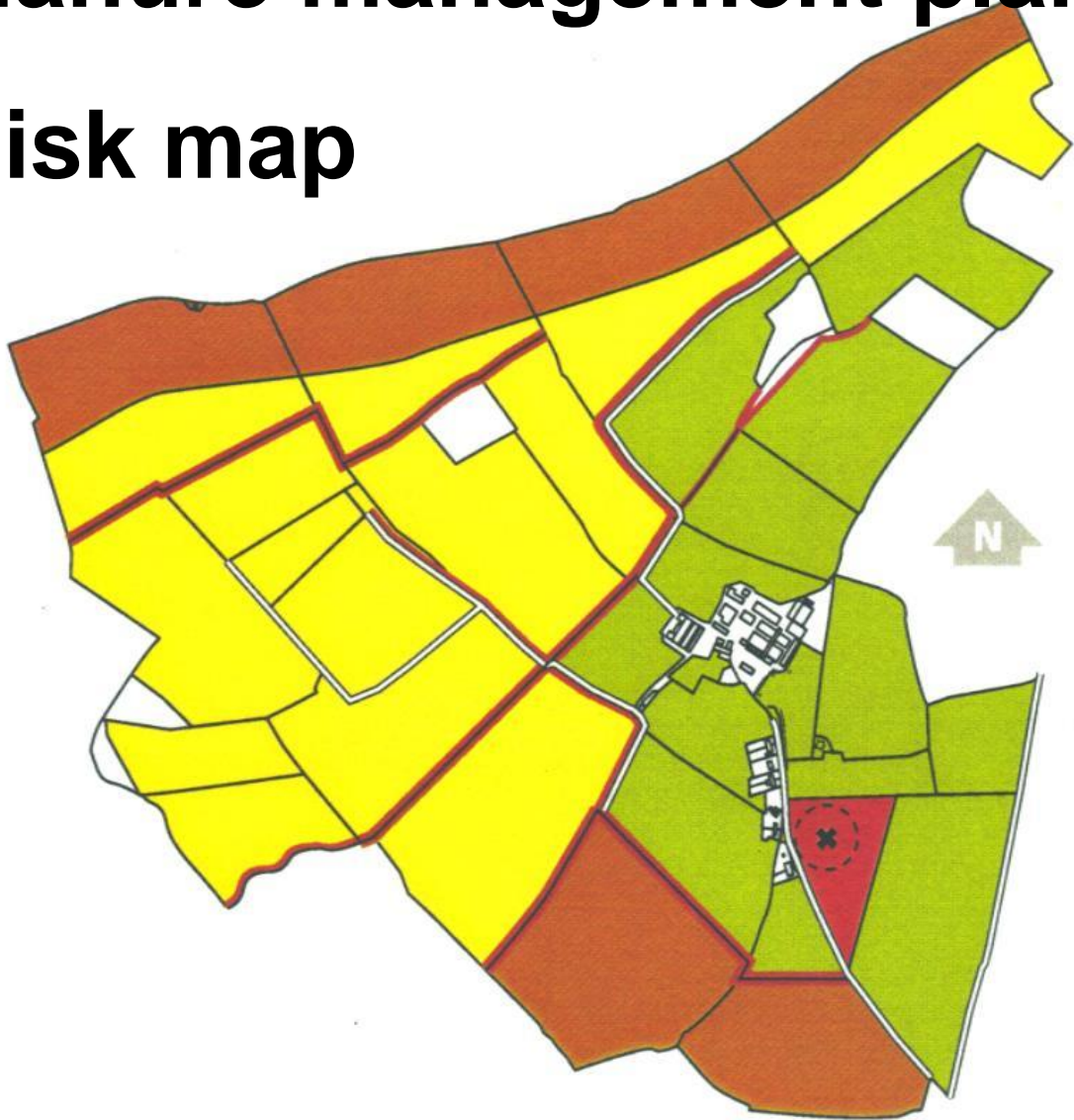
- Only use field site if manure can be stacked without free drainage from within the heap








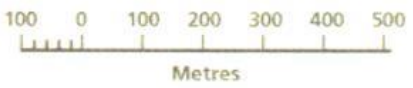
- Must provide a cover for field heaps of poultry manure if no bedding or litter is mixed into it e.g. laying hen manure

# Manure management plan

## Risk map



-  Don't spread in the red areas.
-  Avoid orange areas in winter and in a dry summer when the soil cracks down to the drains, or when the soil is compacted.
-  You can use yellow areas throughout the year subject to ground conditions, but restrict application rates in the winter.
-  Green areas can be used throughout the year.
-  Borehole



# Improved slurry spreading – to improve N use efficiency



Typical splash plate



Shallow injector



Band spreaders



# Nutrient leaching measurement approach

- Measurements of nutrient concentrations in soil below the rooting depth = potential leaching (use porous cups)
- Two types of porous cups:
  - ceramic cups only suitable for  $\text{NO}_3$  and  $\text{NH}_4$  (not  $\text{PO}_4$ )
  - Teflon cups suitable for  $\text{PO}_4$  (and  $\text{NO}_3$  and  $\text{NH}_4$ )
- Porous cups not suitable for all soils
  - Most suitable for freely draining light textured (sandy, loam) soils
  - Clay rich soils have preferential flow pathways, so porous cups can be bypassed
- Estimation of drainage volumes (water balance model)

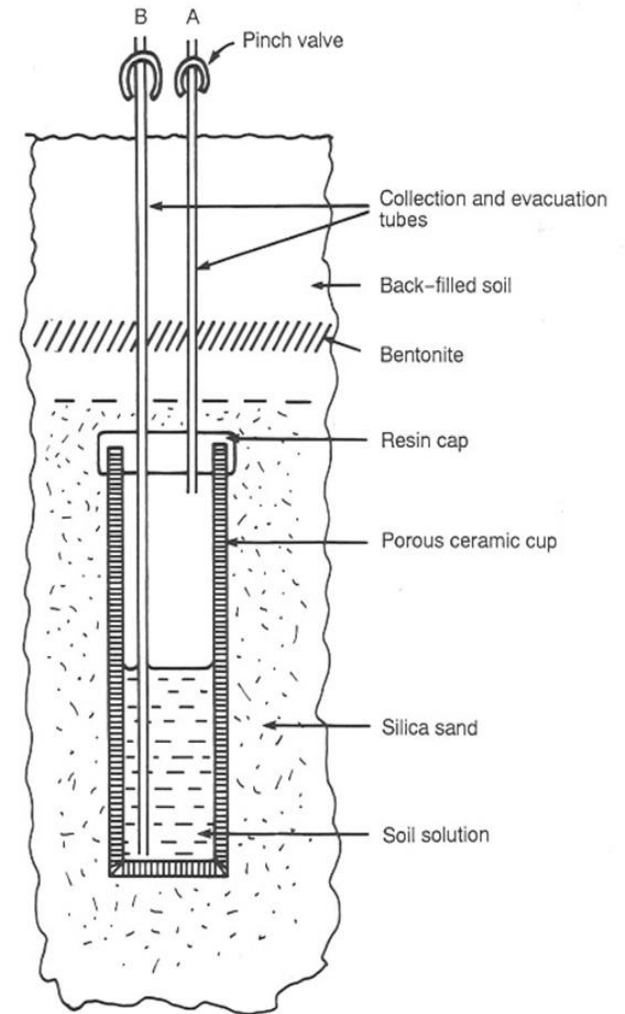
# How do porous pots work?

- Ceramic/teflon cups with a fine pore size which can hold a vacuum of up to 70kPa (0.7 atmosphere)
- If water is held in the soil at tensions less than the applied suction, water will move from the soil to the cup



# Installation

- An auger (usually 50mm diameter) is used to make the installation hole
- A slurry of fine silica sand is poured into the hole before the ceramic cup is pushed into the bottom
- The silica sand ensures continuous capillary contact between the cup and the soil.
- (Bentonite) clay seals the hole to prevent water moving preferentially from the soil surface



# Installation

Use a soil auger is used to make the installation holes

The pots are installed at an angle of  $30^\circ$  to ensure water sampled is from undisturbed soil



# Installation

After installation the sample tubes are protected against damage by livestock

Typically 5 porous pots are used on 24 m x 5 m plot to account for soil heterogeneity





# Installation

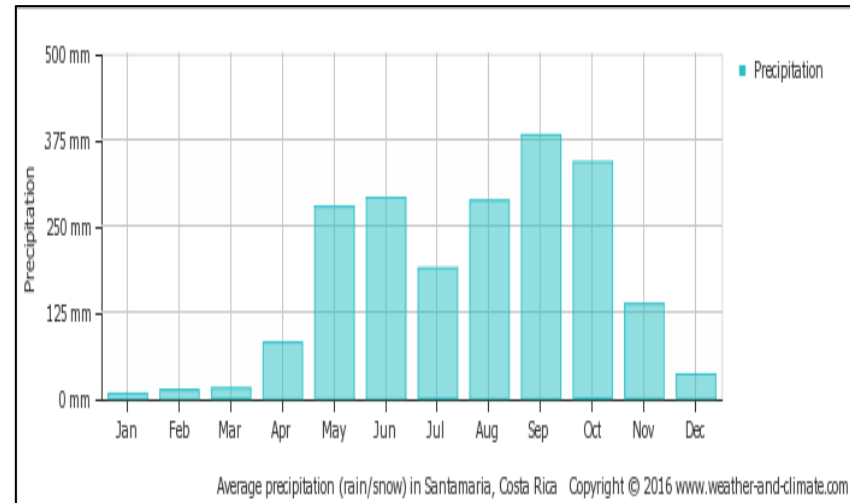
Porous cups are put under vacuum for at least 30 minutes (or overnight)

Porous pots only work when soils are at or close to field capacity and drainage is occurring

Water is collected in sample vials and kept refrigerated before analysis

In the UK, samples are usually collected every 2 weeks or 25 mm of drainage – c.8-10 samples per drainage season.

What sampling frequency is needed for Costa Rica?



**Average monthly precipitation (mm) in Turrialba.**

# Next steps

- Visit CATIE farm to demonstrate installation
- Decide which field to install the preart samplers
- Decide how many samplers to use in each field
- Determine sampling frequency, based on hydrological balance (= estimate / model simulation of effective drainage throughout the year)