Relationship between solute hysteretic behaviour and hydrological pathways at farm-scale

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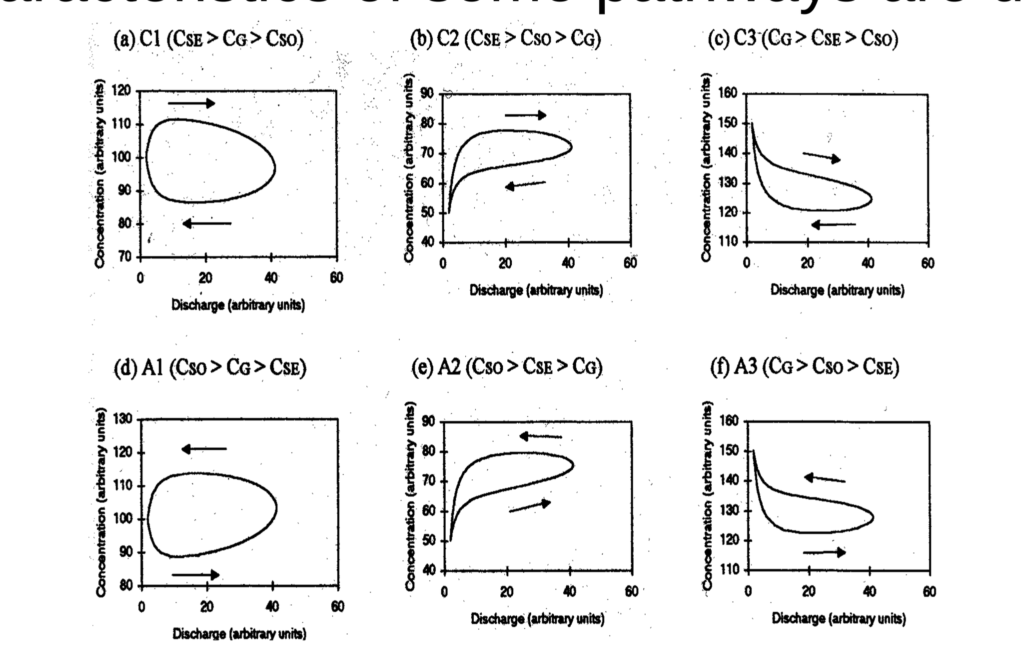
Introduction

Solute hysteretic behaviour describes the varying patterns that are usually exhibited by the time varying concentration of dissolved solids with discharge. The patterns often vary from simple to complex, and 2 to 3D. Evans and Davis (1996) suggested a framework for few determinable shapes (Fig. 1), while many other complex patterns appear in literature. Fig 2 highlights known sources of dissolved solids, their pathways and environmental vulnerability to pollution impact. The characteristics of some pathways are described in Table 1.



C= Clockwise directional pattern; A = Anticlockwise directional pattern;
C1, A1 = Convex; C2, C3, A2, A3 = Concave
C2, A2 = Positive trend; C3, A3 = Negative trend
C_{SE}, C_G, C_{SO} refer to concentrations in surface event, ground and soil waters, respectively.

Fig.1: Some c-Q patterns (Evans & Davis, 1996)

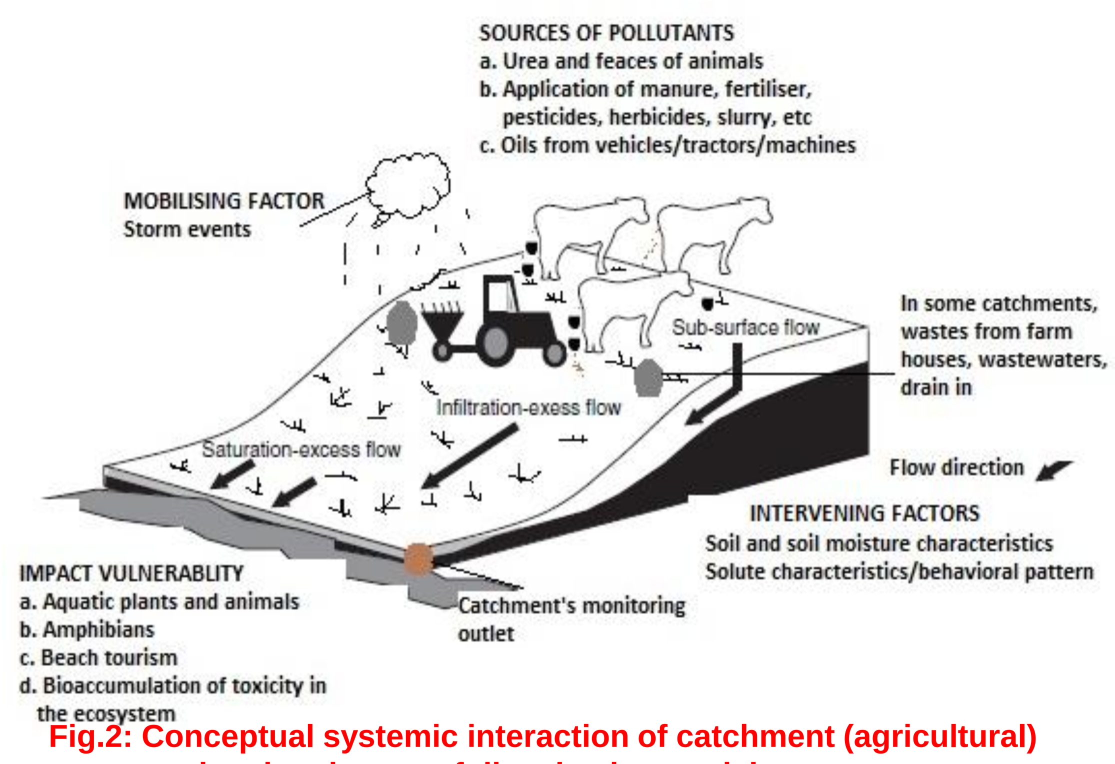


Fig.2: Conceptual systemic interaction of catchment (agricultural) processed and pathways of dissolved materials

Table1: Hydrological pathways and their attributes

Name	Pathway	Description	Dominant water type
Hortonian Flow	*Surface*	Occurs when and where rainfall intensity exceeds infiltration capacity	Event
Saturation Excess Flow or Hewlettian runoff / Return flow	Surface & throughflow	Occurs when and where rainfall rate is greater than the soils saturated hydraulic conductivity. Explained by the variable source area concept	Event
Lateral flow	Sub-surface	Occurs when infiltrated storm water encounter s a less permeable layer at some depth before groundwater. The top soil posses high hydraulic conductivity	Pre-event
Preferential flow (PF)	Sub-surface	Occurs where water infiltrates through macropores or pipes and bypass a large portion of soil matrix	Pre-event
Drain flow	Surface & interflow	A form of PF. It is a system whereby a subsurface conduit is laid to intercept surface runoff	Event
Piston flow	*Sub-surface*	Occurs as downward drains through the soil with a generally uniform wetting front, carrying pollutants towards the groundwater zone; in soils with generally uniform wetting front	Pre-event
Groundwater	Groundwater	Occurs as runoff initially goes into the soil and thence through groundwater flow to the stream or evaporated	Pre-event

Research Questions

- Would the c-Q pattern for same solute significantly vary in catchments with similar dominant soil types?
- How would c-Q patterns vary significantly with seasons?
- Are c-Q patterns nonlinear and time invariant?
- Would c-Q, End Member mixing and a nonlinear (wavelet analysis) model produce similar interpretation, such that one can substitute for the other in interpreting hydrological pathways?
- What are the effects of rainfall, soil moisture, soil properties and gradient and catchment size on c-Q patterns?

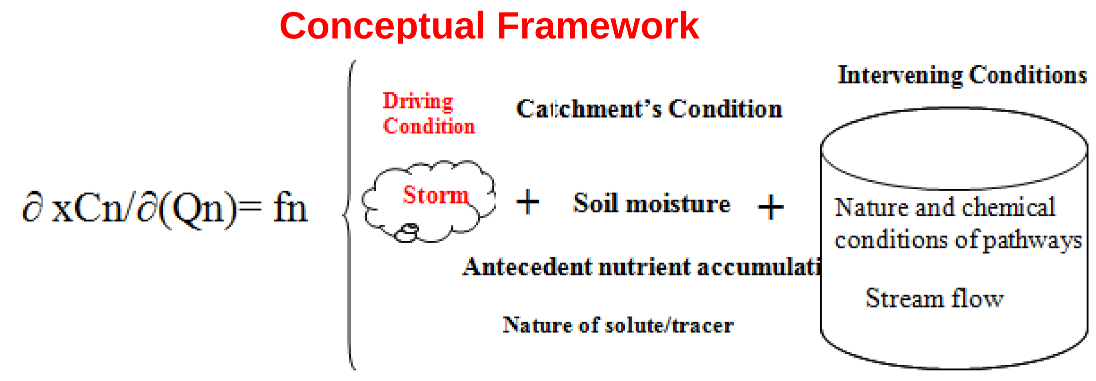
Table 2: Existing approaches to hydrological pathways

Method	Catchment characteristics		
	Catchment name	Vegetation	Dominant soil
Hydrograph separation	Kawakami Experimental basin,	Dense forest	Soils developed from the Neocene volcanic rocks
Hydrograph, Chemograph	Denbrook catchment,	Grasslands	Clay (Hallsworth series)
Statistical models			Peat
	Unterehrendingen	Spruce-breech forest	Fine loamy Dystric Cambisols
Riparian flow concentration integration model	Vastrabacken	Spruce and Scots pine	Podzol, Peat
End Member Mixing Analysis (EMMA)	Alt a Mharcaidh	Borea heather, moor, alpine	Podzol
c-Q patterns, EMMA	Panola Mountain Research Watersheds	90% forest, 10% exposed granite outcrops	
Factor analysis, EMMA	Megget Catchment,	Semi natural moorland and grassland communities	Peaty Podzol
Soil Conservation Service model, water balance models	Nossa	Cultivated pasture	Podzol, *Typic Paleudult*

** these approaches have been criticised as inadequate for determination and prediction of hydrological pathways

METHODS

Conceptual Framework

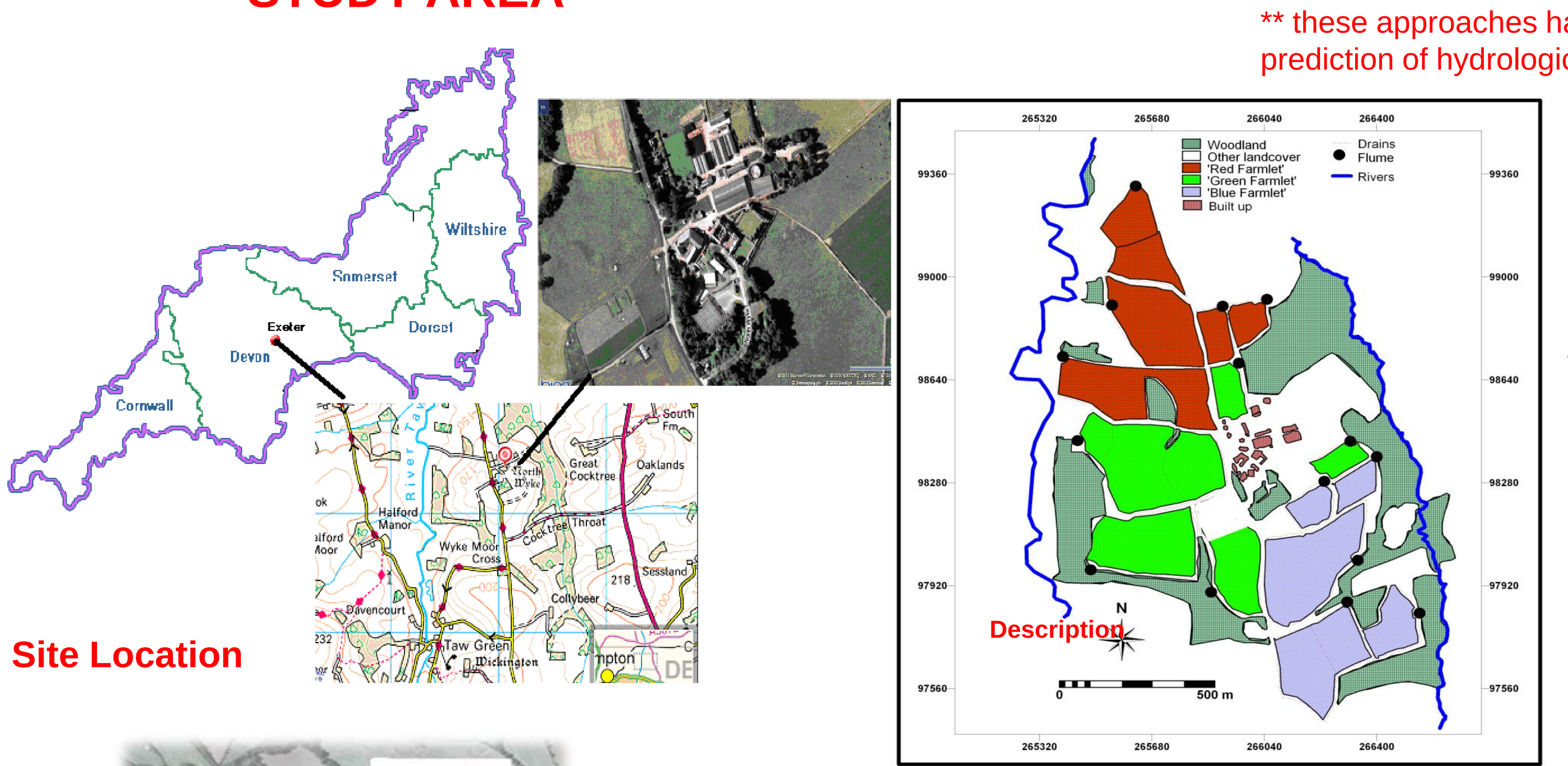


Cn= concentration of 'n' ion (mg/L), Qn = discharge of 'n' ion (L/s), fn= function

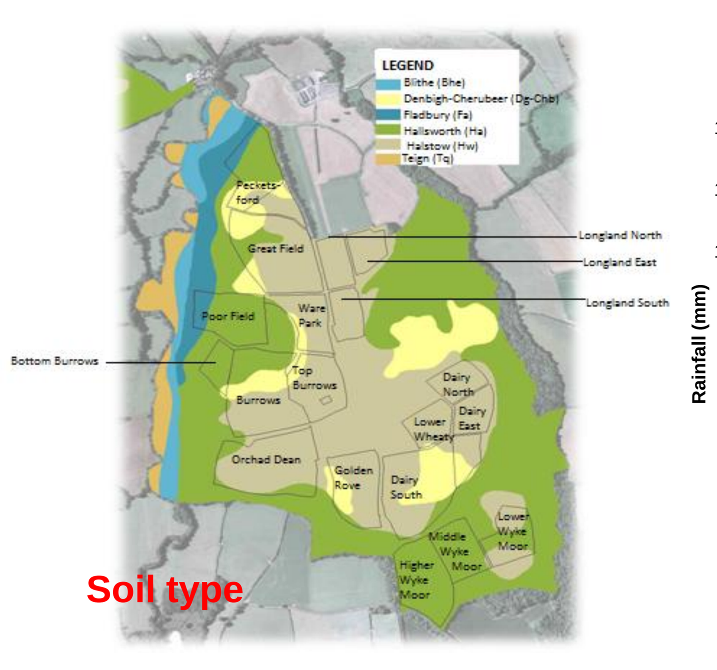
Field Instrumentation

a. Soil water (20, 30cm depth) sensor, b. Bubbler flow meter , c. rain gauge, d. probes for measurements of pH, and selected ions, e. telemetry connection for data transfer (Available for 15 hydrologically separated farm platforms)

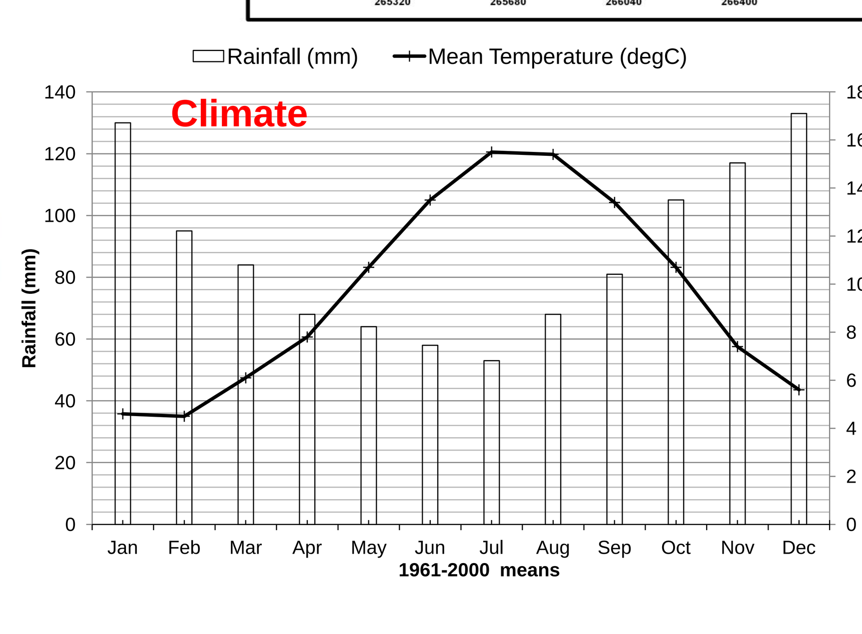
STUDY AREA



Site Location



Soil type

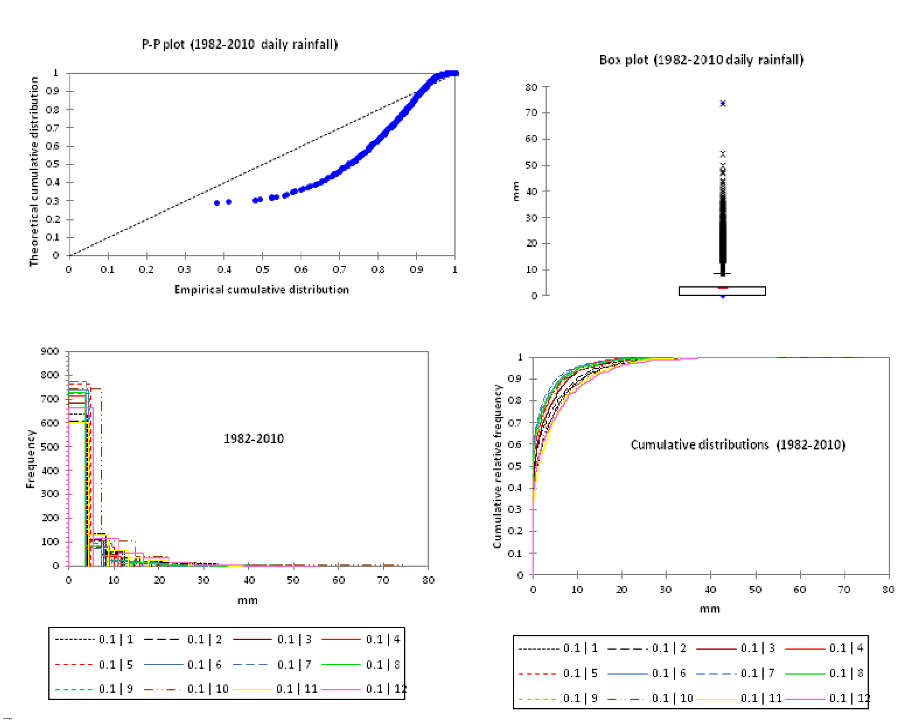


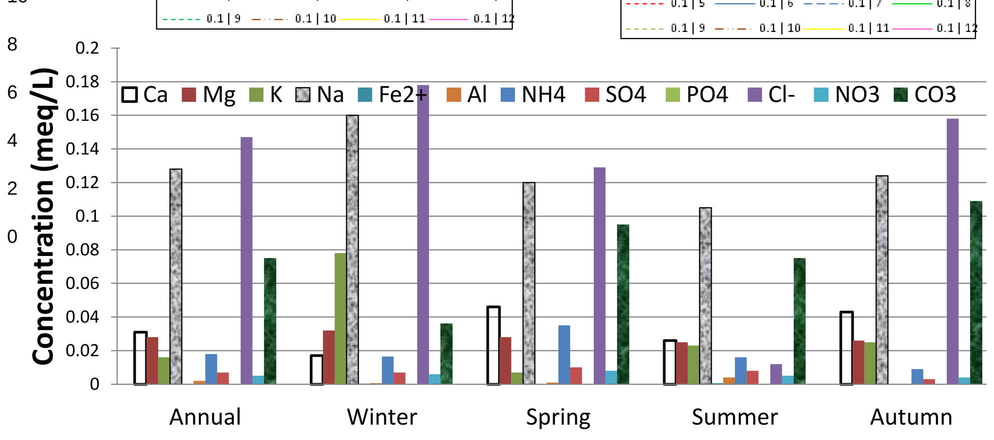
Hogan and Harrod (1980)	FAO (1990)	USDA (1992)	Avery (1990)
Halstow	Stagni-vertic cambisol	Aeric haplaquept	Typical non-calcareous pelosols
Hallsworth	Stagni-vertic cambisol	Typic haplaquept	Pelo-stagnoley soils
Denbigh	Stagni-eutric cambisol	Dystric eutrochrept	Typical brown earths
Fladbury	Gleyi-eutric fluvisol	Vertic fluvaquent	Pelo-alluvial gley soils

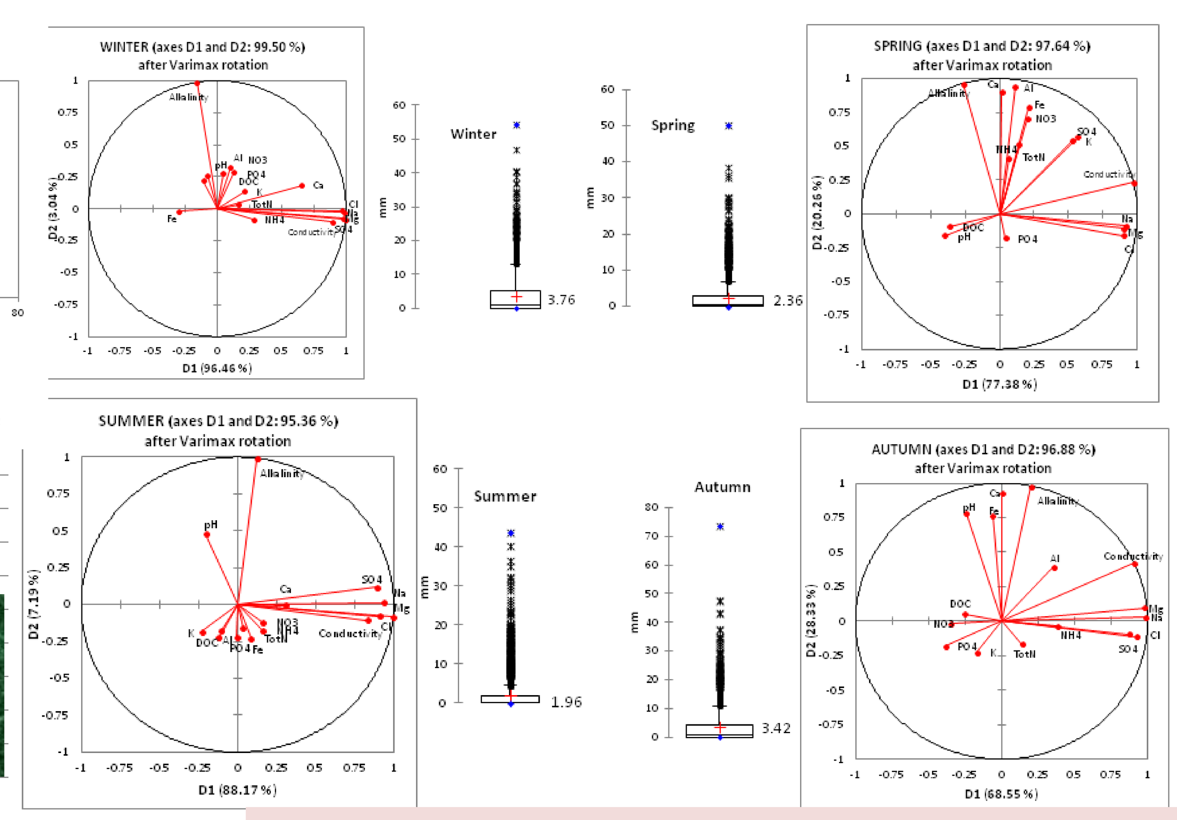
Dominant land cover

Dominant land use: grazing

SOME RESULTS: Rainfall Characteristics







Research Objectives: Further study

- Assess the influence of rainfall chemistry on water quality patterns through analysis of data from 9 selected hydrologically separated farmlets and an Ecological Change Network station at North Wyke;
- Establish relationships among discharge, concentration of dissolved solids, rainfall and soil moisture for each farmlet;
- Assess the hydrographs separation, EMMA, Statistical and wavelet analysis techniques for flowpath delineation in selected farmlets; and
- Characterize the hysteresis in discharge-concentration relationship as affected by rainfall, soil moisture, soil types, and other 'catchment's characteristics.

Some Findings

- Rainfall has significantly increased in summer but decreased in winter between 1995 and 2010
- Rainfall pH varied from 4.29 to 7.34, with median (5.33) being lower than the level recorded for the county (Devon) in 1980-2011
- Annual dominance of Na^+ and Cl^- in rainwater, attributed to sea sprays
- Seasonal variation in the atmospheric constituents; agricultural influence in the spring and summer and natural occurring sea sprays in the winter.

Some References

Evans C, Davies T (1998) Causes of concentration/discharge hysteresis and its potential as a tool for analysis of episode hydrochemistry. Water Resources Research 34: 129-137

Harrod T, Hogan D (1981) The soils of North Wyke and Rowden. Unpublished Report to North Wyke Research, revised edition of original report by TR Harrod, Soil Survey of England and Wales

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