Characterising the Hydromorphology of Irish Lakes

Scottish Freshwater Group
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TRINITY COLLEGE DUBLIN

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Lake Hydromorphology and the WFD

1. Lake typology includes area and depth.
2. Quality element for ecological status.
3. Morphology and hydrologic condition are supporting elements for ecology.
4. Required for developing risk assessments for eutrophication and abstraction pressures.
5. Influence effectiveness of POM's and the timescale of 'recovery'.

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Characterisation of Hydromorphology

1. Landscape limnology conceptual framework
2. Hydromorphology metrics
3. Relationships between hydromorphology and lake water quality.

Photo by R. Little EPA Ireland

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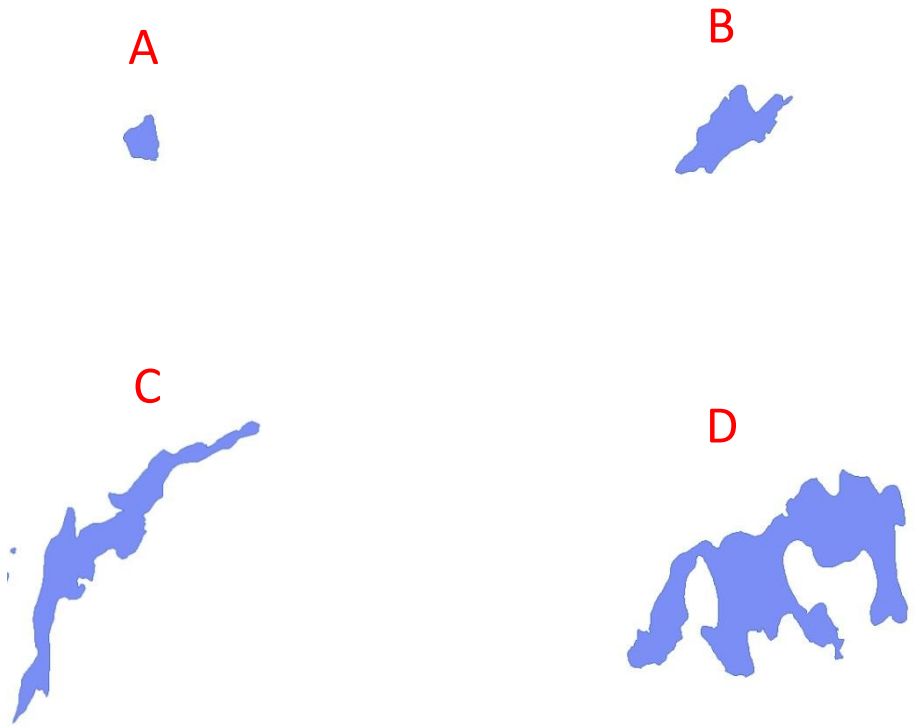
Lakes as Bounded Ecosystems



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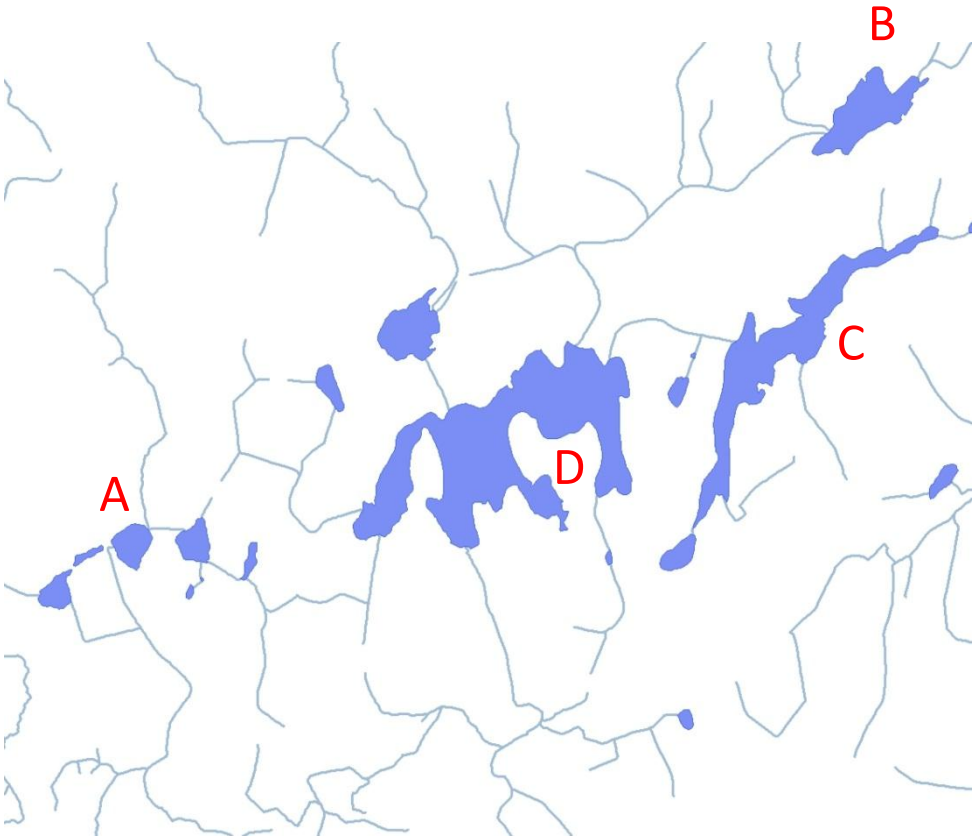
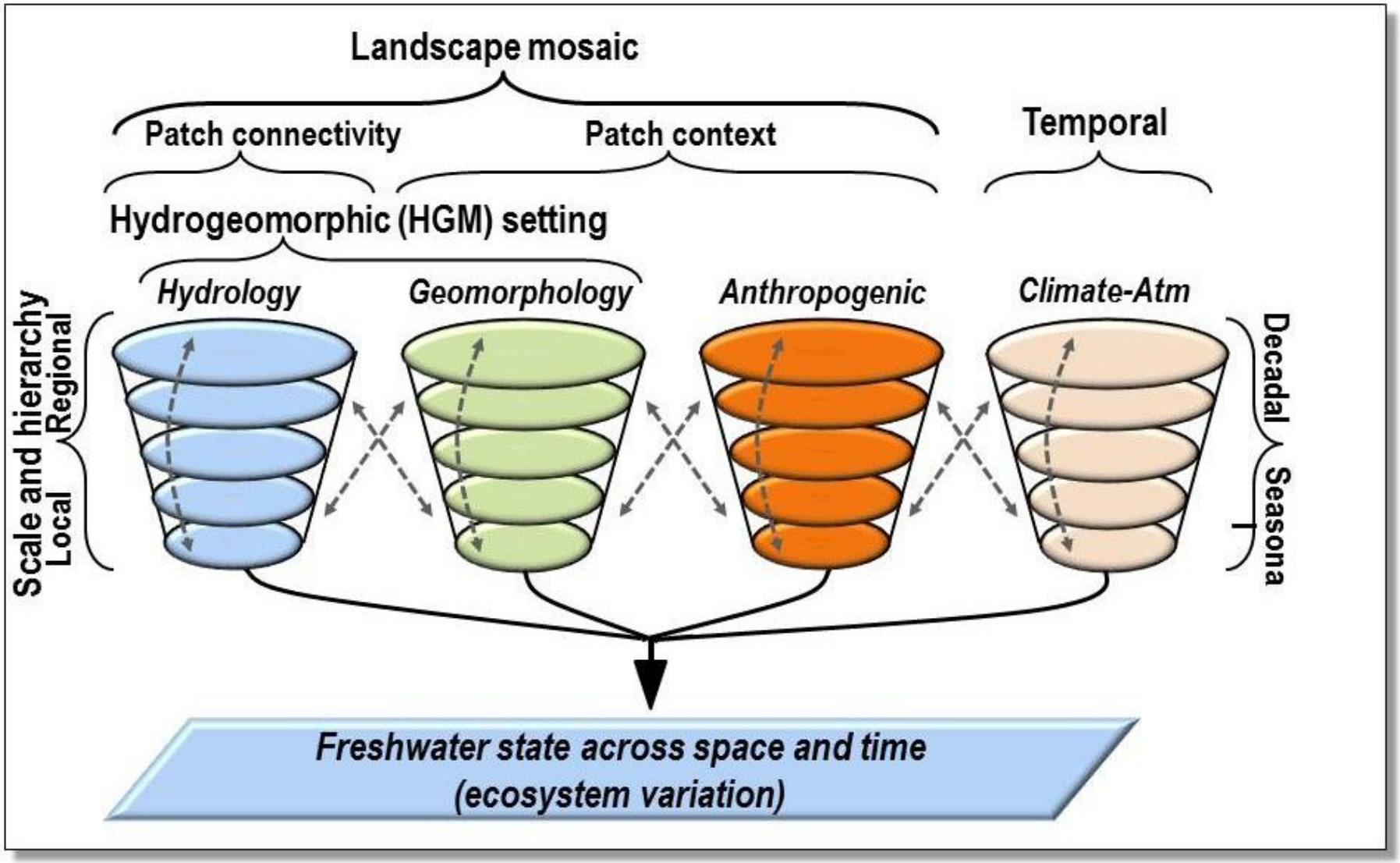
Landscape Limnology

Landscape limnology is the spatially-explicit study of lakes, streams, and wetlands as they interact with freshwater, terrestrial, and human landscapes to determine the effects of pattern on ecosystem processes.



Soranno et al. 2010. BioScience; http://www.fw.msu.edu/~llrg/

Landscape Limnology Conceptual Diagram



Adapted from Soranno et al. 2010. BioScience;

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Photo by D. Tierney, EPA Ireland

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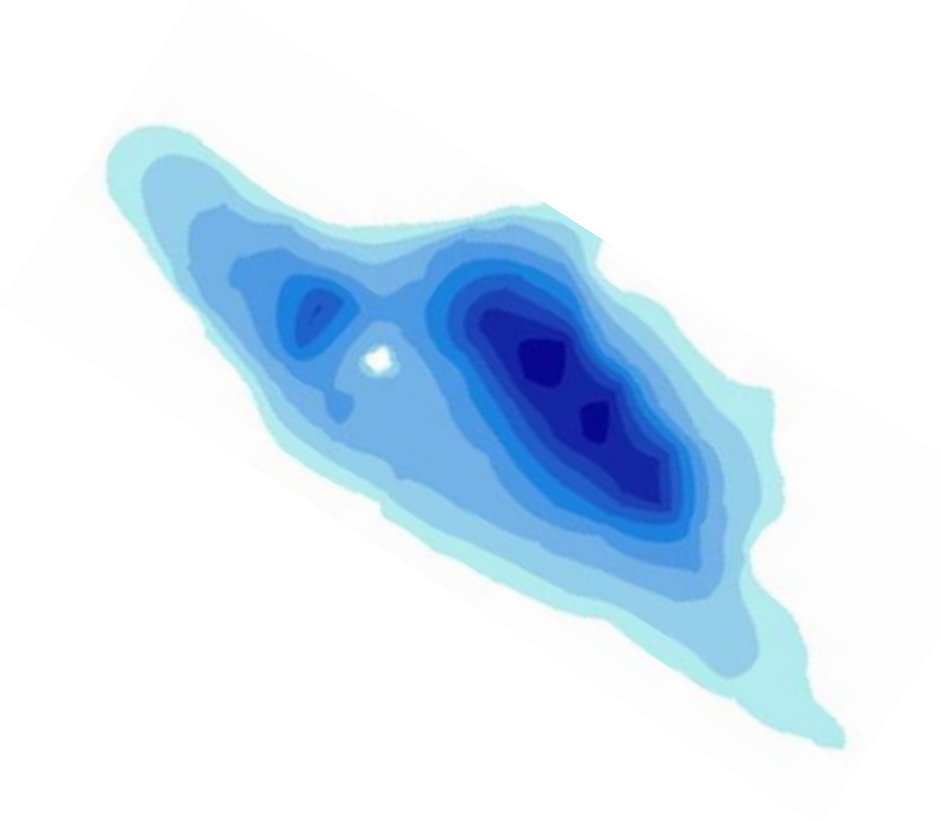
Hydromorphology Metrics- Morphology

1. Morphology (bathymetry)
   a. Lake depth surveys for ~ 500 lakes
   b. Standard protocol with geoprocessing in ArcGIS



Volume & mean depth
Area/volume x depth
Basin shape and slope
Perimeter, shoreline complexity

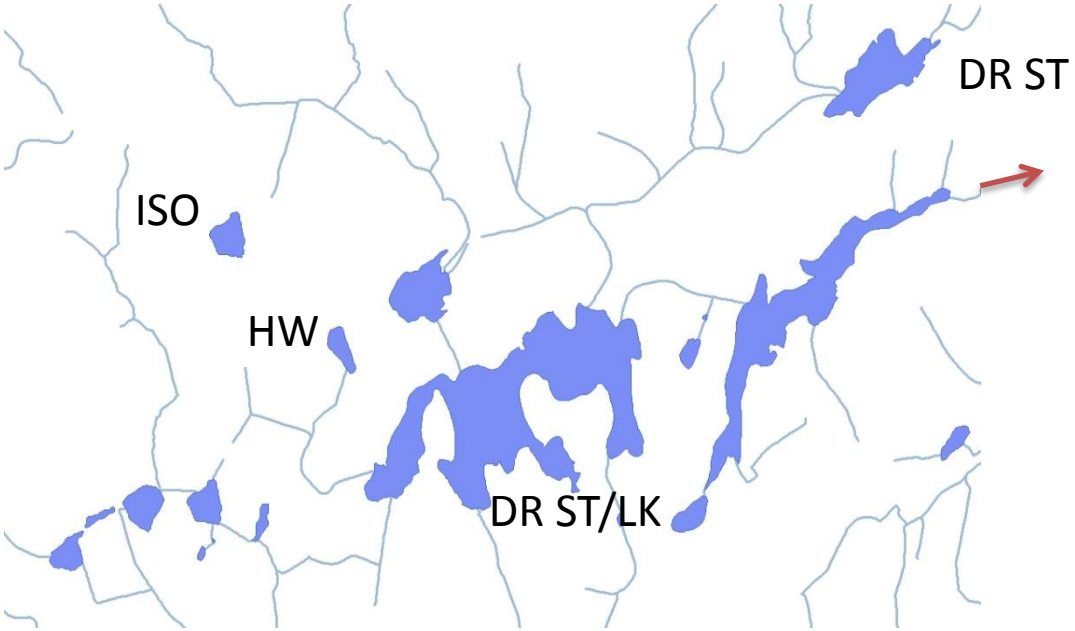
Water residence time

Hydromorphology Metrics – Connections

2. Hydrologic Connections

a. Position in the flow system and lake order

1) Isolated (no inlets/outlet)
2) Headwater (no inlets/outlet)
3) Drainage ST (inlets/outlets, no upstream lakes)
4) Drainage ST/LK (inlets/outlets, upstream lakes)



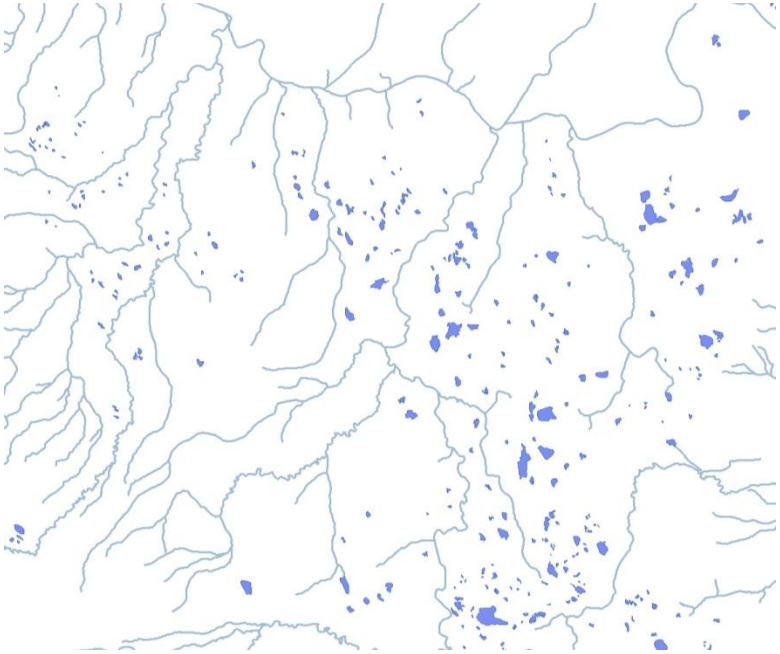
Hydromorphology Metrics – Connections

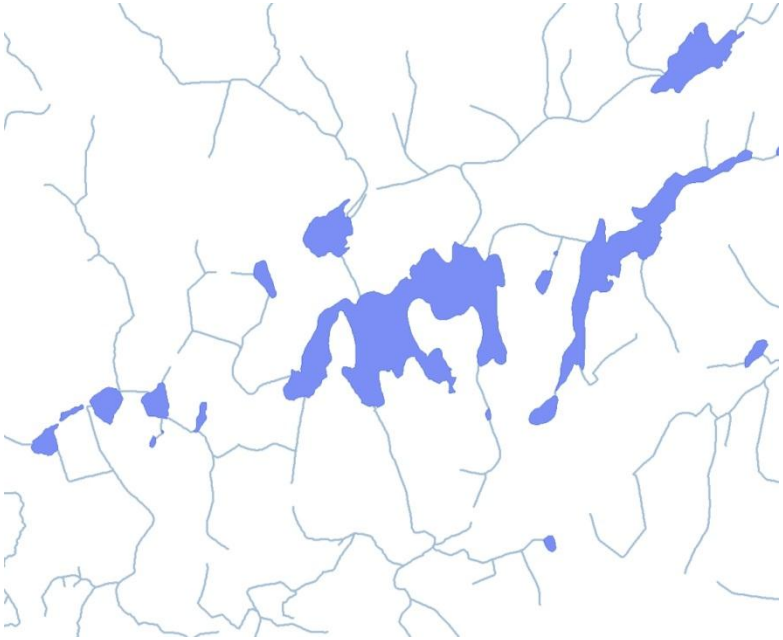
2. Hydrologic Connections

   b. Aquatic connectivity

      1) Stream network density & density of upstream lakes

      2) Soil permeability / groundwater connectivity



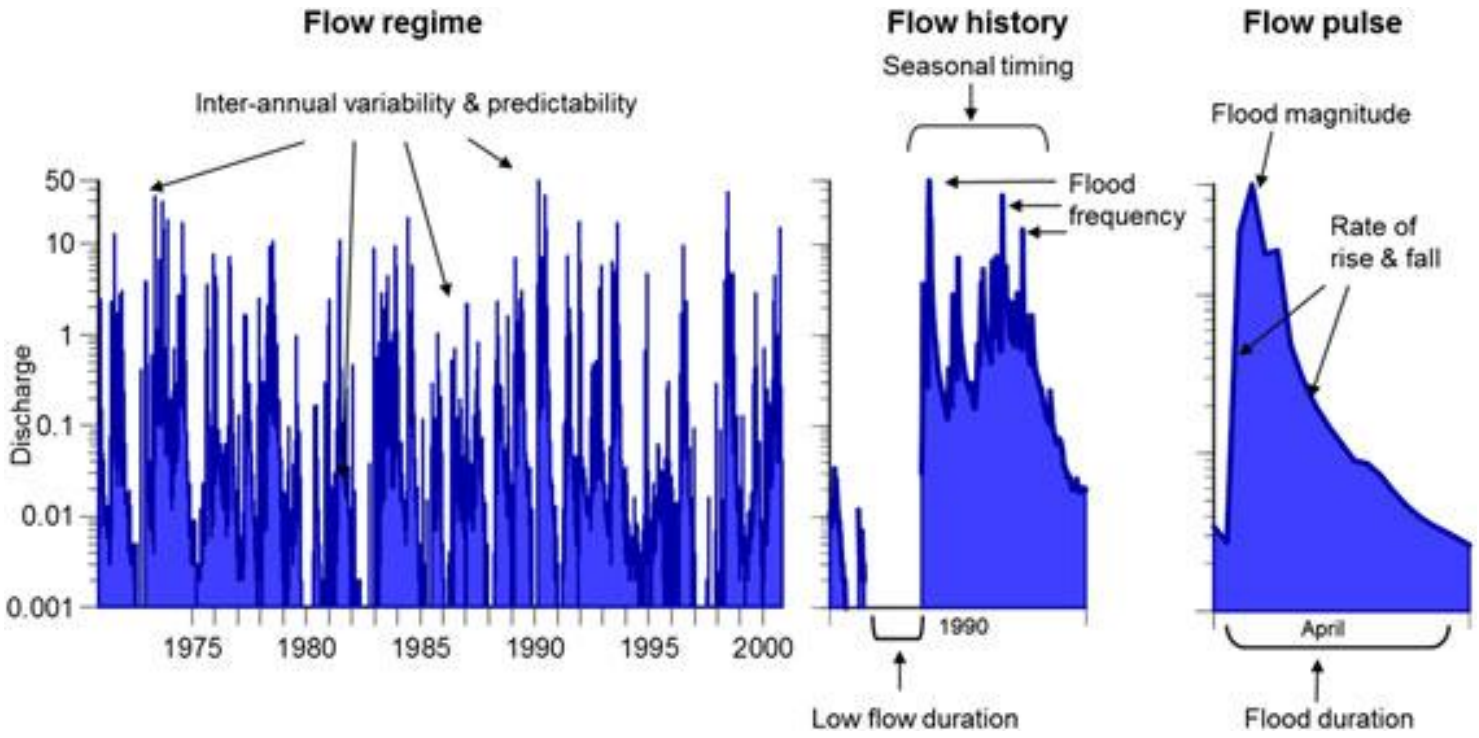


Hydromorphology Metrics: Hydro Regime

Olden et al. 2012. Ecohydrology

3. Hydrologic Regime *(in progress!!)*

a. Precipitation (monthly grids)
b. River flow (daily flow for ~ 100 sites)
c. Lake outflow (daily flow for ~30 sites)
d. Lake level (daily for ~ 40 sites)



Characterisation of Hydromorphology

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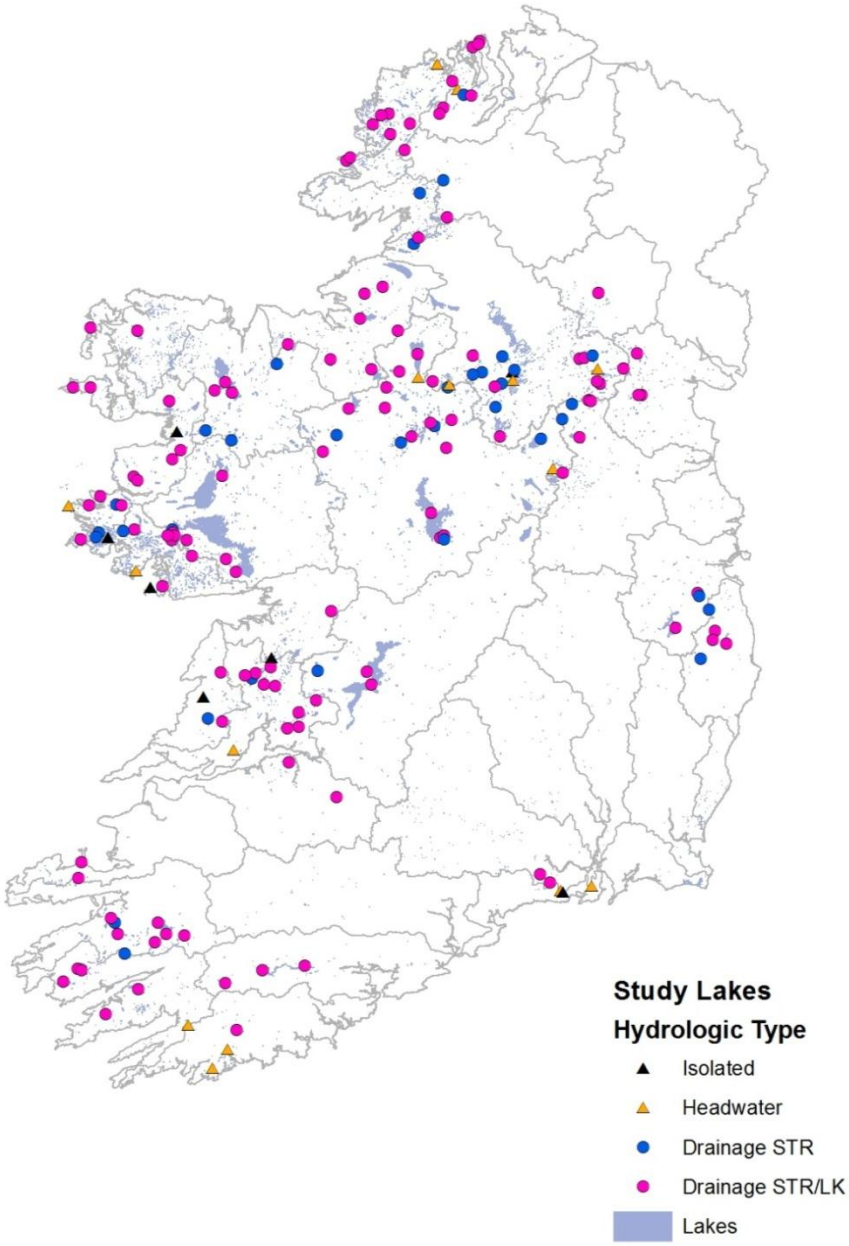
Study Lakes

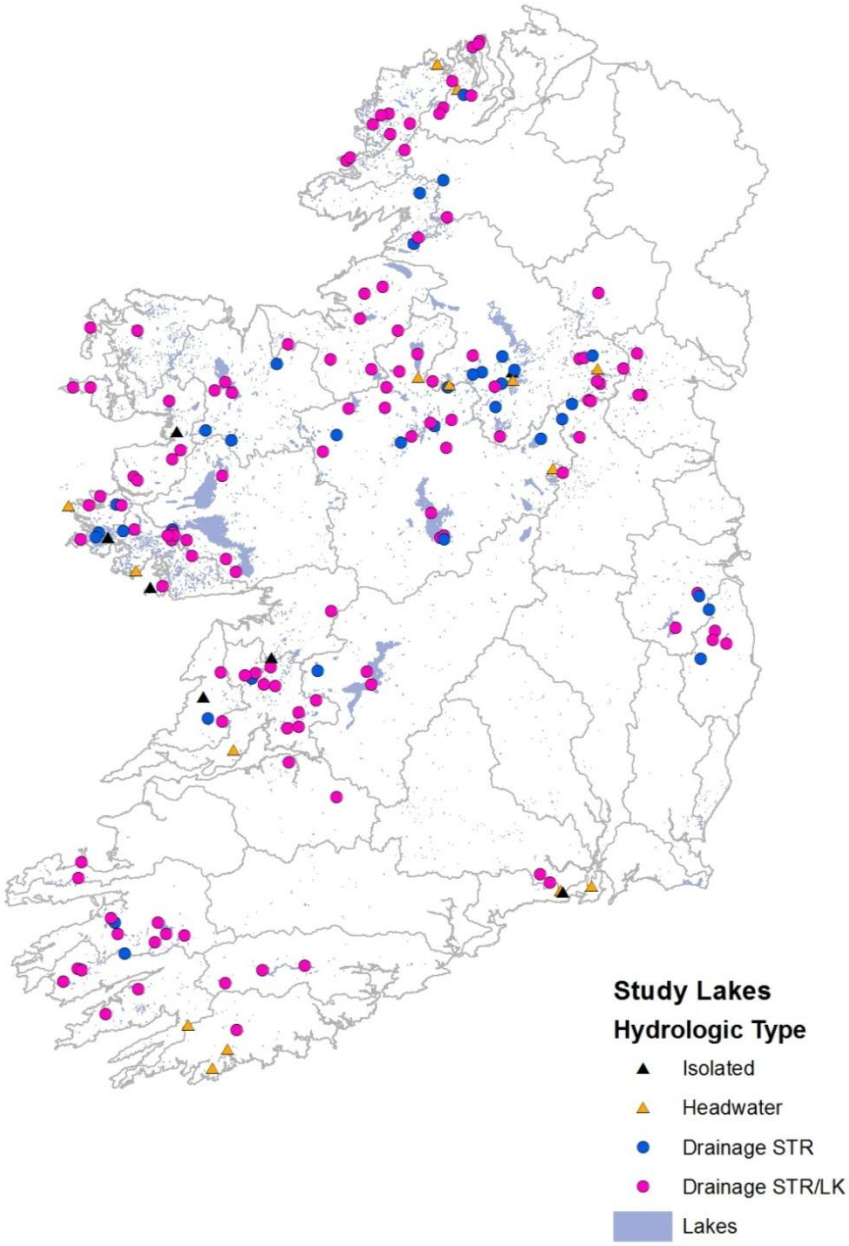


186 WFD monitoring lakes

Wide range of characteristics

- WRT: 0.35 (0.002 – 9.1) yrs
- LK Area: 647 (22-116505) ha
- Hydrologic type
  - 8 Isolated
  - 16 Headwater
  - 36 Drainage STR
  - 126 Drainage STR/LK

Study Lakes Water Quality



Median values from 4-5 years of summer and spring values

	Median	Range
Alkalinity	37	1.7 - 282
Total P	13	4 - 143
Chlorophyll	4.7	0.4 – 43
Colour	43	6 - 167

Lake Landscape Predictors

GOAL: Identify hydromorphology metrics that best explain variance in lake water quality.

Hydromorphology
Lake area, mean depth, order, water residence time
Catchment area, slope, stream density, lake density; CA:LK area ratio
Soil permeability (~Groundwater?)
Runoff

Lake Landscape Predictors

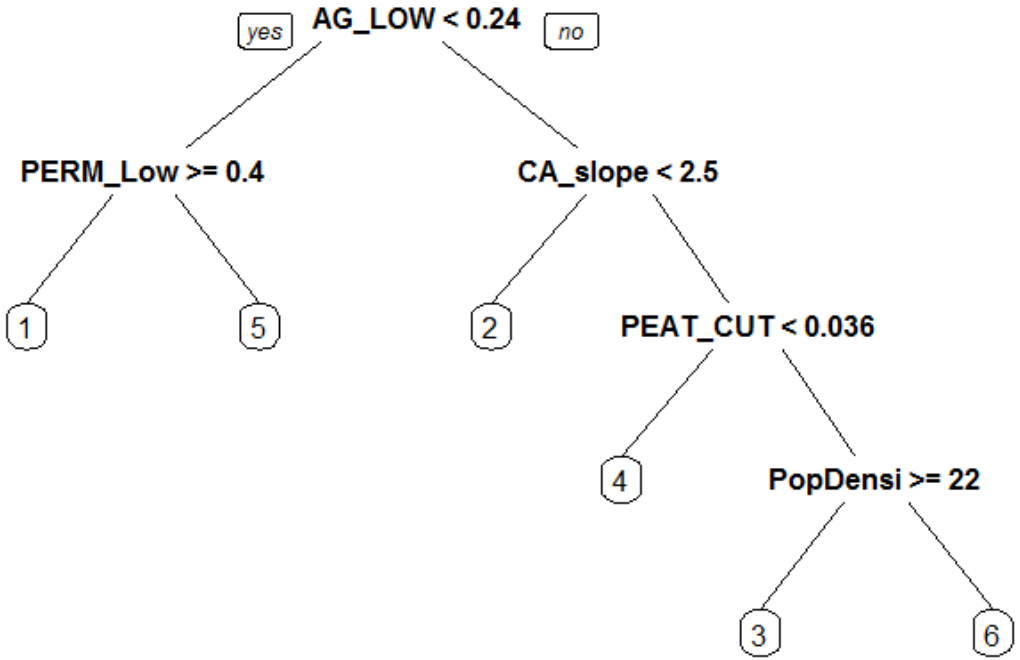
GOAL: Compare hydromorphology to geomorphology and anthropogenic features.

Hydromorphology	Geomorphology	Anthropogenic
Lake area, mean depth, order, water residence time	Catchment elevation	Population density, Drinking water supply
Catchment area, slope, stream density, lake density; CA:LK area ratio	Land cover: mixed/broadleaf forest, grassland	Land use: low-intensity AG, high-intensity AG, coniferous (managed) forest
Soil permeability	Soils: alluvium, sand+gravel, blanket peat, fen+raised bog, till, exposed bedrock	Soils: cut peat
Runoff	Bedrock: basalt, igneous, sedimentary, limestone	Presence of zebra mussels

Exploratory Data Analysis

randomForest package in R

- Constructs 500 regression trees via bootstrapped samples of the response data and the predictors
- 'Importance' values for each predictor based on how often it is included in the 500 trees and tree position.
- % variance explained



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Random Forest Results – %Variance

WQ Variable	Hydro-morph	Geo-morph	Anthro-pogenic	*All*
Alkalinity	58.5	**76.8**	53.9	***82.3***
Total P	32.9	**42.6**	36.4	***42.4***
Chlorophyll	31.2	**47.2**	25.1	***47.4***
Colour	**36.9**	32.6	10.6	***38.5***

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Importance – Hydromorphology

Alkalinity	Total P	CHL	Colour
$R^2 = 58.5$	$R^2 = 32.9$	$R^2 = 31.2$	$R^2 = 36.9$
Runoff	Runoff	Perm low	Perm low
CA slope	Perm high	Runoff	*CA stream dens*
CA stream dens	CA slope	*CA:LK area*	Perm high
Perm low	Perm low	CA slope	*LK mean depth*
CA:LK area	*CA:LK area*	*Perm high*	*CA area*
Perm high	*CA stream dens*	*Lake area*	
CA area			

Negative *(very low correlation)*

Positive *(very low correlation)*

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Importance – Geomorphology

Alkalinity	Total P	CHL	Colour
$R^2 = 76.8$	$R^2 = 42.6$	$R^2 = 47.2$	$R^2 = 32.6$
Bed limestone	Till	Till	Blanket Peat
Blanket Peat	Bed basalt	Bed basalt	Bed exposed
CA elevation	*CA elevation*	Blanket Peat	CA elevation
Fen + Raised Bogs	Bedrock exposed		

Negative
Positive

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Importance – Anthropogenic

Alkalinity	Total P	CHL	Colour
$R^2 = 53.9$	$R^2 = 36.4$	$R^2 = 25.1$	$R^2 = 10.6$
Ag low intensity	Ag low intensity	Ag low intensity	Conifer forest
Peat cut	Peat cut	Pop density	Ag low intensity
Pop density	Pop density	*Peat cut*	*Pop density*

Negative

Positive

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Importance – All predictors

Alkalinity	Total P	CHL	Colour
$R^2 = 82.3$	$R^2 = 42.4$	$R^2 = 47.4$	$R^2 = 38.5$
Bed limestone	Till	Till	Perm low
Ag low intensity	Bedrock basalt	Bedrock basalt	Conifer forest
Runoff	Ag low intensity	Perm low	Blanket Peat
Peat cut	Runoff	Ag low intensity	CA elevation
Blanket Peat	*CA elevation*		*CA stream dens*
CA slope	Peat cut		

Negative

Positive

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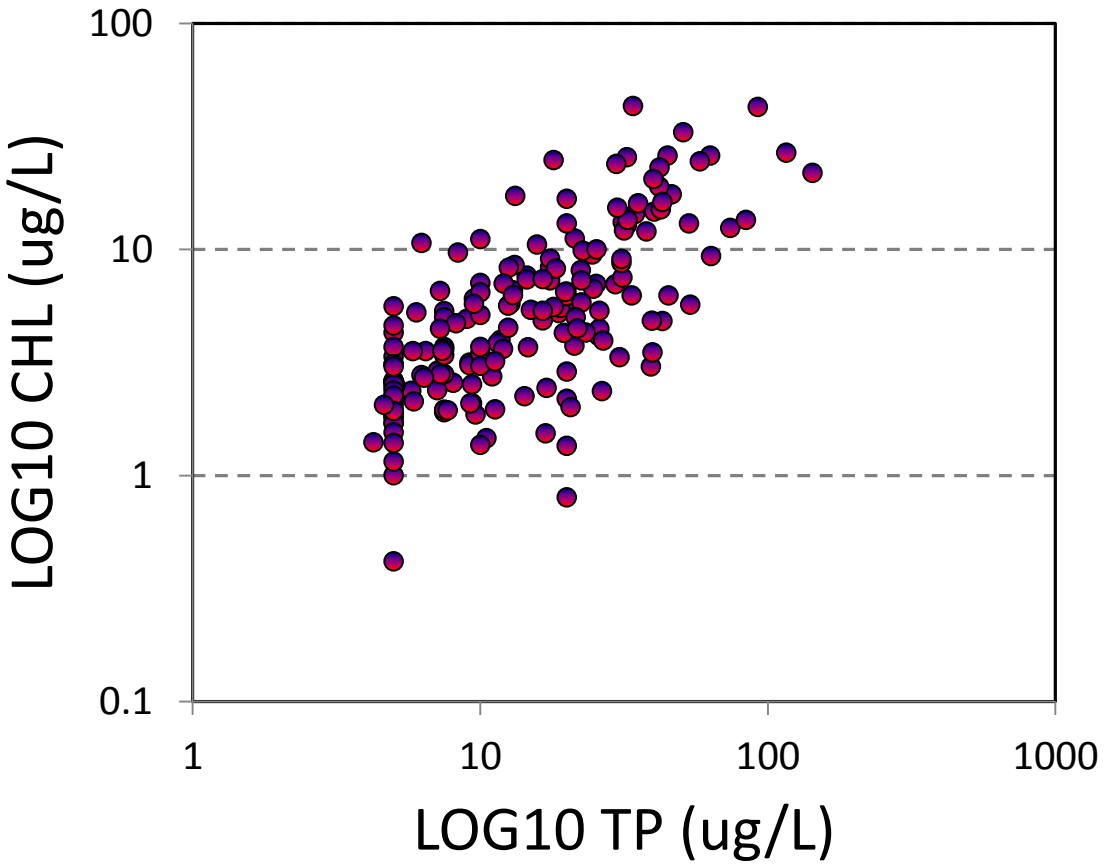
TP – CHL Relationship



CHL:TP
R^2 = 23.5
Bed sedimentary
Perm low
CA slope
CA stream dens
CA lake density

Negative
Positive

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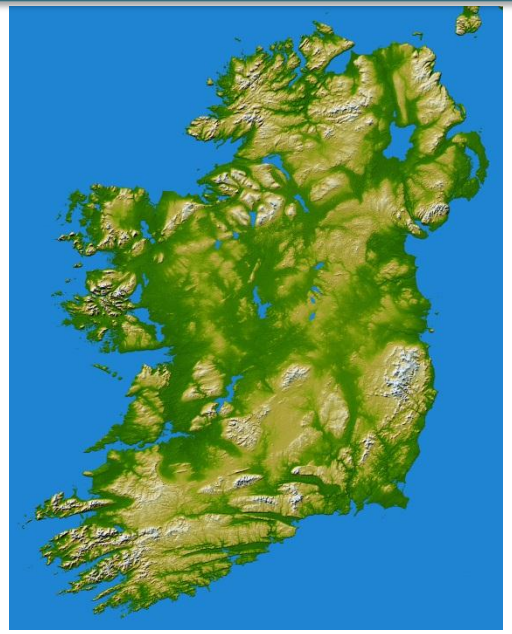
Conclusions

1. Runoff, soil permeability, stream density and catchment slope were most important hydromorphology metrics.
2. Hydromorphology metrics were secondary in importance compared to geomorphology for alkalinity, TP, and chlorophyll….
3. But, were more important for colour and CHL:TP.
4. Lake-specific features – water residence time, landscape position – not important.
5. Need to consider lake-specific features nested within landscape units.

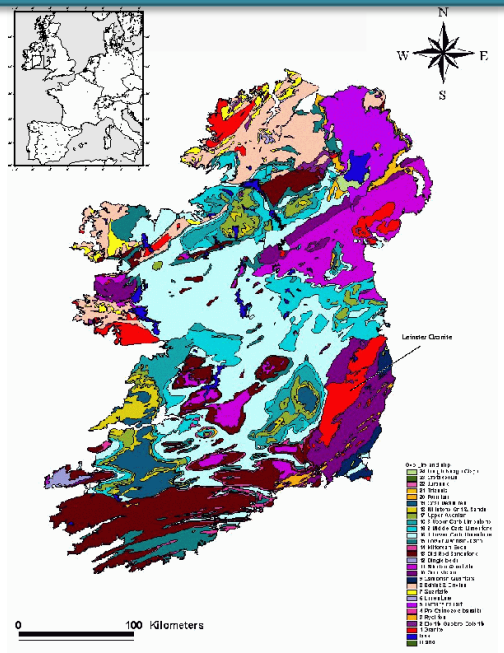
Photos by W. Trodd, EPA Ireland

Spatial Complexity of the Irish Landscape

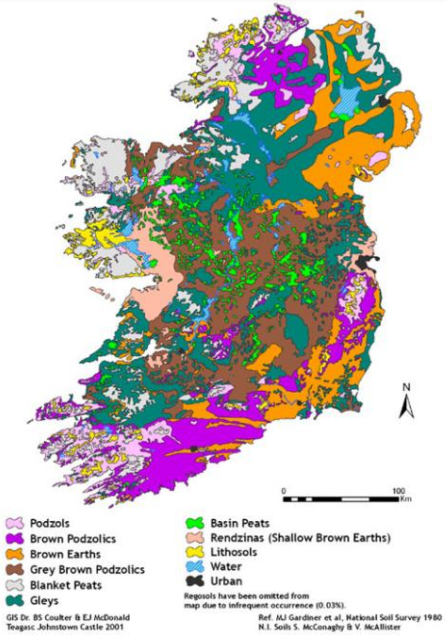
http://earthobservatory.nasa.gov/IOTD/view.php?id=5343



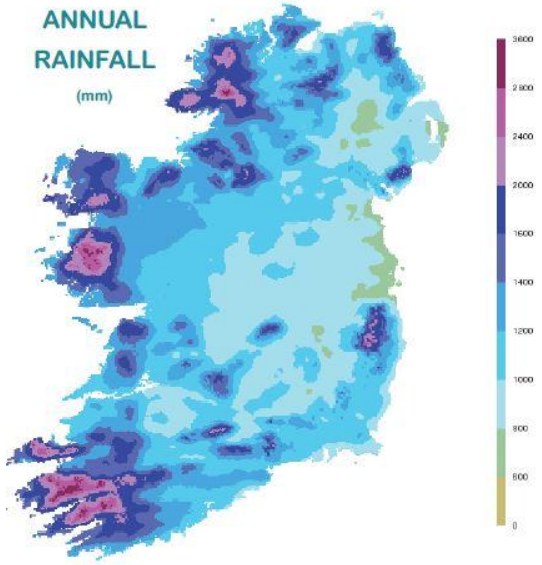
http://www.geophysics.dias.ie/projects/LEGS/AGU/index.shtml



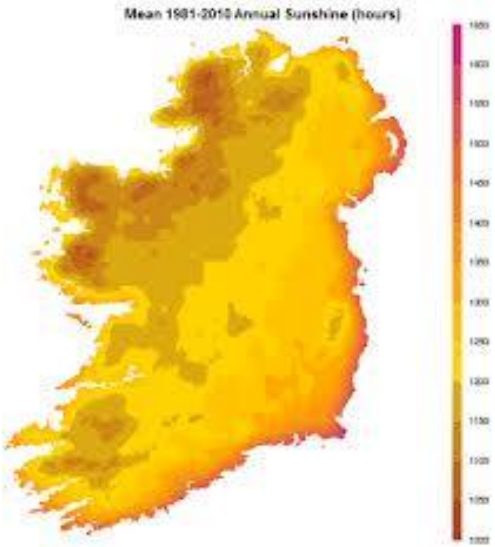
http://www.askaboutireland.ie/enfo/irelands-environment/biodiversity/definitions/soils-in-ireland/



http://www.met.ie/climate/rainfall.asp



http://www.met.ie/climate/sunshine.asp



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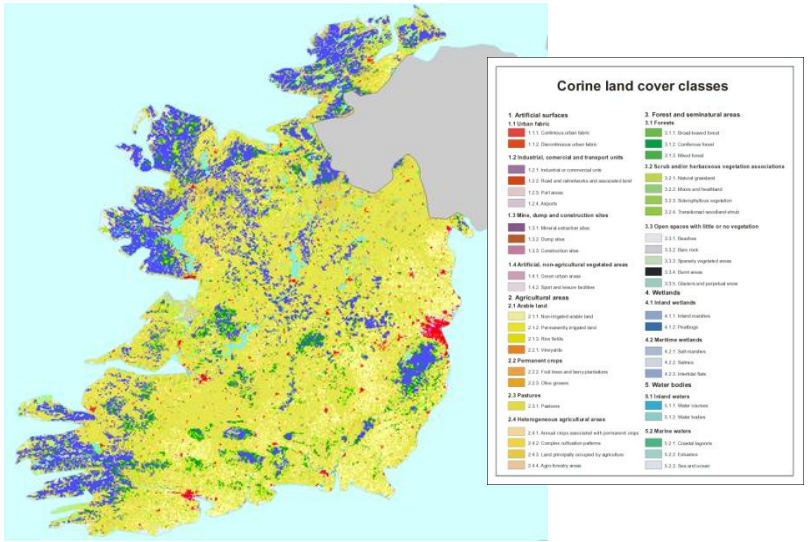
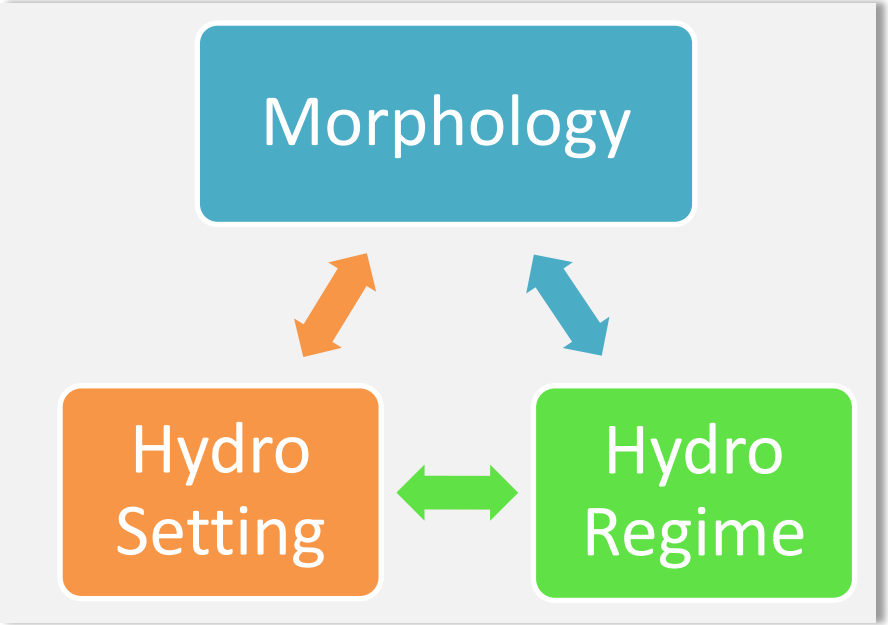
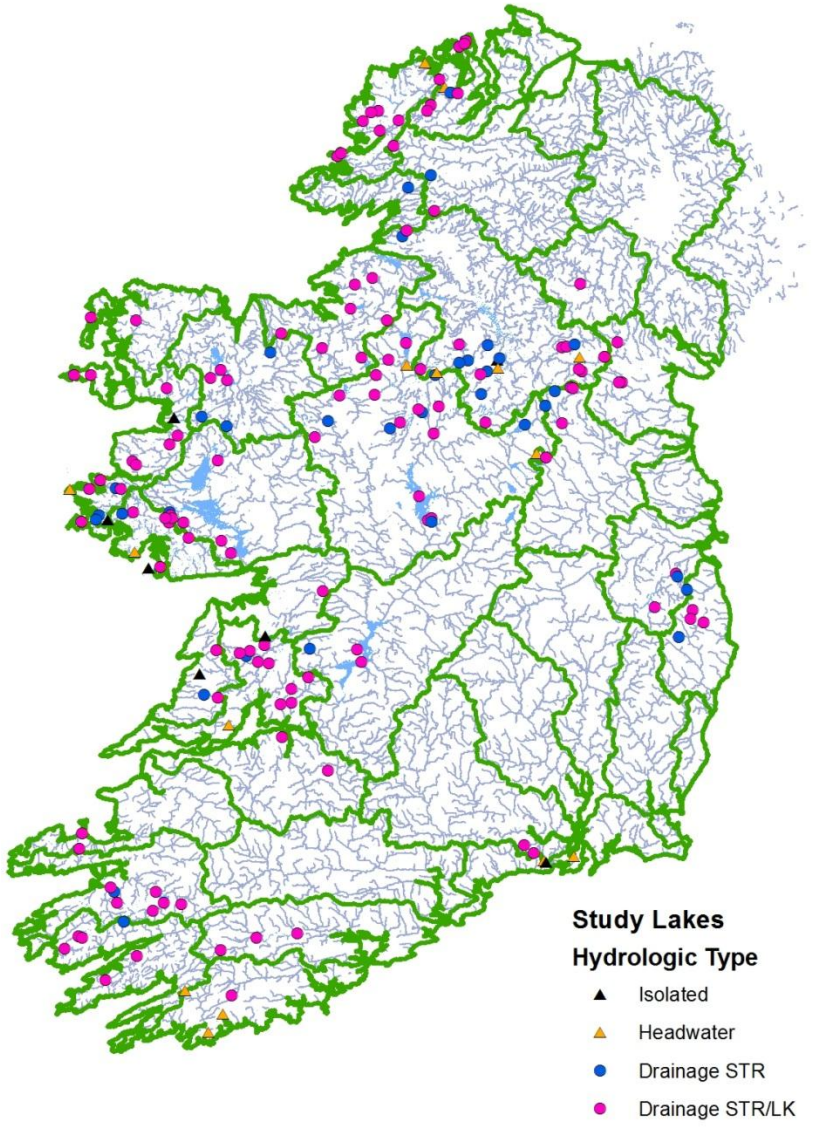


Hydromorphology relationships nested within landscape units?





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Hydrologic Regime

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Landscape Limnology / Lake Hydrologic Position

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