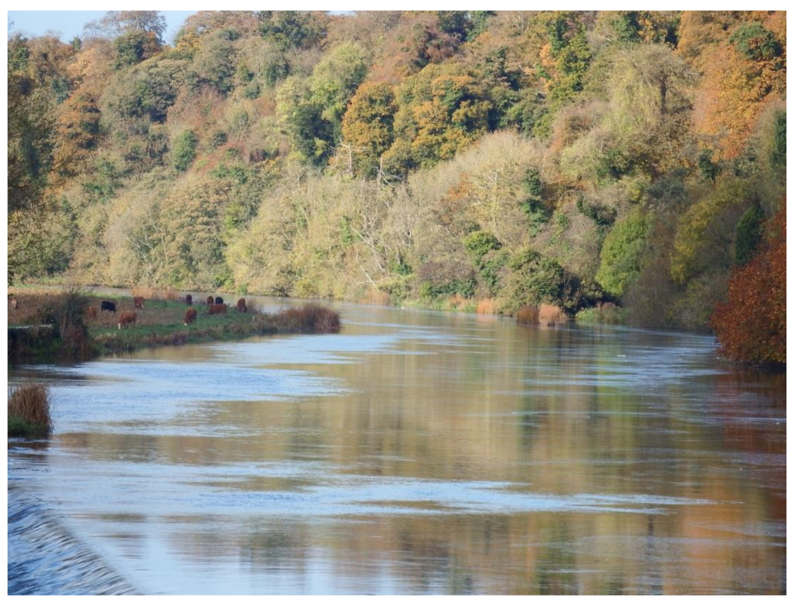
Identification of high risk catchments for public and private water supplies in relation to NOM across Ireland

C. O'Driscoll[1, 2], J. Sheahan[3], F. Pilla[1], B. Misstear[1], X. Zhan[2], L. Xiao[1]

[1]Department of Civil, Structural and Environmental Engineering, TCD, Dublin 2, Ireland
(Email: connieodriscoll@gmail.com; fpilla@tcd.ie; liwen.xiao@tcd.ie; bmisstear@tcd.ie)
[2]Department of Civil Engineering, NUIG, Galway, Ireland
(E-mail: xinmin.zhan@nuigalway.ie)
[3]School of Mathematics, Statistics and Applied Mathematics , NUI, Galway, Ireland
(E-mail: jerome.sheahan@nuigalway.ie)

Introduction

NOM is one of the main sources of environmental pollution to drinking water supplies in Ireland (1). The Irish EPA found that total trihalomethane concentrations (THMs) – where NOM is the precursor – exceeded 100 µg l^{-1}, the parametric value set by the Drinking Water Regulations (SI 278 of 2007) in 12.9 % of all public water supplies during 2010 (2). The majority of THMs failures were caused by either the absence of adequate treatment to remove organic matter or the presence of treatment that is incapable of removing high organic matter (2). Casey et al. (3) investigated the demand of chlorine and the formation of THMs in Irish water supplies and found a positive correlation between THMs and NOM. The potential risk of THMs formation in all surface waters in Ireland is considered as high, due to high NOM concentrations (4). The objectives of this study were to 1) identify high risk catchments for water supplies in relation to NOM across Ireland using GIS datasets; 2) identify the key catchment characteristics responsible using statistical approaches .



Methods

1. National datasets were obtained: Soils and subsoils were obtained from http://gis.epa.ie; average annual rainfall dataset from the most recent Long-Term Averages (LTA) available dataset for Ireland (5); slope (%) was calculated in ArcMap (6) using the DEM (7); groundwater vulnerability, based on combining 2 GIS layers of subsoil thickness and permeability, plus karst features where present was obtained from www.GSI.ie. Land use type was taken from CORINE 2012 data and grouped into peat, crop, heterogeneous agriculture, industrial, pasture forestry, upland percentage in the catchment above the abstraction point. National THM routine sampling results from 2006 - 2013 were obtained from the Irish EPA.

2. THM sampling results are taken from water zones/ schemes in accordance with the Drinking Water Regulations (2014). Water schemes differ in area, in the size of the population served and in the volume of water supplied. Small, rural schemes may serve 200 people whereas others may deliver to 50, 000 people. Schemes where abstraction information is not available were omitted. Repeated measurements from each zone were averaged between and within years. Schemes in which the boundary and source did not change over the study period were included (Figure 1).

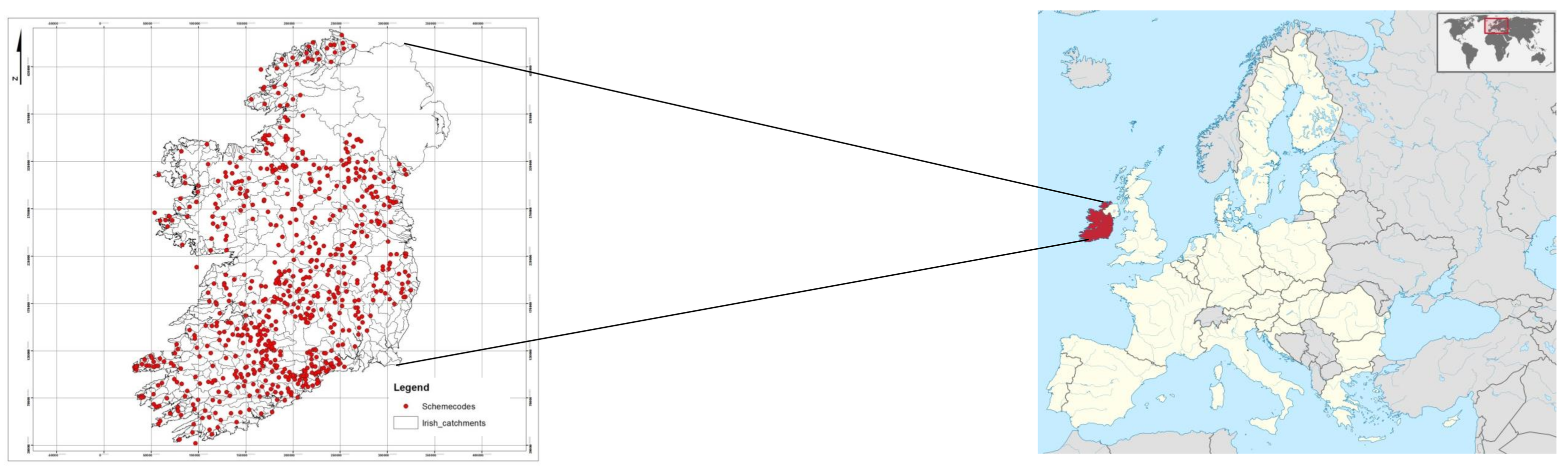


Figure 1. Geographical locations of abstraction points for each water scheme (Schemecode)

3. To define catchments deemed to be at high risk for NOM the following criteria were used: All soils and subsoils listed as peat were given a high risk category. Summary statistics were calculated to define the high and low rainfall volumes for the country using the first and third quartile. Based on this data <1000 was deemed low rainfall, 1000 – 1400 mm medium rainfall and >1400 was deemed high rainfall. Catchments with slope <5.25 were considered higher risk. Groundwater vulnerability was classified as extreme, high, medium, low and water.

4. To identify the key catchment characteristics responsible for causing higher THM values, we studied the effect of the following 7 variables (2 factors and 5 covariates) on THM:
   - Treatment code (Level 1 – absence of adequate treatment to remove organic matter; Level 2 - the presence of treatment that is incapable of removing high organic matter);
   - Vulnerability (Level 1 – surface water; Level 2 – high vulnerability/ karst; Level 3 – low vulnerability);
   - Peat,
   - Forest,
   - Upland,
   - Crops, and
   - Pastures percentage in the catchment above the abstraction point.

   Average THM was taken as the response variable and due to the fact that the same number of observations was not used at all schemes a weighted least squares analysis was employed. A General Linear Model was fitted to study the effect of the 7 explanatory variables on the response and possible interaction effects among these. Residual diagnostics were conducted to examine any violations of assumptions underlying the linear model, that are needed to justify the analysis. These assumptions include linearity of the model (relating THM to the input variables), normality of the response at each combination of values of the input variables, homogeneity of variances of these responses and independence of the responses. While normality is not crucial in the present study due to the reasonably large sample size available where other violations occurred transformations of the response were conducted in addition to the abovementioned weighting.

Results

The results from the GIS exercise highlight that high risk catchments are likely to be found along the west coast of Ireland (Figure 2a). When the THM results were overlaid on top of this high risk map the correspondence between the two variables was observed (Figure 2b).

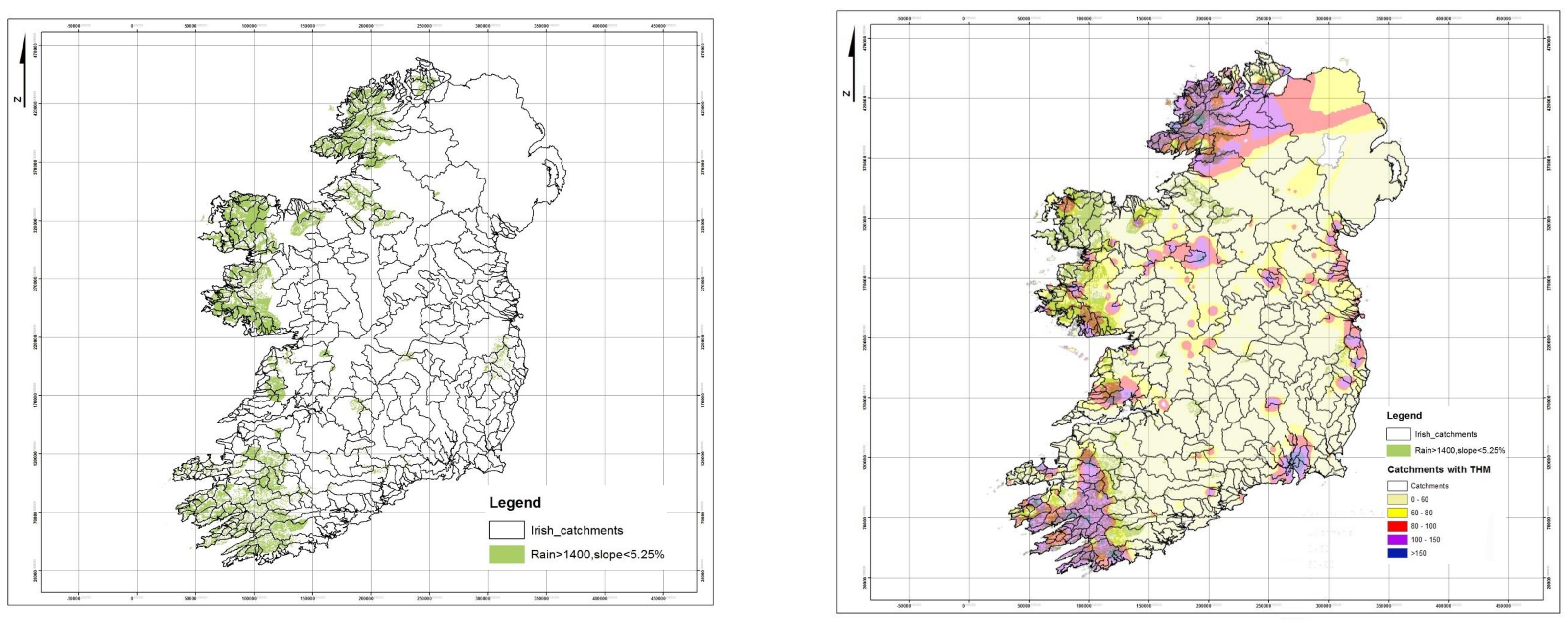


Figure 2. a) Annual average rain > 1400 mm in peat areas with slope < 5.25 %, and b) overlaid with THM results

Similarly when highly vulnerable catchments were extracted with peat, rain >1400 mm and a slope of < 5.25 % mostly areas along the west coast are highlighted (Figure 3a. When the THM results were overlaid on top of this high risk map a correspondence between the two variables was observed also.

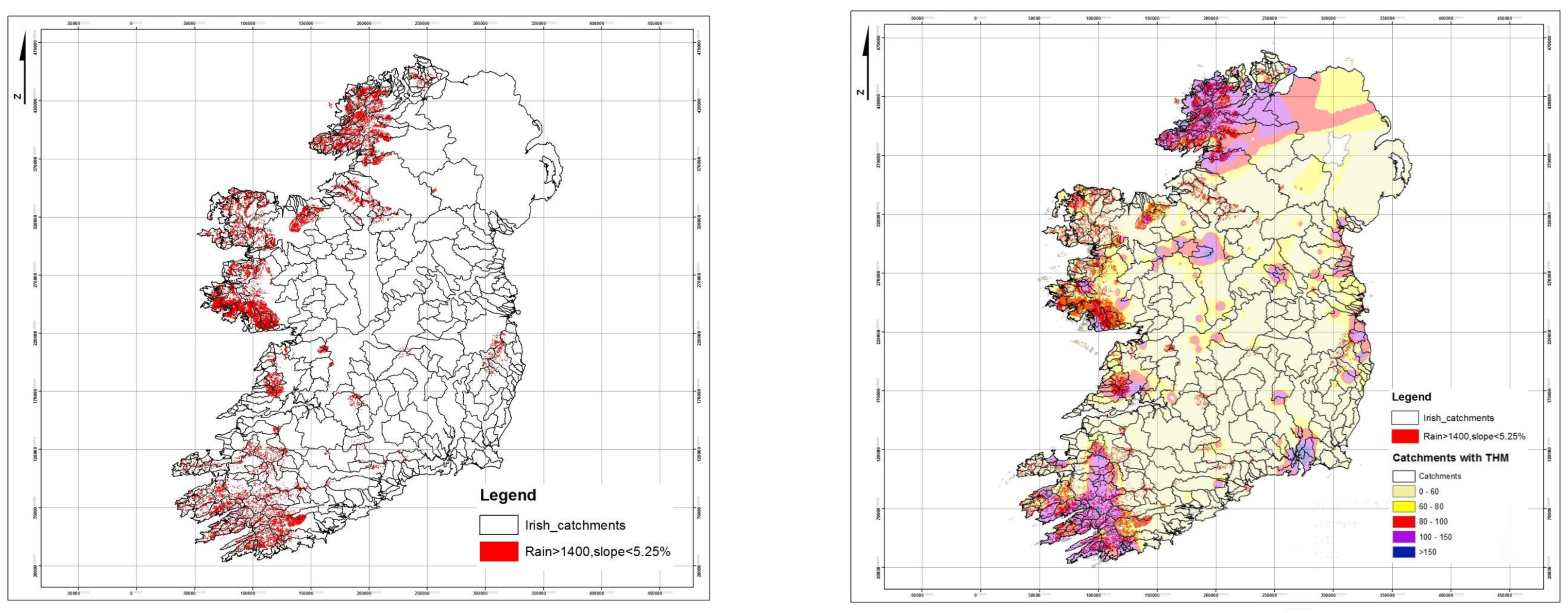


Figure 3. a) Peat areas classified as extreme and highly vulnerable with slope < 5.25 % and annual average rain >1400 mm, and b) overlaid with THM results

The type of treatment and the percentage of land use for pasture are the significant main effects. Percentage of peat in the catchment is significant at Level 1 of treatment type (absence of adequate treatment to remove organic matter). Percentage of peat in the catchment is also significant at Level 1 and 2 of vulnerability. Similarly percentage of pasture land in the catchment is significantly effected by the level of vulnerability with greater vulnerability at Level 1 and 2 . There is also a significant interaction between the percentage peat and pasture land in the catchment with greater THMs expected with increased peat and pasture.2

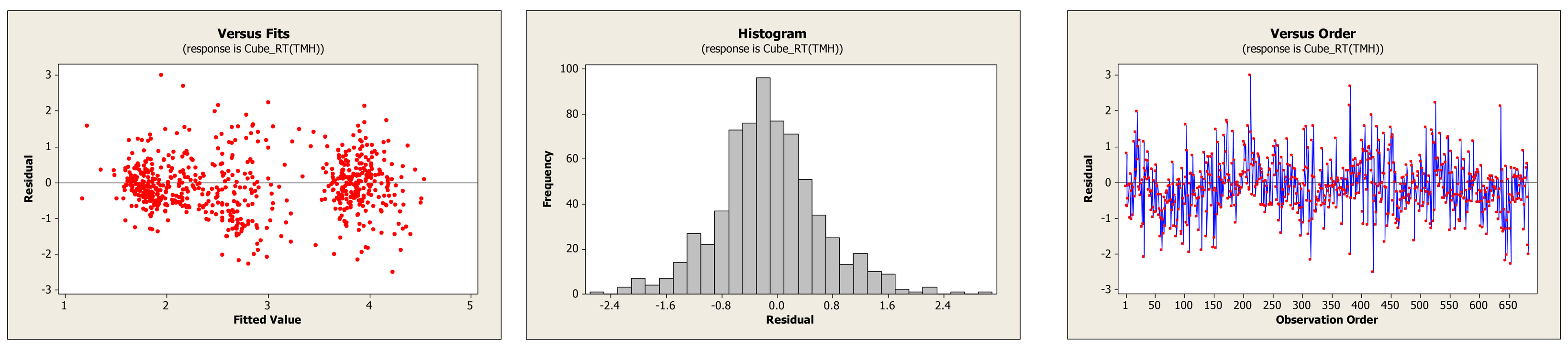


Figure 4. Residual plots for the fitted model illustrating a) homogeneity of variance, b) normality and c) independence.

Conclusions

This study investigated the effect of land use type on THMs at a national scale. The map based exercise demonstrated that THMs are generally greater in areas with higher peat. The statistical analysis elaborated that the for the majority of schemes where peat is causing high THMs there is an absence of adequate treatment to remove organic matter. The statistical analysis highlighted that pastures also increase the likelihood of greater THMS irrespective of treatment type. Furthermore, areas of vulnerability, i.e. Karst areas increase the likelihood of higher THMs in both peat and pasture areas.

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