Soil sampling in the Garren Catchment

A report prepared on behalf of Wye Salmon Association

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As part of a wider study of the catchment of the Garren Brook, Wye Salmon Association (WSA) identified a need for better understanding of the phosphorus loadings within the catchment soils. In the absence of any public domain data more recent than 2007, it was clear that a survey of current soil phosphorus levels was required. With able support from local volunteers from the Campaign for Protection of Rural England (CPRE), 22 soil samples have been collected from across the Garren Catchment and have been analysed by an agricultural laboratory. This report presents and reviews the resulting data.

Introduction

It is axiomatic that soil phosphorus concentration is a key driving parameter for several diffuse pollution pathways from agricultural land into rivers. When bulk soil erosion occurs from arable land during winter storm events, it is self-evident that the mobilised soil carries the prevailing phosphorus concentration. It is also well understood that soil leachate transported via groundwater pathways has a strong, non-linear relationship with soil phosphorus concentration (Heckrath et al., 1995; Smith et al., 1998). Recent work by RePhOKUs using soils from within the Wye Catchment reinforces this point (Withers et al., 2022). Therefore, we cannot possibly understand the agricultural contribution to river phosphorus levels without first understanding soil phosphorus concentrations within the catchment.

The Garren Catchment

The Garren Brook is relatively small, with a mean annual flowrate of 1 m^3/s. It drains approximately 90 km^2 of Herefordshire farmland, flowing approximately southeast to join the River Wye just downstream of Goodrich. Agricultural activity within the catchment is approximately evenly split between livestock pasture and arable/vegetable crops. A map of the catchment is shown in figure 1.

There are no large settlements within the catchment and consequently no significant sewage treatment works or combined sewer overflows outputting into the river system. It is therefore to be expected that river phosphorus concentrations are dominated by diffuse pollution from agriculture and septic tanks – in that order.

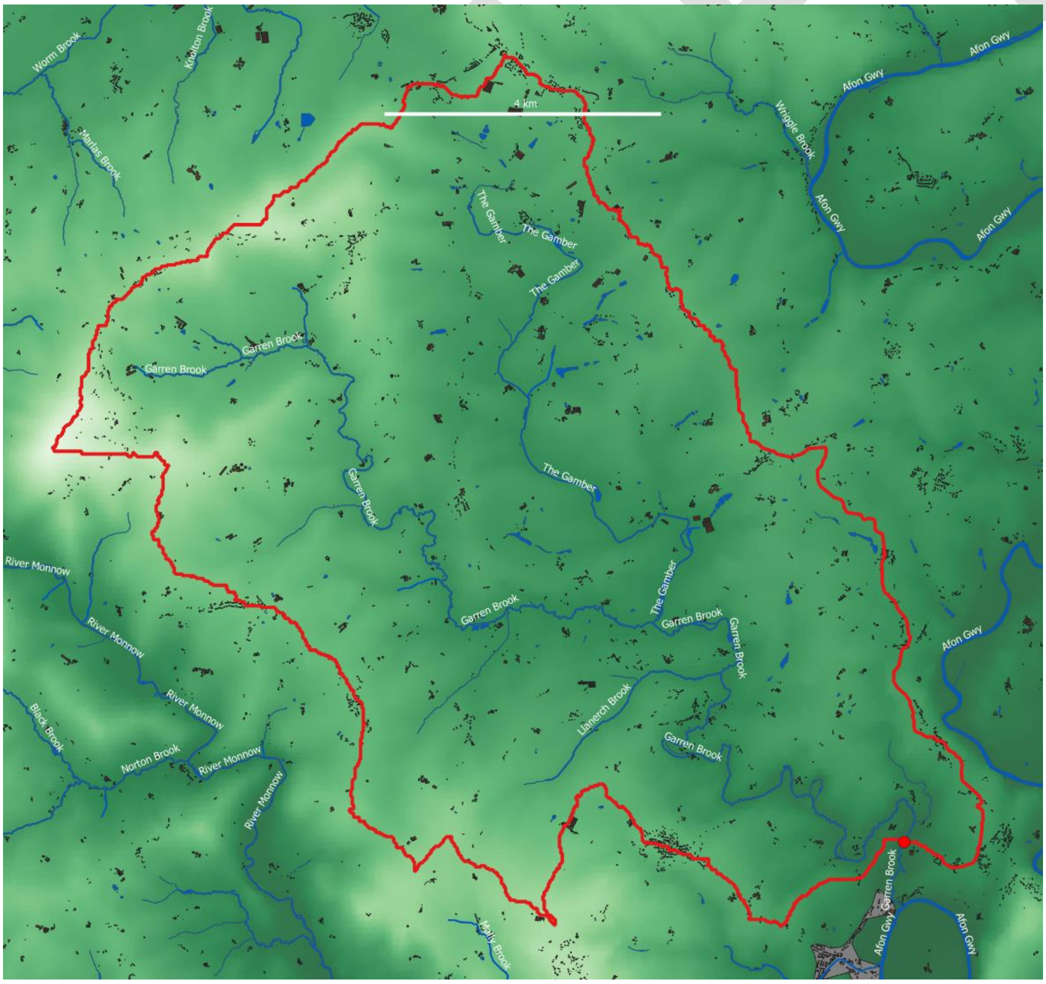

Figure 1: topography of the Garren catchment; the red outline is the catchment above the Environment Agency (EA) gauging station at Marstow Mill (red circle, bottom right).

Phosphorus in soil

Due to its chemical reactivity, the behaviour of phosphorus in soils is unlike other nutrients. A substantial fraction of applied phosphorus (whether mineral phosphate or applied within organic materials) binds to soil particles and becomes unavailable to plants. The fraction of applied phosphorus remaining plant available and, importantly, readily leachable is a function of the type of soil. For a given soil, the proportion of plant available phosphorus is assumed to be relatively constant. Thus, the plant available fraction can be used as a proxy for total phosphorus if the soil characteristics are known. The soils of the Wye catchment are known to have particularly high phosphorus availability (Withers et al., 2022).

The most common method used within the UK for determining soil phosphorus concentration is the Olsen-P test. This uses a relatively weak desorption chemistry, and the result is generally thought to approximate to plant available phosphorus. Olsen-P is widely used in UK agriculture and forms the basis of the best practice guidance on soil phosphorus management (ADHB, 2022). Table 1 below shows the soil index classifications for phosphorus.

Index	*Olsen-P (mg/l)*
0	0-9
1	10-15
2	16-25
3	26-45
4	46-70
5	71-100
6	101-140
7	141-200
8	201-280
9	> 280

Table 1: soil indices for phosphorus. Index 2 is the target for grass, forage crops and arable crops; some vegetable crops require index 3.

Existing data

The *UK Centre for Ecology and Hydrology* (CEH) provide UK-wide soil data based on the Countryside Surveys conducted in 1978, 1998 and 2007. The spatial resolution of the data is limited, but it provides a datum of sorts. The data has been downloaded as digital mapping (GIS) data and analysed in QGIS software[1]. By sampling the data at points within the Garren Catchment, mean values for soil phosphorus have been derived as follows.

Land use	*Olsen-P (mg/l)*
Improved grassland	31
Arable & horticulture	54

Table 2: mean values of Olsen-P within the Garren Catchment in 2007, derived from CEH data.

Both principal types of land use are found to be above ADHB target index. Grassland is mid index 3 and arable land is mid index 4. The excess phosphorus (above target index) provides no economic benefit to the farmer but nevertheless does increase leaching and run-off to the rivers (Withers et al., 2022).

Methodology

The spatial resolution of the sampling performed within this project was determined by cost and practicality. A 2km grid was placed over the Garren catchment, yielding 23 sampling locations. Each of these locations was then adjusted to (a) avoid buildings, etc. and (b) align to public access routes. The result is shown in figure 2 below. Note that these locations were determined without reference to land use or other agricultural factors.

[1] https://www.qgis.org/

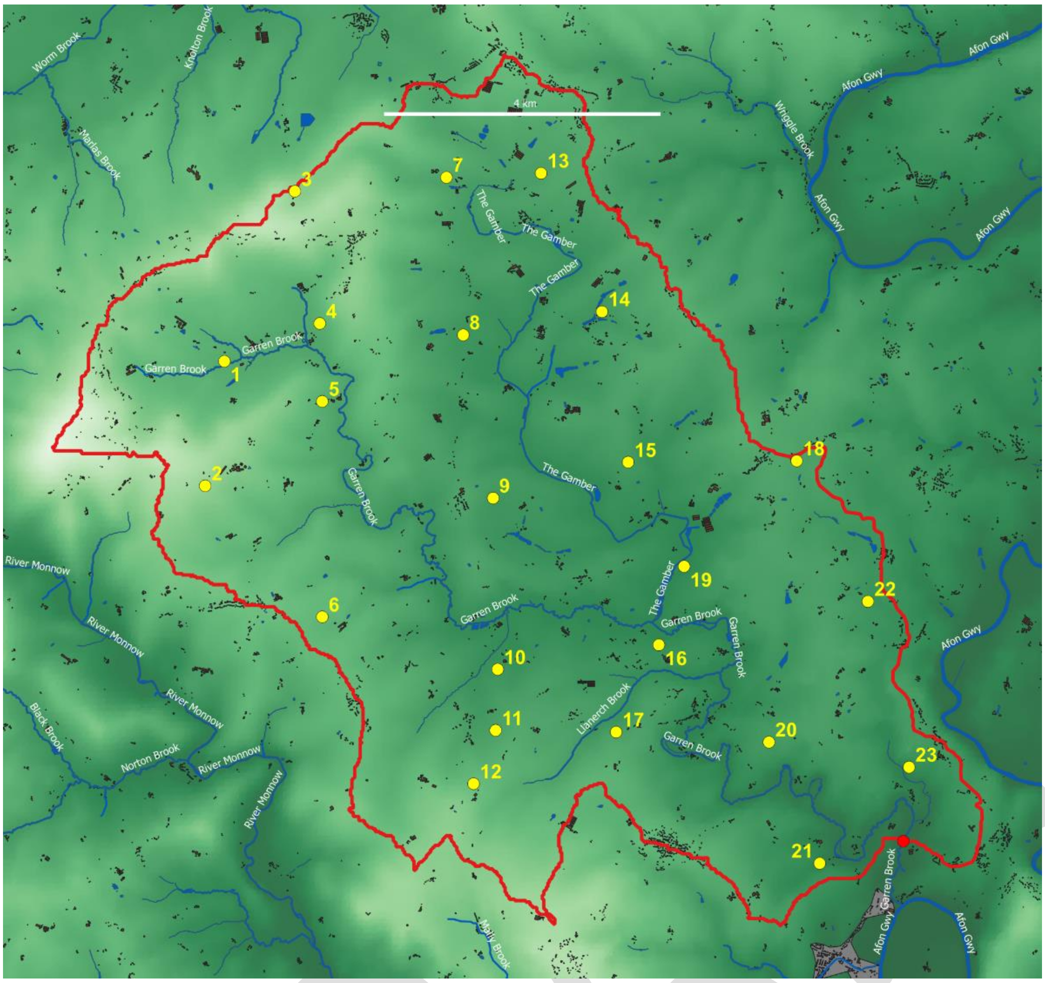

Figure 2: soil sampling locations

Soil samples were collected in mid-June, using a standard 25mm diameter sampling tool, to a depth conforming to ADHB guidance (75mm for grassland; 150mm for tillage). Multiple, spatially separated samples were taken at each location, in order to accumulate approximately 250g of material (typically 10 for grassland and 5 for arable). Whilst this procedure did not sample across the entirety of a field, it was sufficient to provide a good sample of one slice of a field and thus mitigated the risk of hitting a hotspot. The land use and crop was also recorded for each sample location.

Results & discussion

22 of the 23 samples were successfully collected. These were thoroughly mixed before shipping to the laboratory[2]. Results are shown in table 3 below.

Location	Land use / crop	Olsen-P (mg/l)
1	Grassland	14
2	Grassland	167
4	Grassland	33
5	Grassland	29
6	Grassland	42
7	Orchard / apples	15
8	Grassland	13
9	Grassland	107
10	Grassland	26
11	Arable / maize	157
12	Arable / oil seed rape	20

Location	Land use / crop	Olsen-P (mg/l)
13	Grassland	82
14	Grassland	37
15	Arable / oats	43
16	Arable / wheat	63
17	Arable / wheat	37
18	Arable / oil seed rape	64
19	Arable / oil seed rape	26
20	Arable / wheat	41
21	Grassland	11
22	Arable / oil seed rape	32
23	Grassland	11

Table 3: Olsen-P results

[2] Hill Court Farm Research Ltd.

Mean values for the two principal land uses are shown in table 4 below. It is also useful to look at the histograms for soil index, shown in figures 3 & 4.

Land use	Olsen-P (mg/l)	Change from 2007
Grassland	48	+17
Arable	54	0

Table 4: mean Olsen-P values compared to 2007 values (table 2)

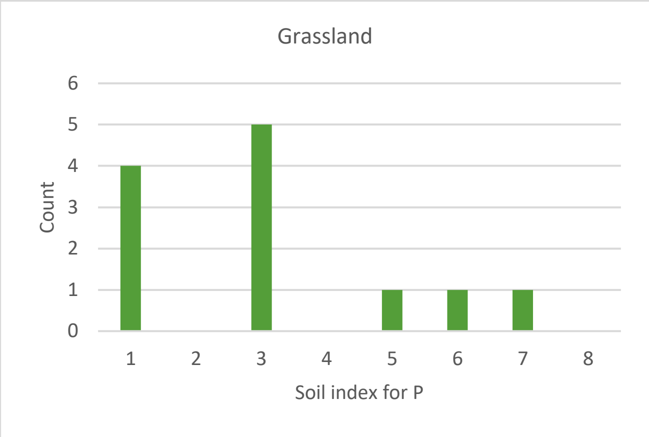

Figure 3: histogram of soil index on grassland (12 locations)

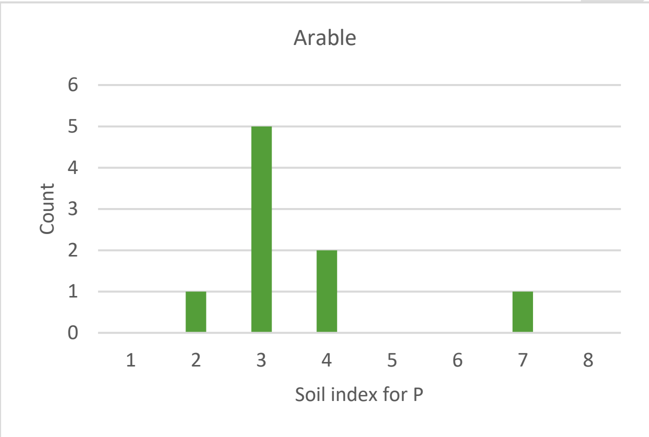

Figure 4: histogram of soil index on arable land (9 locations)

On grassland, we find a divergence. A significant number of farms (8/12) are operating above index 2, the target index for pasture. Of these, 5/12 are at index 3 – similar to the 2007 level for grassland. On the other hand, a significant minority (4/12) are operating – presumably successfully – at index 1. This suggests a divergence in feeding approach. The overall mean value shows a very significant increase since 2007. However, the mean is being influenced by the three samples spanning indices 5-7. Excluding these samples would reduce the grassland mean to index 2.

On arable land we find a broad distribution centred on index 3. However, all of the crops listed for the arable samples should be targeting index 2. The mean value is the same as the 2007 value, suggesting a consistency of approach on arable land. Again, there is an anomalous sample from a field of maize at index 7. There is no agronomic justification for this.

Thus, we have 4/22 samples (locations 2, 9, 11 & 13) with excessively high Olsen-P results. It is informative to view their location on the map. This is shown in figure 5 overleaf. Also indicated are the locations of known intensive poultry units (IPUs) within the catchment. The two sample locations labelled index 5 and index 7 (circled) are in obvious close proximity to IPUs. The other two are within a ten-minute tractor journey of one.

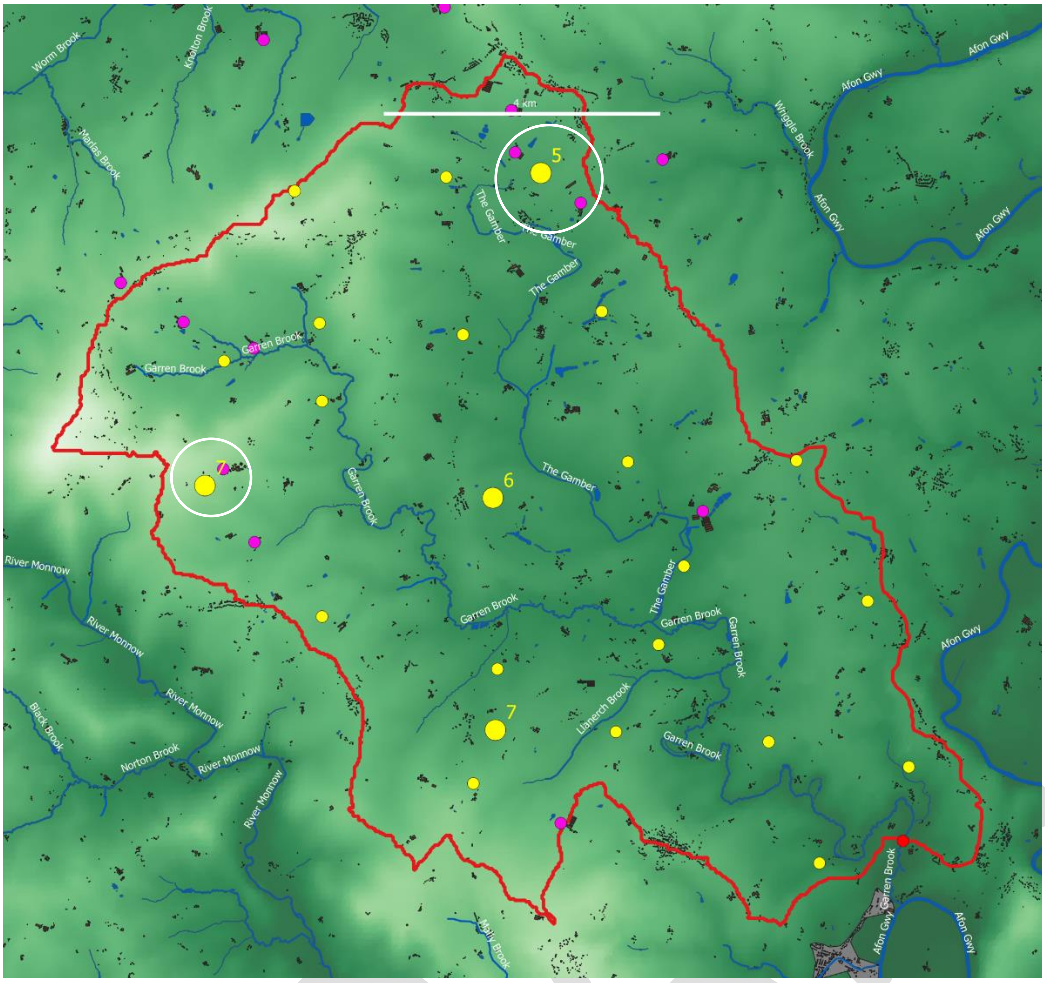

Figure 5: geographical location of samples with elevated soil index for P (larger yellow circles with number indicating soil index); locations of known IPUs are shown as magenta circles.

What we are undoubtedly seeing is the result of the poultry industry's practice of "spreading as a means of disposal", rather than in line with crop needs. By examining planning applications on the Herefordshire CC planning portal, it is found that, of the nine IPUs falling within the catchment, one spreads poultry manure on site (one of our four elevated samples), one spreads on a neighbour's land (another of our four elevated samples) and a third spreads on site after anaerobic digestion. Of the remaining IPUs, four are exporting manure to other local farms and two cannot be determined due to absence of planning documentation. Thus, it seems highly likely that all four of the elevated soil index samples are associated with poultry manure disposal.

Conclusion

- Consistent with the findings of recent national and Wye Catchment studies *(Rothwell et al., 2022; Withers et al., 2022),* we find the major phosphorus challenge within the Garren Catchment to be associated with grassland.
- Mean Olsen-P values for grassland appear to have increased from 31 mg/l (index 3) in 2007, to 48 mg/l (index 4) in 2022. This represents an increase of approximately 1 mg/l per year and is significantly above best practice guidance for grassland (16-25 mg/l).
- A major driving force behind the increase in Olsen-P on grassland appears to be the disposal of poultry manure. This is indicated by a significant subset of the locations sampled having highly elevated Olsen-P; levels which have no agronomic justification. It should be understood that these locations will continue to increase for as long as poultry manure disposal continues. This is not a system in equilibrium.

- A significant minority of grassland samples were found to be at index 1. This begs the question as to whether this would be a workable target for the area more widely.
- Mean Olsen-P for arable land appears to be relatively stable at 54 mg/l. However, this remains significantly above the best practice guidance (16-25 mg/l) applicable to all of the arable crops sampled.
- One of the arable locations also appears to be associated with poultry manure disposal.

This work demonstrates, more generally, the utility of soil measurement as a tool for understanding phosphorus flows within a catchment. Whilst the ultimate aim is to reduce river phosphorus concentrations, riverine reactive phosphorus measurements suffer from a number of disadvantages: natural temporal & spatial variability, variable relationship to total phosphorus, temporal lag with respect to changes in land management, etc. It is well established that soil phosphorus concentration is a key driving factor for diffuse agricultural pollution pathways to the river. Therefore, soil phosphorus measurement can provide a more complete picture of agricultural phosphorus flow than relying solely on riverine data.

References

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Acknowledgements

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Catchment maps make use of OS data © crown copyright 2022, OS Open Zoomstack | OS Products (ordnancesurvey.co.uk).