Initial Findings of Flooding Survey

As you know, we have been visiting your farm for the last 9 months to investigate the effects of last winter’s flooding. In particular, we are interested in how the soils have been recovering and the subsequent impacts on productivity. The field work carried out on your land has been combined with more detailed laboratory studies designed to understand exactly what goes on with soil chemistry and biology while the soil is being flooded, and immediately after the flood water recedes. As we have now finished the monthly monitoring on your farm, we have written this initial summary of our findings for your interest. There will be a more comprehensive report to follow in which we will conduct a more detailed analysis. However, as we are still collecting data from the laboratory studies and still conducting a field experiment on the best way to alleviate flood damage, the next report could be several months down the line.

What we’ve been doing

Back in April and May, just after the last of the flood water had receded, we located a total of 15 fields (study sites) that had been severely affected by the winter floods. These sites were spread across Somerset, Worcestershire, Herefordshire and North Wales. After an initial survey, we selected five of these sites to study in more detail every month; these sites were selected for having a clear physical separation between ‘Flooded’ and ‘Control’ (not flooded) areas.

Survey timeline:

April – May (weeks 1-5): Initial survey of sites and selection of sites for regular sampling.
A total of 15 sites were sampled across Somerset, Worcestershire, Herefordshire and North Wales. Many areas of the sites were still under water in April but all had dried up by the end of May (week 5) when regular sampling started. Soil density, above ground biomass, soil pH, soil salinity, and soil nutrients (phosphorus, ammonium, nitrate) were measured at each site. Microbial community structure, soil nitrogen and soil carbon will also be measured.

Five of the 15 sites were selected for regular sampling:
- **Site 3 (Worcestershire)** – An arable field which was fertilised and re-seeded with mustard after the flooding.
- **Site 4 (Worcestershire)** – An arable field which was fertilised and re-seeded barley after the flooding.
- **Site 7 (Somerset)** – A grassland which had no intervention since the flooding.
- **Site 14 (Somerset)** – An arable field which was re-seeded with wheat. This site had a distinct strand line left by the floods (see picture opposite).
• **Site 15 (Somerset)** – A grassland field which had been mown, also with a distinct strand line left by the floods.

**June – July (weeks 9 & 14): Regular sampling continues.**

• **Sites 3 and 4** – Crops continued to grow as normal, but there were clear differences in yield between flooded and control areas.

• **Site 7** – Grass continued to grow naturally with minimal intervention. The diverse sward consisted of naturally flood-resistant species.

• **Site 14** – Both the prominent strand line and the flooded area were dominated by weeds, but the wheat in the control area was doing well.

• **Site 15** – A herd of approximately 20 cattle were introduced to the field and the strand line had all but disappeared.

**August – October (weeks 19 & 24): Agricultural fields are harvested and re-seeded.**

• **Sites 3 and 4** – Both fields were harvested in August and were re-seeded with wheat at the end of September.

• **Site 7** – The grass was cut for silage in mid-September.

• **Site 14** – The wheat was harvested in August and the field was not re-seeded. The ditches around the field were re-cut in August and the weeds were cleared from the edges.

• **Site 15** – The cattle remained on the field and, as with site 14, the ditches around the field were re-cut in August and the weeds were cleared from the edges.

**November – December 2014 (weeks 29 & 34): Sampling finishes and initial sites are re-sampled.**
The wheat on sites 3 and 4 continued to grow well, although there were still some differences between flooded and control areas. Sites 7 and 14 remained much the same, with some of the grass and wheat growing back. The cattle were removed from site 15, and all evidence of the strand line had disappeared. As well as re-visiting the five main sites, we went back to the rest of the 15 sites sampled in the initial sample.

**Equipment and Methods**

At each site, we had 2 areas (‘Flooded’ and ‘Control’) and within each area, we had 3 plots. We measured the following in each plot:

**Aboveground biomass** was measured to compare the yield of flooded and control plots. We clipped a 20 x 20 cm (approximately 8 x 8 inch) area in each plot. The vegetation was then dried and weighed.

**Worm numbers** were monitored to assess the recovery of the worm population. We dug a 20 x 20 x 20 cm (approximately 8 x 8 x 8 inch) hole and sifted through the soil to count the worms. The hole was dug between crops (where necessary),
all the soil was put back into the hole (with the worms), and any turf was placed back on top.

**Soil bulk density** is a way of measuring the density, or compaction, of the soil. We used a metal ring of known volume to take a sample of soil (see picture opposite). We then weighed how much soil was in this known volume – the less soil there was in the ring, the less compact, or dense, the soil was.

**Soil samples** were taken alongside the bulk density samples (approximately 100 grams). We then used this soil to measure pH, salinity, and nutrient content (nitrate, ammonium and phosphate) back in the laboratory.

**Infiltration rate** was measured to gauge how fast water could drain through the soil. This is affected by soil compaction and moisture. It was measured using specialised tubes full of water placed on the soil (see picture opposite). The amount of water that seeped into the soil was measured every 5 minutes for 30 minutes and an average ‘infiltration rate’ was calculated.

**Soil respiration** was measured as an indication of microbial activity in the soil. Microbial activity is a good indicator of soil conditions, but can also be affected by temperature and soil moisture – therefore there can be big seasonal changes in soil respiration. We used an infra-red gas analyser to measure the average amount of CO₂ released from the soil per hour.

**Water samples** were taken in addition to the measurements taken at each plot. We also took a sample of water from the ditches adjacent to the fields to see how the flood water differed from the water normally draining off the fields. As with the soil samples, these water samples were analysed for pH, salinity and nutrients.
The measurements at each plot:

- Above ground biomass
- Worm count
- Bulk density
- Soil nutrients, pH, salinity
- Infiltration rate
- Soil respiration

Measurements:
- 400 cm²
- 8000 cm³
What we’ve found so far

Overall Results
Below are the combined results from all five of the sites. There is a more detailed look at your farm after this section.

Aboveground biomass
Plant yields were significantly lower in flooded areas during May, June and July (weeks 5-14), but this may have been due to the difficulty of sowing crops in the muddy flooded areas. The two grasslands we sampled showed similar yields in both flooded and control areas during this period. Once crops were harvested in August (week 19) and the fields were re-seeded, the yield of flooded and control areas were similar.

![Vegetation Biomass Over Time](image1)

Worm numbers
Worm numbers have steadily been increasing since the flooding. The dip in worm numbers in June (week 9) is possibly due to the warm, dry weather – we sampled to a depth of only 25 centimetres, and the worms were likely deeper than this in the wetter soil. Throughout the sampling period, there were generally fewer worms in the flooded areas than in the control areas, although this difference has been decreasing.

![Worm Numbers Over Time](image2)
**Bulk Density and Infiltration Rates**

Soil bulk density and water infiltration rates did not differ between flooded and control areas. This was perhaps due to the fact the control areas were subject to soil compaction by heavy machinery. As such, any soil compaction caused by the flooding in the flooded areas would be hard to differentiate from soil compaction by machinery in the control areas. The downward trend of the infiltration rate over time is likely due to the weather conditions – the wetter the soil, the lower the infiltration rate.

**Soil Salinity**

Soil salinity was lower in the control areas than in the flooded areas, although this difference lessened in September when many of the fields were re-seeded. The higher salinity in the flooded areas was most likely due to salt deposits left by the flood water and the lack of nutrient uptake by the slower growing or absent vegetation.
Soil pH didn't differ greatly between flooded and control areas, but it was slightly lower in the flooded areas. There were fluctuations in soil pH in April to June (weeks 1-9), which were likely due to the soil drying out, the addition of several fertilisers, and the sowing of crops after the flood water receded.

Soil Respiration
Soil respiration is measured by quantifying the amount of carbon dioxide (CO₂) released from the soil. This carbon dioxide is given off both by the microbial community and by the plants themselves, so it is merely an indication of total biological activity rather than a direct measurement of just soil microorganisms. The microbial activity in the soil is impacted by both moisture and temperature. Generally, the higher the soil moisture and soil temperature, the more microbial activity there is, and more CO₂ is released. Microbial activity tends to decrease later in the year due to the lower temperatures, as seen in the results below. There were peaks in soil respiration in June (week 9) and August (week 19) where soil moisture is not too low and temperatures were still high. The dip in July is likely to have been due to very low soil moisture levels. Generally, microbial activity in flooded and control areas were similar, except in May and June where microbial communities may still have been recovering from the flooding.
Soil Nutrients

Soil nutrients didn’t tend to differ between flooded and control areas, but they did change over time. Large spikes in ammonium, nitrate and phosphate are evident around the time the fields were fertilised and re-seeded (May and September – weeks 5 and 24).
Initial Findings of the Flooding Survey – February 2015

Soil Phosphate Over Time

- Flooded
- Control

Week Number

PO₄ [P] in soil (µg g⁻¹)

Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec

0 5 10 15 20 25 30 35 40 45 50 55 60
Your Farm (Farm 1 - Worcestershire)

Below is a more detailed look at the data from your farm. This data has been used to make up the overall data discussed above, but has not been sent to anyone else in this more detailed form.

The sites:
The two fields we sampled at your farm were labelled ‘Site 3’ and ‘Site 4’ (see the map below). We also sampled ‘Site 1’ and ‘Site 2’ at the start and end of the study (May and December). Although all of the sites had ‘Flooded’ and ‘Control’ areas, Site 3 also had a ‘Medium’ area. This medium area had been flooded but had not been under water for as long as the flooded area. We had 3 plots in each of the areas.

The results:
Vegetation biomass was lower in the flooded area at Site 4 from May to July (barley), and even after the field was re-seeded in September it seems as though the yield was still higher in the control area than in the flooded area. Site 3 is a little more complex – although the flooded area showed the lowest yield, and the yield of the control area was higher than the other two areas in June and December (as expected), the yield of the medium area was higher in July than in both flooded and control areas. When looking at photos of the vegetation in July, it is evident that the vegetation type was very different in the different areas; there was a lot of smaller dried, vegetation in the control area whereas in the medium area there was a lot of taller, succulent vegetation.
**Worm numbers** remained relatively low across both sites and all areas until December when numbers in control and medium areas of site 3, and both control and flooded areas of site 4, showed an increase in worm numbers. The low numbers were likely due to a combination of soil type and low moisture levels; the soil was quite loose and sandy compared to that of a grassland (where worm numbers are usually high). This in turn led to it being well drained and quite dry during the summer. Worms may have been more abundant lower down than our sampling depth.
Soil bulk density showed a similar pattern to that in the overall data set. Soil bulk density didn’t differ between flooded, medium and control areas on site 3. The flooded area on site 4 was more compact than the control area, however this difference was small.

Infiltration rates were generally lowest in the flooded areas suggesting they were more saturated with water or had smaller pore spaces in the soil.

Soil pH and salinity did not differ greatly between areas on either site, although soil salinity was slightly higher in the flooded area on site 4 during June and July (the warmest months). Soil pH changed very little over the course of the sampling period, but soil salinity showed large peaks in May and September, perhaps due to the addition of fertilisers.

Soil respiration did not differ much between areas on either site and there were few seasonal fluctuations throughout the sampling period. The only exceptions to this was a large spike in CO₂ levels in August on site 3, most likely caused by the harvesting of the crop, and high CO₂ levels in May on site 4, perhaps caused by re-seeding.
Soil nutrients did not generally differ between areas, although on site 4, soil nitrates were higher in the flooded area during May and June. This could have been due to the lack of vegetation in the flooded area; less soil nitrogen was taken up by plants so soil nitrate levels were high. The seasonal fluctuations in soil nutrients reflected fertilisation and re-seeding patterns.
Your Farm (Farm 2 – Somerset)

Below is a more detailed look at the data from your farm. This data has been used to make up the overall data discussed above, but has not been sent to anyone else in this more detailed form.

The site:
The field we sampled monthly at your farm was labelled ‘Site 7’ (see the map below). The site had both ‘Flooded’ and ‘Control’ areas and we had 3 plots in each of the areas.

The results:

**Vegetation biomass**

Vegetation yield showed a predictable seasonal pattern with the highest biomass in August before it was cut. However, contrary to most of the other sites we sampled, vegetation biomass was generally higher in the flooded area than in the control area. This is down to the vegetation community composition in both areas; the species found in the flooded area were generally larger than those found in the control area. The flood resistant species that have developed here seem to thrive well after an extreme flooding event.
**Worm numbers**

Apart from a dip in June when the weather was warmest, worm numbers were generally quite high on this site. However, it seems that, despite a high vegetation yield, worm numbers were significantly affected by the flooding; there were more worms in the control area than in the flooded area until November. It wasn’t until after the field was cut that the worm numbers started to increase again in the flooded area.

![Worm Numbers - Site 7](image)

**Soil bulk density**

As with the overall data set, there was little difference in soil bulk density between the flooded and control areas, although bulk density in the flooded area was consistently slightly lower than in the control area. This may have been down to a difference in the root structures of the two different vegetation communities – the sward in the control area may have a denser or more developed root structure holding the soil together.

![Bulk Density - Site 7](image)

**Infiltration rates**

Infiltration rates did not differ between flooded and control areas. This is likely because the vegetation sward was well developed in each area. As such, the soil was kept reasonably well aerated by the root systems. There was a peak in infiltration rates in July due to the warm, dry weather; infiltration rates were lower again in August after a large amount of rain.

![Infiltration Rate - Site 7](image)
**Soil pH and salinity**

Soil pH did not differ between flooded and control areas, nor did it fluctuate much over the sampling period. Soil salinity did differ significantly between flooded and control areas. Initially, soil salinity was greater in the flooded area as salt was deposited by the flood water, but these salt levels reduced quickly after a couple of months as the plant community recovered. In contrast, soil salinity gradually increased in the control area. As the control area was also underwater for a short amount of time, it is likely some salt was also deposited here too. However, the plant community in this area is perhaps less resistant to flooding and could not process the salt in the soil as the plants in the flooded area did.

**Soil respiration**

Soil respiration generally didn’t differ between flooded and control areas and showed seasonal changes with high soil respiration levels in the summer gradually reducing to lower respiration rates in the winter. There was, however, a large dip in soil respiration in the control area in July. This may have been because the soil in the control area was too warm or too dry for high levels of microbial activity.

**Soil nutrients**

As with the overall data set, soil nutrient levels did not differ between flooded and control areas, and seasonal fluctuation reflected farming practices such as the addition of fertilisers and cutting.
Initial Findings of the Flooding Survey – February 2015

Soil Ammonium - Site 7

Soil Nitrate - Site 7

NH$_4$ (N) in soil (µg g$^{-1}$)

NO$_3$ (N) in soil (µg g$^{-1}$)

Week Number
Your Farm (Farm 3 – Somerset)

Below is a more detailed look at the data from your farm. This data has been used to make up the overall data discussed above, but has not been sent to anyone else in this more detailed form.

The sites:
The two fields we sampled monthly at your farm were labelled ‘Site 14’ and ‘Site 15’ (see the map below). We also sampled ‘Site 13’ at the start and end of the study (May and December). Each site had both ‘Flooded’ and ‘Control’ areas and we had 3 plots in each of the areas.

The results:

**Vegetation biomass**

On the wheat field (site 14), vegetation biomass was much higher in the control area than in the flooded area during the summer. This is because the flooded area was not re-seeded and instead was dominated by smaller weeds. Once the field was cut in August, there was no difference between flooded and control areas as vegetation regrew in each area. The grassland (site 15) showed very little difference in yield between flooded and control areas. This is perhaps because the vegetation was more resilient to flooding.
Worm numbers

There was a general increase in worm numbers on both sites throughout the sample period, although worm numbers were initially high on site 15. On site 14, worm numbers were greater in the control area than in the flooded area, although this difference lessened later in the year. There was no such difference on site 15 – worm numbers remained relatively high in both flooded and control areas. The dip in the summer months was likely due to dry soils; it’s likely that the worms were present in the deeper layers of the soil that we didn’t sample.

Soil bulk density

Bulk density was higher on the wheat field (site 14) than on the grassland (site 15); this is most likely due to the recent use of heavy machinery on site 14. Generally, soil bulk density didn’t differ between flooded and control areas on site 14, perhaps because compaction caused by the flood water matched that caused by farm machinery in the control area. On site 15 however, soil bulk density was consistently higher in the control area than in the flooded area. This may have been due to compaction by the cattle on the field, or a denser root structure holding the soil together. There was also a dip in soil bulk density in September after the field had been cut.
**Infiltration rates**

On the wheat field (site 14), infiltration rates did not differ between flooded and control areas, although there was a peak in June, when the soil was very dry. Again, infiltration rates on site 15 didn’t tend to differ between flooded and control areas, although in September and November infiltration rates were higher in the flooded area. The fluctuations in the control area could have been due the presence of large roots, which may have blocked the flow of water into the soil.

**Soil pH and salinity**
On both sites, soil salinity was higher in the flooded areas than in the control areas, although the salinity in the control area of site 14 matched that in the flooded area after the wheat was harvested. Soil salinity in the flooded area of site 15 remained high throughout the sampling period. This salt was likely deposited by the flood water.

**Soil respiration**

Soil respiration in the control area of site 14 and in both flooded and control areas of site 15 showed seasonal fluctuations, with higher soil respiration rates in the summer gradually reducing through the autumn. Respiration rates in the flooded area of site 14 however, were much lower through the summer, suggesting that there was less microbial activity in this area. Soil respiration in this flooded area did increase throughout the summer however, and almost matched the levels recorded in the control area by the end of the study. This difference between flooded and control areas was not evident on the grassland site (site 15), perhaps because the microbial community was able to survive the flooding due to the more complex root structures and the resilience of the grass sward.

**Soil nutrients**
As with the overall data set, soil nutrient levels showed little difference between flooded and control areas on each site. Instead, nutrient levels fluctuated when fertiliser was added to the fields or when the fields were re-seeded or cut.

**Overall Conclusions**

The winter 2012-13 floods had a lasting impact on plant yields, soil salinity and worm numbers. However, flooding had little impact on many of the measured soil characteristics (soil pH, density, nutrients); instead, these fluctuated more with interventions such as the addition of fertilizers. Although all of the sites have shown great improvement since the flooding, there were still differences between flooded and control areas 8 months after the flood water receded. Re-seeding and the addition of nutrients do seem to have helped restore the agricultural fields, particularly when done after the soil had dried out sufficiently to enable efficient use of farm machinery. The grasslands in the study seem to have been more robust than the agricultural sites; this may have been due to a more diverse and flood resistant sward, capable of thriving in wetter soils.

In addition to this monthly survey we have been conducting a study to compare different methods of soil aeration to see which may be the best way to alleviate the effects of flooding on agricultural soil. In the final report, we will report the results of this alleviation study, along with a more in depth analysis of the monthly survey and the results from our lab studies.

Once again, thank you for your cooperation and for letting us take samples from your land. We’ll keep you updated with our reports, and if you have any questions let us know.