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RECOVERY AFTER CYCLONE GABRIELLE – "BUILDING SOIL BACK BETTER"

Alexandra Dickson[1], Dan Bloomer [1], Alec Mackay[2], Alan Palmer[3]

1 LandWISE, 21 Ruahapia Rd, RD10, Waipatu, Hastings

2 Farm Systems & Environment, AgResearch, Tennent Drive, Fitzherbert, Palmerston North

3 Farmed Landscapes Research Centre, School of Agriculture and Environment, Massey University, Palmerston North

Email: alex@landwise.org.nz

Background

On the 13th of February Cyclone Gabrielle tore a path across much of the north and east of the North Island, causing devastation across many regions. The cyclone decimated homes, productive land and crops, and livelihoods, with the cost of rebuilding estimated at $14.5 billion (Wilson et al., 2023). Cyclone Gabrielle was the third in a series of serious storms to hit New Zealand in two months. Across Hawke's Bay, Wairoa, and Gisborne, highly productive land was impacted. Land used for cropping, orchards, vineyards, and livestock production was inundated with water and buried under sediment and debris after rivers burst through or overflowed stop banks and shifted their courses. In Northland, flood and extended wetness devasted crops, including maize and kumara. Cyclone Gabrielle also impacted coastal Wairarapa, parts of the Central Plateau and the Pohangina Valley in the Manawatu.

Following Cyclone Gabrielle a consortium of organisations formed to provide immediate advice to affected growers. Activities broadened to capture data on the initial impact of the cyclone on farmers, growers, and their productive land, and to document the lessons that could be learnt about recovery from a natural disaster such as this. The group included LandWISE Inc., AgResearch, Massey University, Hawke's Bay Regional Council, Gisborne District Council, Plant and Food Research, Vegetable Research & Innovation Board, and Vegetables NZ. Activities progressed with support from the Ministry for Primary Industries and alongside several of the national producer groups including NZ Apples and Pears, Summerfruit, Onions NZ, New Zealand Buttercup Squash Council, and the Foundation for Arable Research.

Cyclone Gabrielle Baseline Study

In the wake of Cyclone Gabrielle, a key challenge for farmers and growers in Hawke's Bay, Wairoa and Gisborne has been the management of sediment deposited on highly productive land that typically grows a range of high value fruit, vegetable, and arable crops. After Cyclone Gabrielle, the main sources of information about managing sediment deposits came from the February 2004 Southern North Island Storm (Smith et al., 2011). It included studies completed by Litherland et al. (2007) and Wilson & Valentine (2005) which assessed regrassing strategies through farmer interviews and data collection on impacted sites 9 months (November 2004) through to 27 months (May 2006) after the event. Decision support tools were developed to guide farmer management decisions when re-establishing pastures. The studies built on work completed after the Gisborne Flood in 1948 (McKee & Graham, 1952) and Cyclone Bola in 1988 (Gray & Korte, 1990), which also focused on reestablishment of pasture. While these studies and decision support tools provided direction for growers after Cyclone Gabrielle, there was little about how best to re-establish producing high value crops, or what the long-term impact to production might be on soils impacted by sediment.

The Cyclone Gabrielle Baseline Sampling project was developed to collect data soon after the flood (within approximately 30 to 90 days) to understand sediment characteristics, and the initial impact on

production before remediation was initiated. In total 155 samples were collected from 116 sites, including flooded areas in Northland. About 70 farmers and growers engaged with the project to complete sampling and generously shared their time. A wide range of land use types was sampled, including permanent tree crops (apples, grapes, cherries, avocados), vegetable crops (process and fresh vegetable), arable crops, and a few dairy and dry stock pastoral farms.

Methodology

The initial focus of the baseline sampling was to analyse samples for nutrient fertility only but was expanded to capture the other components of soil health. Sampling was completed soon after the event (30-90 days) provided a unique opportunity to capture a wider range of data, so sampling expanded to include:

- Sediment depth
- Sediment texture
- Sediment bulk density
- Visual Soil Assessment (VSA)
- Nutrient fertility
- Contaminant analysis (on a select few representative sites)
    - Multiresidues Pesticides
    - Acid Herbicides
    - Faecal Coliforms and E. coli Profile
    - Heavy Metals
- Earthworm abundance and diversity

The extent of sediment damage to particular areas varied according to many factors. The aims of collecting a wider range of data were (i) to identify the origin of the sediment and its characteristics across the landscape of each of the targeted catchments, (ii) to provide information to growers on what sediment characteristics they were managing, (iii) to link sediment characteristics to implications for future land use and management, and (iv) to add to the knowledge base on the impacts of flooding. A sampling protocol to create consistency in sampling across the impacted regions was developed at a workshop held 9th March 2023. Flexibility was built into the protocol as some sites required a 'bespoke' approach to sampling.

Sites were selected with the aim of capturing information on impacted catchments (at, with samples collected at different points along river flow pathways. Different land uses were captured including orchards, vineyards, cropland, and pasture.

Three categories were defined:

i. topsoil eroded and stripped leaving subsoils exposed,
ii. soil impacted by sediment deposition, and
iii. areas inundated with water for an extended period.

Sites impacted by sediment deposition were divided into four categories, based on the depth categories outlined in the decision tree developed through the Lower North Island Combined Provincial Federated Farmers Storm Group (2007). They were:

i. 0 cm sediment deposition
ii. < 5cm sediment deposition
iii. 5 – 20cm sediment deposition
iv. > 20cm sediment deposition

Sampling at each site was conducted at 0 m, 25 m and 50 m along a transect.
While some areas had varying depths of sediment, e.g. from 5 cm to 50 cm, each transect was constrained to only one depth class (i.e. < 5 cm, 5 – 15 cm or > 20 cm) as the likely future management options for each of these scenarios may be different. At some sites with more than one depth category, multiple transects were established and sampled to capture the differences.

Samples for laboratory analysis were defined as sediment only, mixed sediment and soil, or soil only. The standard sampling depth for horticultural and cropping soils is 15 cm. In areas where sediment depth was less than 15 cm, two samples were collected for nutrient analysis:

1. sediment only. This sample was used to classify sediment type etc.,
2. a mixed sample, e.g., 10 cm sediment and 5 cm of original topsoil. This "agronomic" information provides a standard indication of the nutrient levels and was thought more useful to growers.

Bulk density was determined for the sediment only. Where sediment depth was less than 10cm (depth of ring) any of the below soil was discarded. The results presented in this report are for sediment only samples.

Regional Sampling Summary

For the purpose of this report, data are presented for Hawke's Bay and Gisborne only, as these are the two regions that had the most significant damage from sediment deposition.

Table 1 Breakdown of number of samples and sites per region

Region	Number of samples	Number of sites
Hawke's Bay	82	60
Gisborne	55	39
Wairoa	6	5
Northland	12	12
Total	**155**	**116**

Hawke's Bay

Nine impacted areas/catchments were studied in Hawke's Bay (excluding Wairoa) (Figure 1):

- Dartmoor Valley
- Esk Valley
- Fernhill
- Meeanee
- Otane
- Pakowhai
- Puketapu
- Tangoio
- Twyford

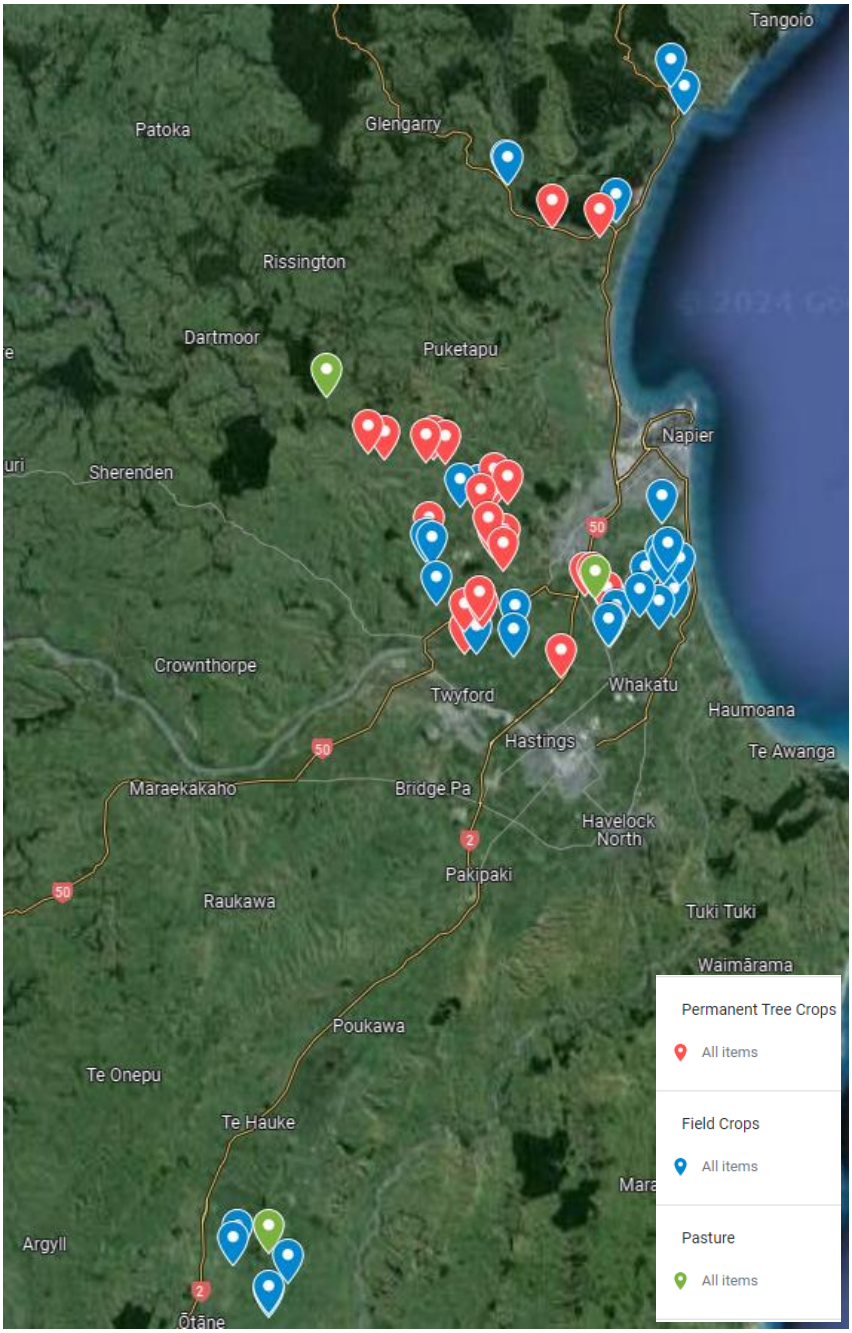

Figure 1 Map showing distribution of sites sampled (Hawke's Bay)

Land use types of sites sampled were predominantly field crops (33) and apple orchards (18), but also included vineyard (4), avocado (1), cherry (1), dairy (1) and drystock (2).

From the 82 samples submitted, 46 were for sediment only tests (Table 2).

Table 2 Number of sites in each sediment depth class/management zone (Hawke's Bay)

Sediment Depth Class	Number of sites within depth class
0 cm	7
< 5 cm	11
5 - 20 cm	16
> 20 cm	26
Total	**60**

Gisborne

Eight impacted districts/catchments were sampled in the Tairawhiti/Gisborne region (Figure 2):

- Hikuwai/Uawa
- Mangaheia
- Mata
- Pakarae
- Te Arai
- Waiapu
- Waihuka
- Waipaoa

Eleven samples were taken from field cropping sites, 17 from orchards, including apple (9), citrus (4), kiwifruit (2), vineyard (2), and 10 from pasture sites. Of the 55 samples submited, 32 were for sediment only tests (Table 3).

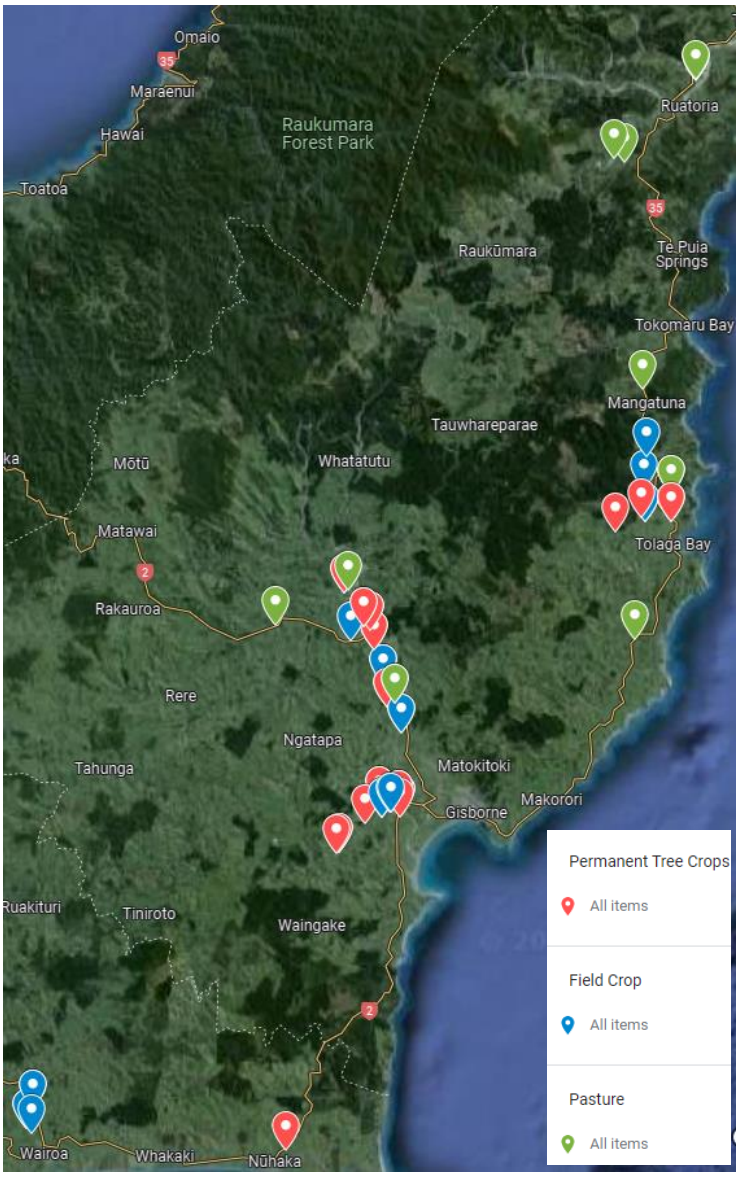

Figure 2 Map showing distribution of sites sampled (Gisborne)

Table 3 Number of sites in each sediment depth class/management zone (Gisborne)

Sediment Depth Class	Number of sites within depth class
0 cm	0
< 5 cm	7
5 – 20 cm	23
> 20 cm	9
Total	**39**

Findings on the characteristics of sediment

Sediment pH

The pH levels of the sediments across both regions were elevated (Figure 3). Optimum pH for many vegetable crop types is between 6 – 6.8 (Reid & Morton, 2019) and for pipfruit trees between 5.8 – 6.8 (Hill Labs, n.d.-a). The lowest sediment pH was found in Hawke's Bay (pH = 6.3), and the highest in Gisborne (pH = 8.5). The mean sediment pH was 7.6 and 8.0 in Hawke's Bay and Gisborne, respectively.

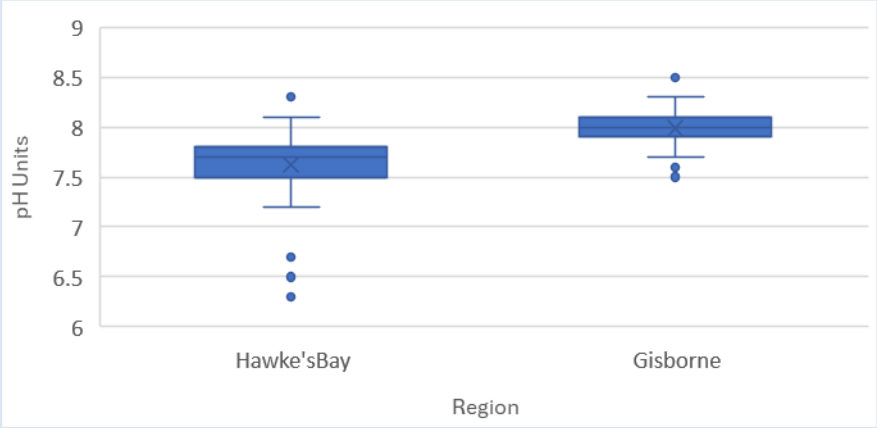

Figure 3 Sediment pH in Hawkes Bay and Gisborne.

Sediment Olsen phosphorus

Olsen phosphorus (P) of sediment deposits were low compared to optimum or target ranges for many vegetable crop types. For example, the range for sweetcorn is 25 – 35 mg/L, beans > 45 mg/L, and onions > 40 mg/L (Reid & Morton, 2019). The target for pipfruit is > 30 mg/L (Hill Labs, n.d.-a). In Hawke's Bay, sediment with an Olsen P of 3 mg/L was found in fine sandy loam textured sediment in

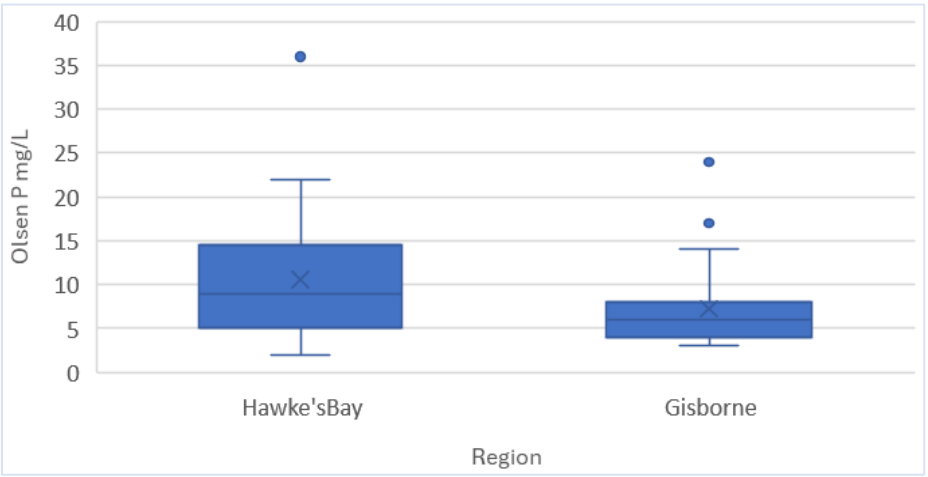

Figure 4 Sediment Olsen P (mg/L) in Hawke's Bay and Gisborne.

the Esk Valley and fine sand in the Dartmoor Valley. An Olsen P of 36 mg/L was found in silty clay loam sediment near Otane in the central Hawke's Bay where paddocks remained flooded for many weeks. Around Gisborne, 11 samples contained Olsen P of 3 – 4 mg/L, predominantly in very fine sandy loams and fine sands. Few sites in either region had sediment Olsen P levels >20 mg/L (Figure 4).

Sediment Potassium

Sediment potassium MAF Units (QTK) varied in both catchments from 2 – 17 QTK in Hawke's Bay to 4 – 16 QTK in Gisborne (Figure 5). Sediment K levels were closely linked to the texture of the sediment, with low K levels (< 5 QTK) predominantly found in areas where sediment texture was classified as loamy fine sand, loamy medium sand, very fine sandy loam, or fine sand. The higher K levels were predominantly found in sediment deposits that had a silty clay loam texture. Potassium requirements vary significantly between vegetable crop types, for example, as low as 5 – 6 QTK for squash, and as high as 13 – 17 QTK for tomatoes.

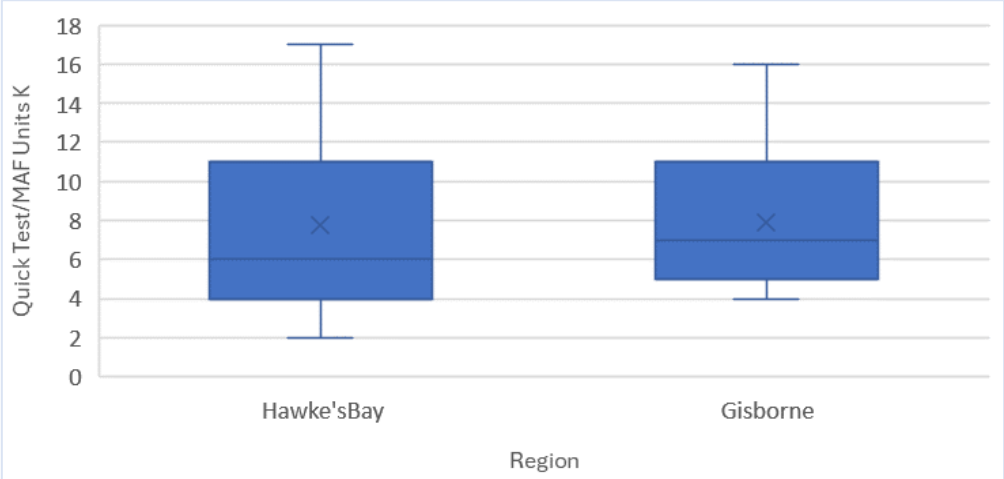

Figure 5 Sediment Potassium levels in Hawkes' Bay and Gisborne.

Sediment sulphate and organic sulphur

Both sulphate sulphur and organic sulphur levels in the sediment were included in the laboratory analyses. There was a wide range in values (Figure 6). In many sediment deposits, sulphate sulphur was elevated, in some cases to extreme levels. The highest recorded result in Hawke's Bay was 222 mg/kg and in Gisborne 231 mg/kg. In Hawke's Bay, only five samples had sulphate sulphur levels below 10 mg/kg, and in Gisborne, all samples were above 10 mg/kg.

The elevated sulphate sulphur levels did not match the organic sulphate levels (not displayed), where 62 of the 76 samples from across both regions had levels below the detectable limit of 2 mg/kg, 13 samples ranged from 2 – 10 mg/kg, with a single outlier at 22 mg/kg.

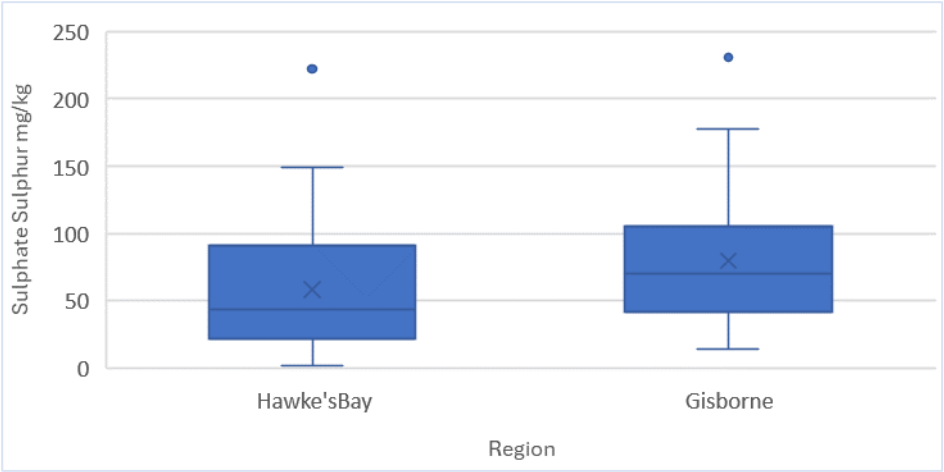

Figure 6 Sediment Sulphate Sulphur levels in Hawke's Bay and Gisborne.

Sediment Organic Matter

Sediment organic matter levels are important to consider for the role soil organic matter plays in aggregate building, food source, moisture holding capacity and nutrient availability. Organic matter levels in the sediment deposits were below 7 across both regions (Figure 7). Organic matter percentages < 3% are considered very low, and between 3 – 7 low (Hill Labs, n.d.-b).

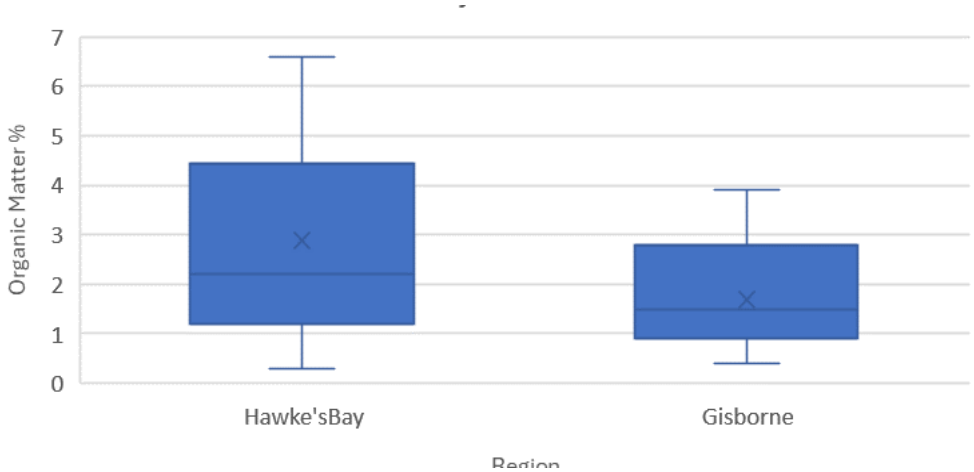

Figure 7 Sediment organic matter (%) in Hawkes Bay and Gisborne.

Contaminants in sediment

In response to concerns of contaminants in sediment, 14 sites from several catchments in Hawke's Bay were selected and tested for contaminants, included heavy metals, Multiresidue Pesticides, Acid Herbicides, Faecal Coliforms and E. coli Profile This sampling did not identify contamination.

Visual Soil Assessment (VSA) of sediment

A Visual Soil Assessment of the sediment was completed at each point along each transect. A modified version of Visual Soil Assessment Version 1 (Shepherd, 2000) was used, assessing porosity, structure, colour, number and colour of mottles, and earthworm numbers. Hawke's Bay sites predominantly achieved a moderate score where sediment depth was less than 15cm and the existing top soil

contributed to the overall score. Where sediment was > 20cm VSA score was considered poor (Table 4).

Table 4 Average VSA total ranking scores per site (Hawke's Bay)

Soil Quality Assessment	Number of Sites	Average Ranking Score
Poor	9	2
Moderate	44	12
Good	2	21

In Gisborne, VSA was assessed on sediment only where sediment was >20 cm deep. If a site had a layer of sediment less than a spade depth, a VSA was completed on the whole top 20cm profile, and an additional VSA was completed for the sediment layer alone (Table 5).

Table 5 Average VSA scores per site (Gisborne)

Soil Quality Assessment	Number of Sites (mixed soil + sediment)	Average Ranking Score
Poor	9	2.
Moderate	14	12
Good	0	N/A
Soil Quality Assessment	**Number of Sites (sediment only)**	**Average Ranking Score**
Poor	11	3
Moderate	17	11
Good	3	20

The full report can be downloaded from the LandWise website https://www.landwise.org.nz/

Initiation of longitudinal Study

In a current project 14 paired sites were resampled in spring, six months after the event (August-September 2023) and will be sampled again in autumn (February-April 2024) 12 months after the Cyclone, all located in Hawke's Bay. Sites were paired by sediment texture and depth at each location but managed differently (e.g. sediment incorporated vs sediment left on the surface). Soil measurements are being repeated, and where crops have been planted (eight sites), crop yield and quality are being collected. The aim of this study is to understand the impact of sediment deposition and different management decisions on the soil, and impact on crop production the following season.

Ideally, this project, now called 'Building Back Better', will form part of a longitudinal study using the locations sampled as part of the baseline study. That will allow a better understanding to be developed of the impact on sediment on high value cropping land. The information collected will be used to update the existing resources and develop new resources to support growers the next time a community is impacted by an event of this magnitude. **It would be a positive legacy from Cyclone Gabrielle**.

Acknowledgement

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