A detailed soil survey was carried out across the monitored site to identify and map the soil types (Masters et al., 2017). The dominant soil is regionally described as Bulgun series, a poorly drained alluvial soil first described by Murtha (1986) and also classified as a very deep dermosolic, redoxic, humose-acidic, dermosolic, redoxic, hydrosol (Isbell, 2016). Based on the world reference base for soil resources 2014 (IUSS Working Group WRB, 2022), the site soil is classified as ‘Stagnic Umbrisol (Pantoclayic, Sideralic, Humic)’ by Enderlin and Harms, 2023. The detailed soil profile, to 4.00 m depth, was stratified into five different layers, predominantly loamy textures (Fig. 2) (Karim et al., 2021). The extended profile to 12.00 m depth was predominantly composed of clay rich layers, followed by aquifer material at 9.00 – 11.00 m depth (Stanley, 2019). These loam and clay rich textures regulate the site hydrology (infiltration, runoff, and deep drainage). The organic matter content of productive agricultural topsoil is usually between 3 and 6% (Fenton et al., 2008) but the present study found higher organic matter, above 20% in the topsoil (0.0-0.7 m depth, Table 1), than the previous study (5.7%, 0.0-0.1 m depth) in wet conditions (Masters et al., 2017).

Table 1. Soil organic matter at the site soil (Loss-On-Ignition, LOI, Method).

Depth (m)	0-0.15	0.15-0.40	0.40-0.70	0.70-1.25	1.25-2.20	2.20-2.90	2.90-3.65	3.65-3.90
Organic matter (%)	20.8	23.07	17.26	3.36	14.29	9.58	6.01	8.38

The study site experiences a humid tropical climate, predominantly influenced by coastal meteorological situations (Tahir et al., 2019). According to the interpolated climatic data available through the Queensland Government’s SILO database from 2010 to 2023 (at SILO Grid point: Latitude – 17.75 and longitude - 146.05), the mean annual minimum and maximum temperatures are 21ºC and 29ºC respectively. The average predicted potential evapotranspiration is 5.18 mm/yr, determined by Morton’s potential Evapotranspiration, during 2010-2023. The annual average interpolated rainfall is 3,202 mm/yr at the monitoring site. According to Bureau of Meteorology (BoM), the annual average rainfall is 3,092 mm/yr at the nearest BoM Station–Bingil Bay (Site 032009), situated nearly 12.5 km of the site. This area typically experiences the highest rainfall in the wet seasons during December - April). For regular rainfall monitoring, the site was fitted with tipping bucket rain gauges, which were organized by the Queensland Government (Masters et al., 2017). The site is not irrigated, which is common in the tropical conditions for sugarcane cultivation. Therefore, the local rainfall patterns govern the site hydrology with respect to soil stratigraphy.

Figure 1. Schematic of the VMS installed in the monitoring site (July 2017). (VSP = Vadose zone Sampling Port and FTDR = Flexible Time Domain Reflectometry).

Figure 2. Vertical distribution of the VMS units and soil profile with clay content (VSP = Vadose zone Sampling Port and FTDR = Flexible Time Domain Reflectometry).

Table 3. Water sampling regime for pesticide analysis (√ denotes samples collected on the corresponding date and X denotes dates when no samples were collected).

Table 4. Soil sampling schedule for pesticide analysis (√ denotes the depths at which soil samples were collected for each of the sampling dates).

“3.2.2 Imidacloprid

During the monitoring time 2017-2019, persistent imidacloprid (half-life, 187 days) was found in the vadose water samples (Fig. 7), four times (Table S 2, 3, 4 & 5), from 1.15 m to 4.00 m depth. Although imidacloprid was not applied in the monitoring site, its transport and concentration beneath the sugarcane root zone varied with depth over time. It was possibly being released from residues present in the upper soil layers or transported imidacloprid from the neighbouring sugarcane fields. During September-November 2017, there were several medium to very high rainfall events which resulted in infiltration (Fig 4). This could have contributed to imidacloprid leaching beyond the root zone and travelling to 4.0 m depth, as it has characteristics of high solubility (610 mg/L) and high leachability (GUS Leaching Potential Index, 3.69, Table A1).

Figure 3. Imidacloprid concentration over time in depth (December 2019 was not shown in the figure as the result was below the detection limit).

After November 2017, imidacloprid was detected only in the upper vadose zone and not at the end of the vadose zone (3-4 m depth), in the proximity of the perched aquifer. Imidacloprid was found to a depth of 1.56 m depth in January 2018, to a depth of 2.96 m in May 2018 and to a depth of 1.15 m in November 2018 (Fig. 7). There was also a reduction in imidacloprid concentrations observed over time. This lowering concentration could be due to the combination of the dilution by infiltration and lateral transport after consecutive high rainfall events, as drainage water was reported to seep laterally into the neighbouring channels at the site (Masters et al., 2017). Finally, in December 2019, imidacloprid was below the detection limit throughout the vadose zone (Fig. 7). The possible explanation for the lower leaching could be its sorption onto the clay rich sediments (Oi, 1999) and lower rain events in December 2019 (Fig. 4) (Gupta et al., 2002).

Imidacloprid was not detected in soil samples collected in September and November 2018 (Table S8). Interestingly, persistent imidacloprid was found at upper part of the soil at 25 cm and 35 cm depth with 0.0122 kg a.i./ha (0.004 mg/Kg) and 0.010 kg a.i./ha (0.01 mg/Kg), and 0.012 kg a.i./ha (0.002 mg/Kg), respectively, in November 2019 (Table S9). It was observed only at 25 cm soil depth, with 0.0366 kg a.i./ha (0.012 mg/Kg) in December 2019. The concentration of imidacloprid at upper part of soil may indicate a source within a neighbouring sugarcane field. This imidacloprid had not yet travelled into the vadose zone till 1.15 m depth or beyond as it was not detected in vadose water sampled in November and December 2019 (Fig.7).

Table S8.: the pesticide and their residues in soil (September and November 2018)

Herbicides in water	Health value	Units	Reporting Limit	September, 2018			November, 2018		
				25 cm	35 cm	50 cm	25 cm	35 cm	50 cm
Glyphosate	**1000**	mg/Kg	***0.70***	<	<	<	<	<	<
Fluroxypyr		mg/Kg	***0.01***	<	<	<	<	<	<
Hexazinone	400	mg/Kg	***0.01***	<	<	<	<	<	<
Imazapic		mg/Kg	***0.01***	<	<	<	<	<	<
Imadacloprid		mg/Kg	***0.02***	<	<	<	<	<	<
Isoxaflutole metabolite (DKN)		mg/Kg	***0.02***	<	<	<	<	<	<
Metolachlor	**300**	mg/Kg	***0.005***	<	<	<	<	<	<
Haloxyfop		mg/Kg	***0.001***	<	<	<	<	<	<

Table S9.: the pesticide and their residues soil (November and December 2019)

Herbicides in water	Health value	Units	Reporting Limit	November 2019			December 2019		
				25 cm	35 cm	50 cm	25 cm	35 cm	50 cm
Glyphosate	**1000**	mg/Kg	***0.70***	<	<	<	<	<	<
Fluroxypyr		mg/Kg	***0.01***	<	<	<	<	<	<
Hexazinone	400	mg/Kg	***0.01***	<	<	<	<	<	<
Imazapic		mg/Kg	***0.01***	<	<	<	<	<	<
Imadacloprid		mg/Kg	***0.02***	**0.004**	**0.010**	<	**0.012**	<	<
Isoxaflutole metabolite (DKN)		mg/Kg	***0.02***	<	<	<	<	<	<
Metolachlor	**300**	mg/Kg	***0.005***	<	<	<	<	<	<
Haloxyfop		mg/Kg	***0.001***	<	<	<	**0.004**	**0.010**	**0.002**