

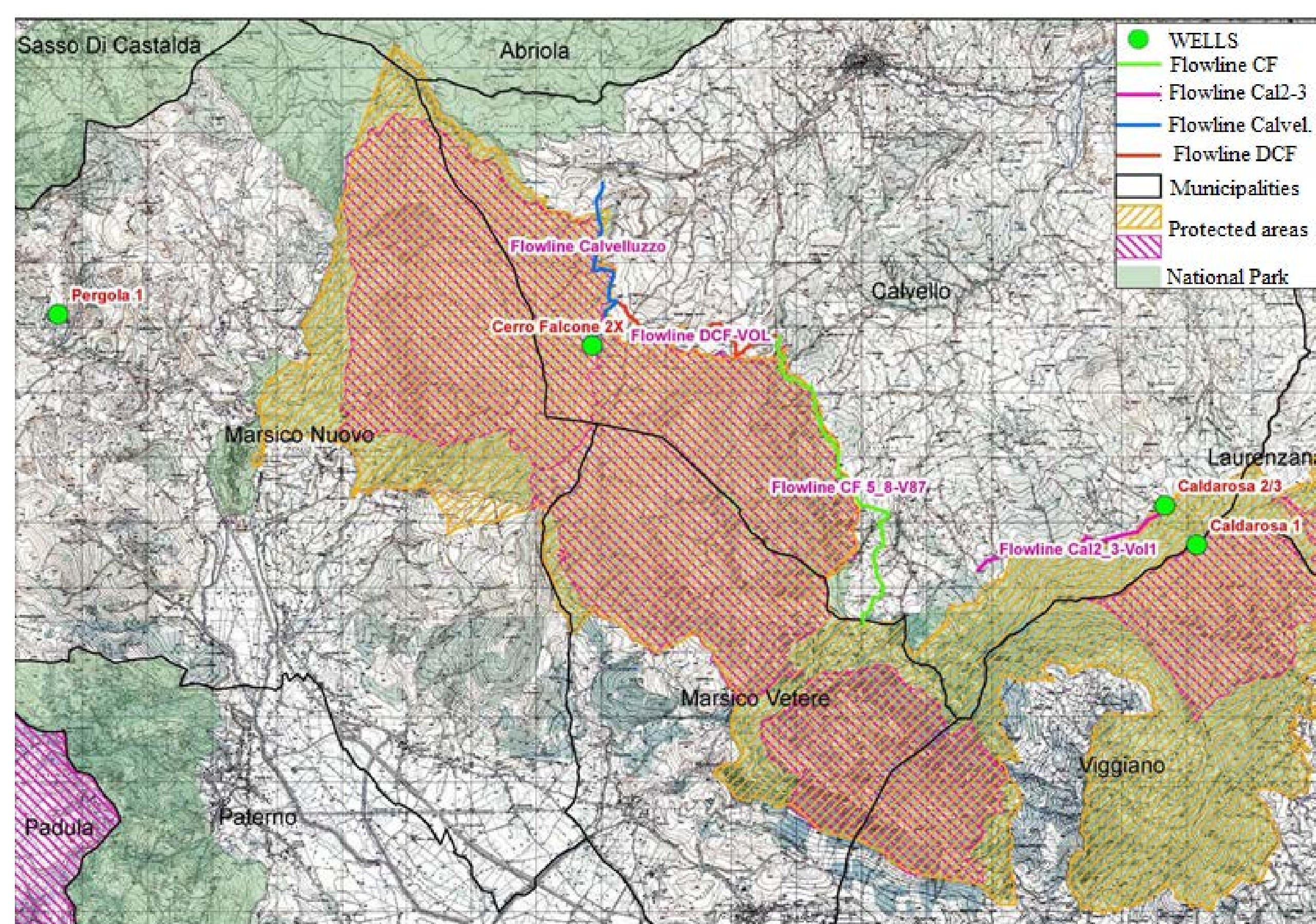


EVOLUTION OF BIOLOGICAL SOIL FERTILITY INDICES IN AN AREA AFFECTED BY OIL EXTRACTION AND PIPELINE IMPLANTATION



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The soil resilience to the stress, due to the presence of both a buried oil pipeline and oil wells, and the subsequent natural mitigation, have been monitored and assessed for three years (2015-2017) by means of a discrete series of usually adopted indices (% organic matter, basal respiration within 24 hours, cumulative respiration within 28 days, microbial carbon, metabolic quotient and mineralization quotient). Other soil properties were annually measured as soil texture, pH, electrical conductivity, lime content, CEC, total-N, total-S, Olsen-P and exchangeable-K.

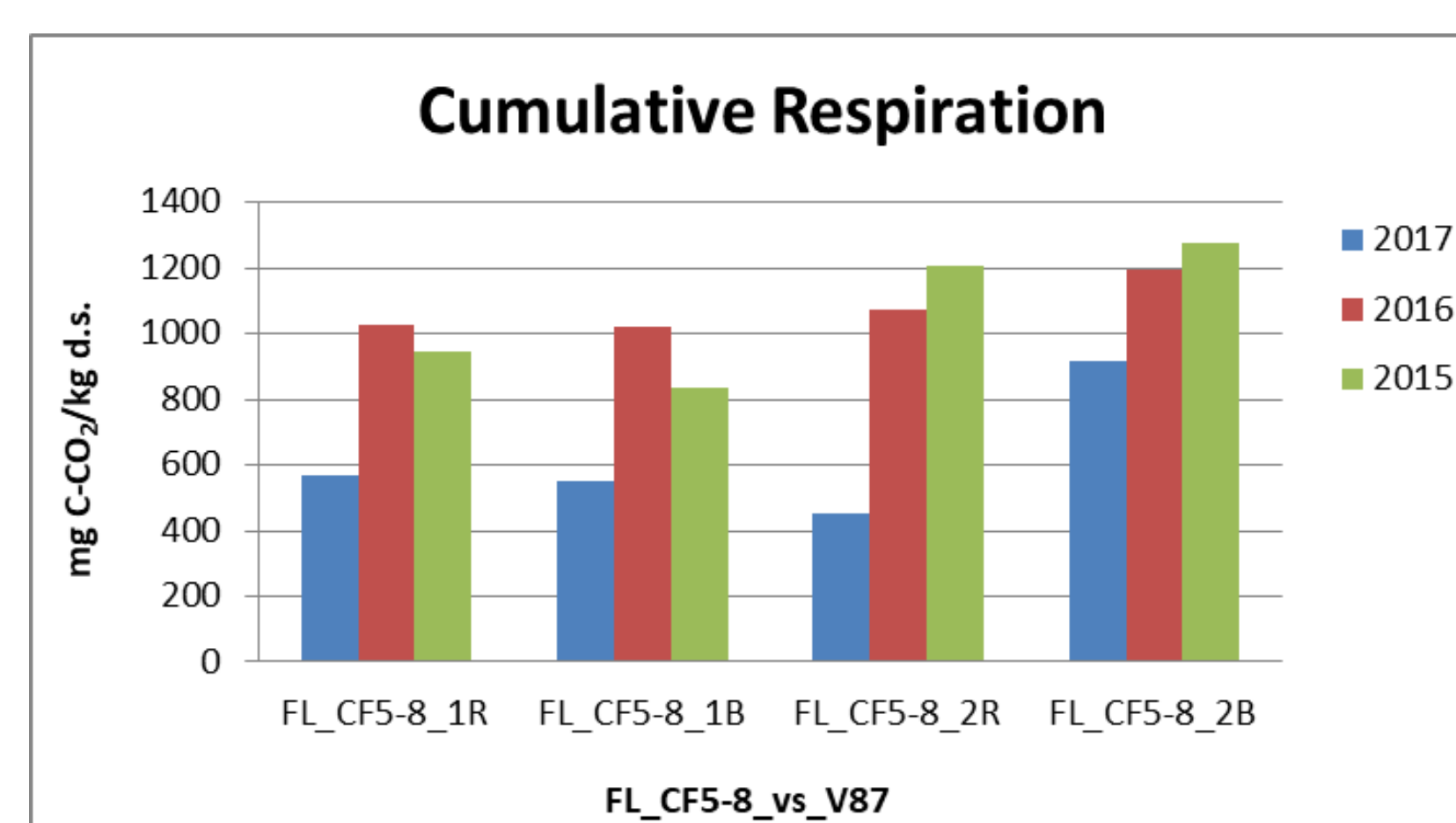


Some properties (2017) of selected soil samples

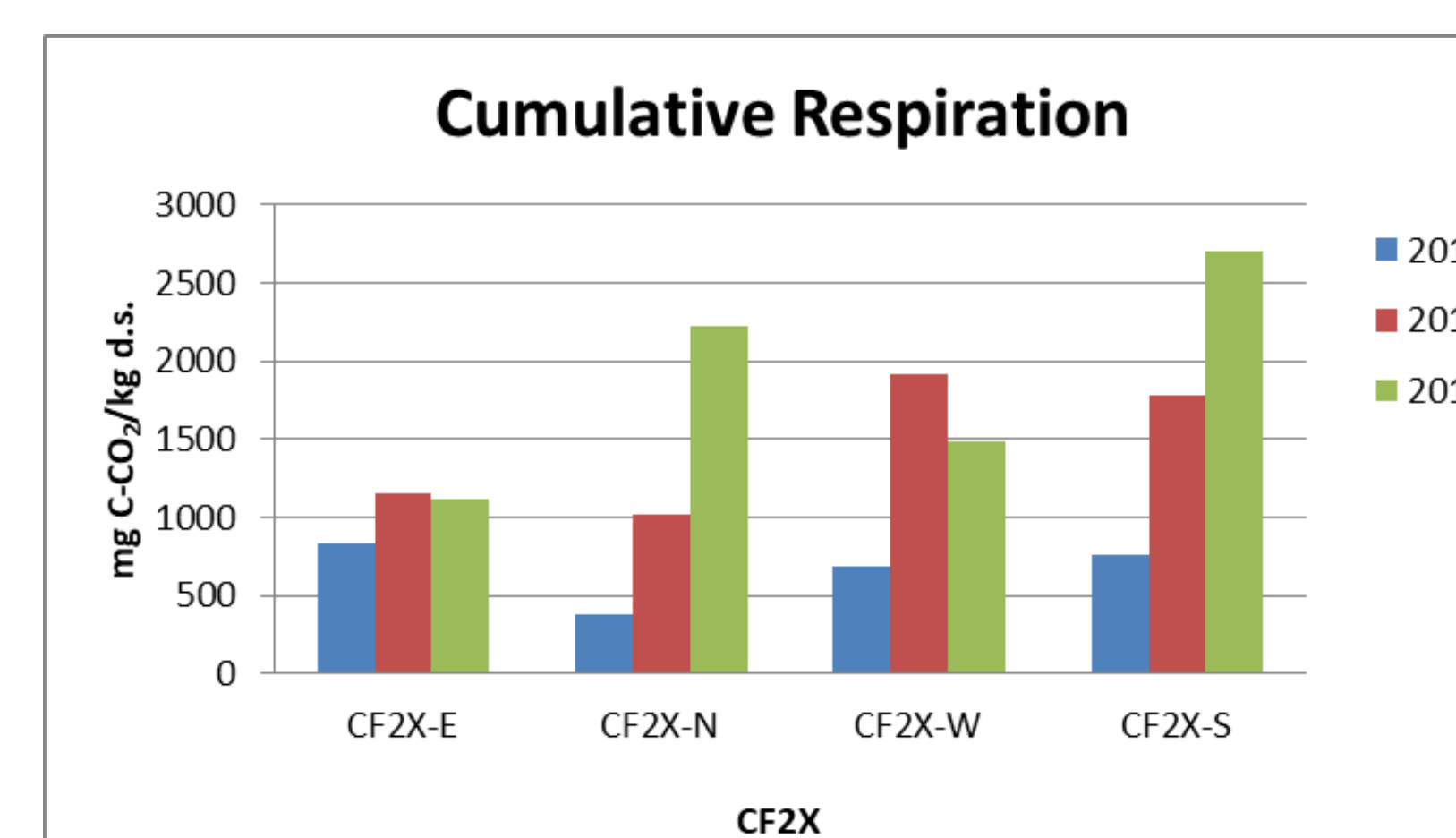
SITE Sampling	Sample	pH	E.C. $\mu\text{S}/\text{cm}$	CEC cmol^+/kg	Lime gCaCO_3/kg	Org. Carbon gC/kg	N g/kg	Bas-Resp $\text{mgC-CO}_2/\text{kg}$	Cum-Resp $\text{mgC-CO}_2/\text{kg}$	Micr-Carb mgC/kg	$q\text{CO}_2$ %	$q\text{M}$ %
Flowline CF	CF5-8_1R	5.4±0.2	126±1	56±6	4.0±0.4	40.6±4.1	1.2±0.2	9±1	567±9	422±4	0.09	1.40
	CF5-8_1B	7.3±0.2	231±2	34±3	8.1±0.8	41.2±4.1	1.5±0.3	5±1	552±9	791±7	0.03	1.34
	CF5-8_2R	7.8±0.2	207±2	46±5	14.2±1.4	17.2±1.7	2.0±0.3	4±1	453±8	369±4	0.05	2.64
	CF5-8_2B	6.5±0.2	170±1	31±3	4.0±0.4	33.4±3.3	3.0±0.4	64±4	918±10	580±5	0.46	2.75
Well Cerro Falcone 2X	CF2X-E	6.2±0.2	93.5±0.5	42±4	4.0±0.4	73.7±7.4	2.7±0.4	62±4	831±10	580±6	0.45	1.13
	CF2X-N	5.5±0.2	57.9±0.5	48±5	6.1±0.6	48.4±4.8	3.0±0.4	3±1	372±7	580±6	0.02	0.77
	CF2X-W	5.8±0.2	71.3±0.5	46±5	4.0±0.4	49.5±5.0	3.5±0.4	54±3	690±9	633±6	0.36	1.39
	CF2X-S	5.3±0.2	77.2±0.5	38±4	4.0±0.4	81.9±8.2	1.8±0.3	66±4	756±9	897±9	0.31	0.92
Flowline CAL2/3-VOL	CAL-VOL1	6.3±0.2	154±1	51±5	0.4±0.1	43.3±4.3	2.5±0.4	68±4	999±12	844±8	0.34	2.31
	CAL-VOL2	5.7±0.2	160±1	43±4	1.2±0.1	30.4±3.0	2.2±0.3	13±2	558±9	316±4	0.17	1.83

Assess the class of biological soil fertility

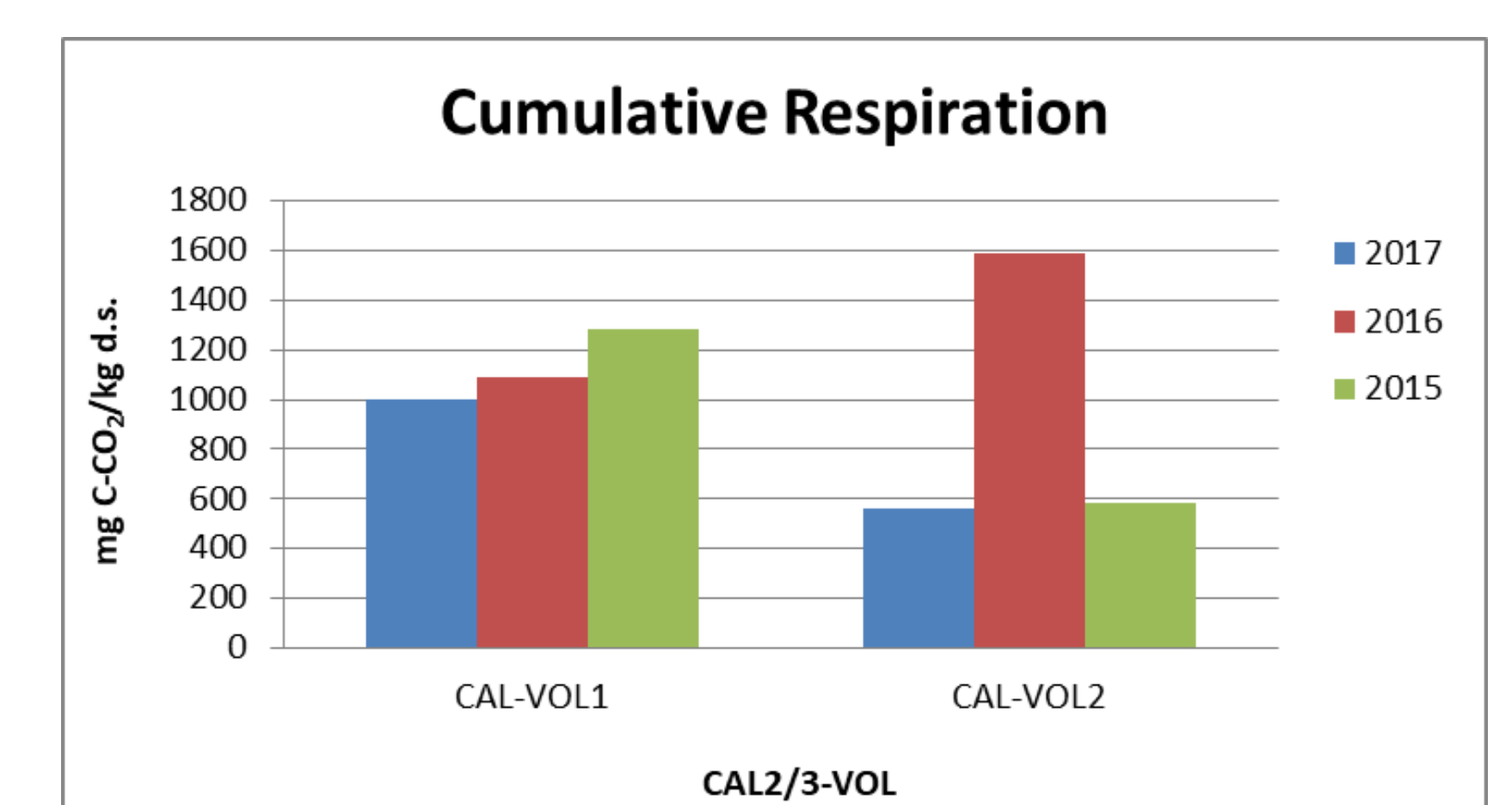
PARAMETERS USED	SCORE				
	1	2	3	4	5
1 - Organic matter %	<1	1 – 1.5	1.5 – 2	2 – 3	>3
2 - Soil respiration at 24 th hour	<5	5 – 10	10 – 15	15 – 20	>20
3 - Cumulative respiration 28 days	<100	100 – 250	250 – 400	400 – 600	>600
4 - Microbial carbon	<100	100 – 200	200 – 300	300 – 400	>400
5 - Metabolic quotient ($q\text{CO}_2$)	>0.4	0.3 – 0.4	0.2 – 0.3	0.1 – 0.2	<0.1
6 - Mineralization quotient ($q\text{M}$)	<1	1 – 2	2 – 3	3 – 4	>4
CLASS OF BIOLOGICAL FERTILITY	I	II	III	IV	V
	stress alarm	early warning	average	good	high
Range of assigned scores	0-6	7-12	13-18	19-24	25-30



Flowline CF Class assigned 2017	Sample	Class
Flowline CF	CF5-8_1R	III
	CF5-8_1B	IV
	CF5-8_2R	III
	CF5-8_2B	IV



Well Cerro Falcone 2X Class assigned 2017	Sample	Class
Well Cerro Falcone 2X	CF2X-E	IV
	CF2X-N	IV
	CF2X-W	IV
	CF2X-S	IV



Flowline CAL2/3-VOL Class assigned 2017	Sample	Class
Flowline CAL2/3-VOL	CAL-VOL1	V
	CAL-VOL2	IV

In Conclusion

The mitigation hierarchy is ideally applied from the earliest stages of a new project, or an existing project's expansion. It is more challenging to apply the mitigation hierarchy retrospectively to a project that is already operational. In this case, the potential for avoidance and minimization is likely to be limited, and the sole opportunity is the natural resilience and auto-mitigation or auto-restoration of the stressed area.

From the results obtained we observed that the soil well reacted to stress: the soil fertility after three years was in net recovery, confirming the ability of nature to restore the balance,.... but with its time.