Stable isotopes of oxygen: the key to understand the soil fate of organic-waste derived phosphorus?

Mario Álvarez-Salas, Federica Tamburini, Jakob Magid, Dorette Müller-Stöver, Astrid Oberson

"This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No.860127"

CRUCIAL Experiment

CRUCIAL long-term experiment field
(**C**losing the **R**ural-**U**rban Nutrient **C**ycle - **I**nvestigations through **A**gronomic **L**ongterm experiments)

Soil treated for two decades with organic wastes (OW):

- Human urine
- Cattle slurry
- Deep litter
- Cattle manure
- Compost
- Sewage sludge

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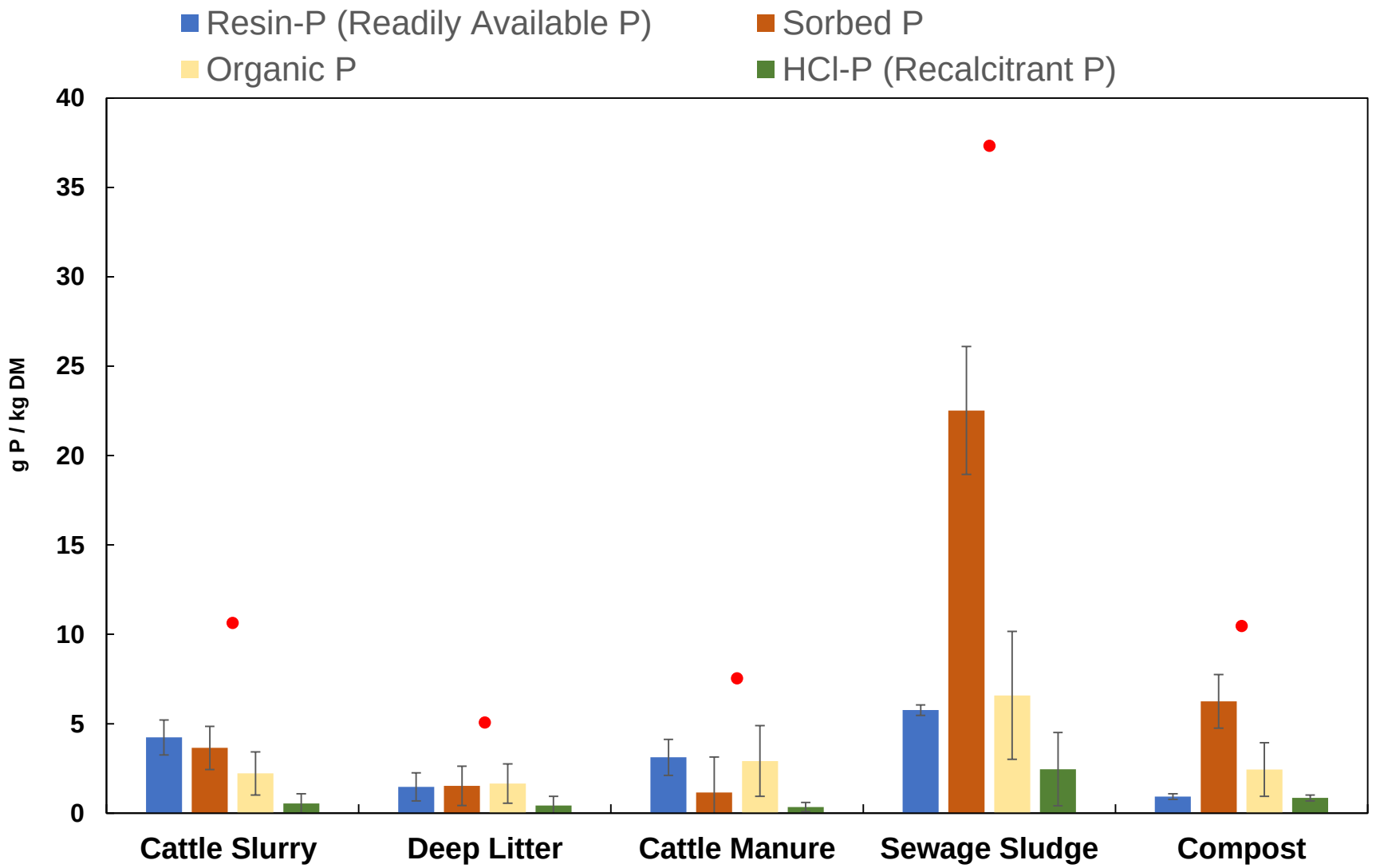
Soil treated for two decades with organic wastes (OW):

- Human urine
- Cattle slurry 45 kg P ha^{-1}
- Deep litter 98 kg P ha^{-1} Net yearly P accumulation!
- Cattle manure 174 kg P ha^{-1}
- Compost
- Sewage sludge

P-fractionation of the CRUCIAL applied wastes



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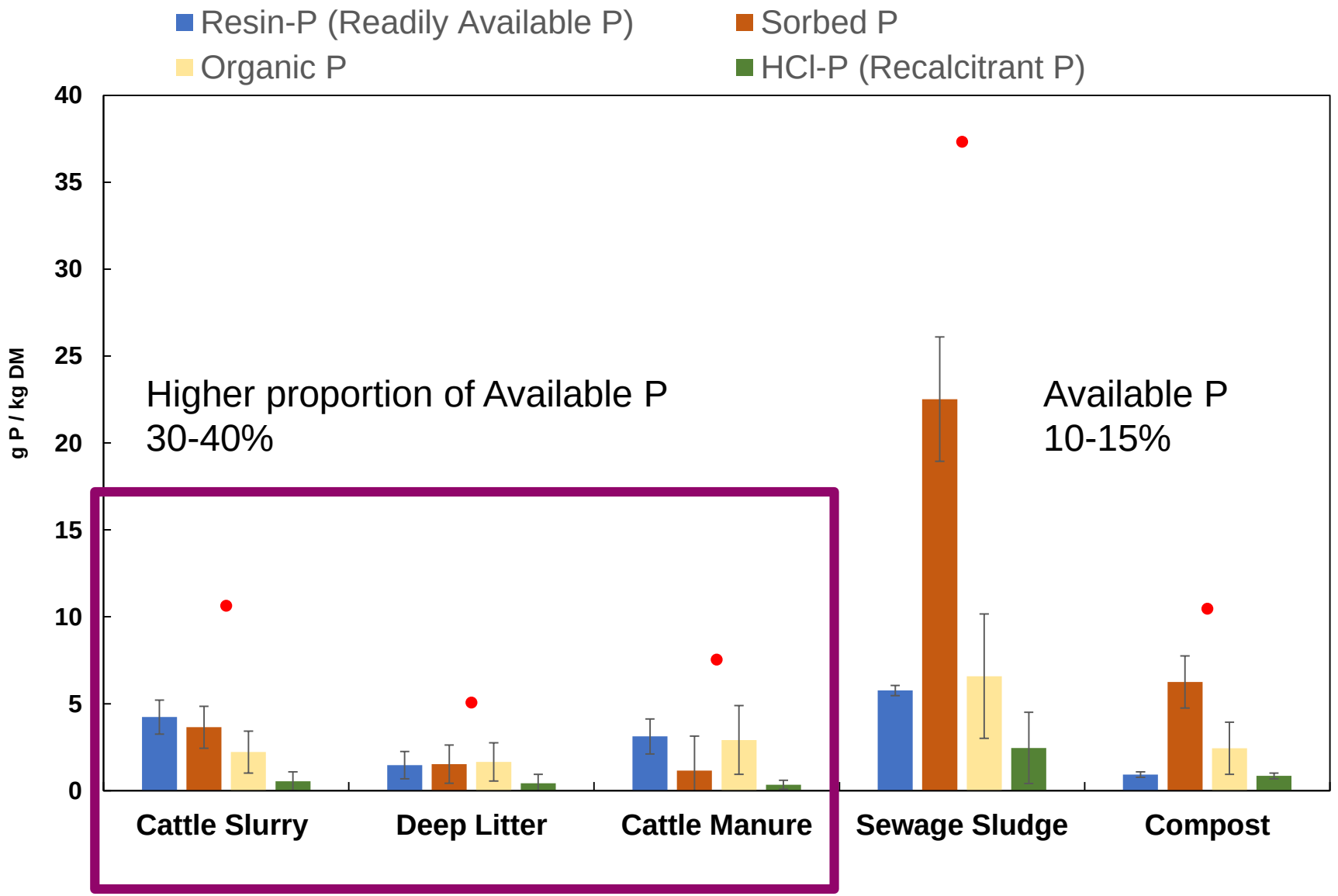
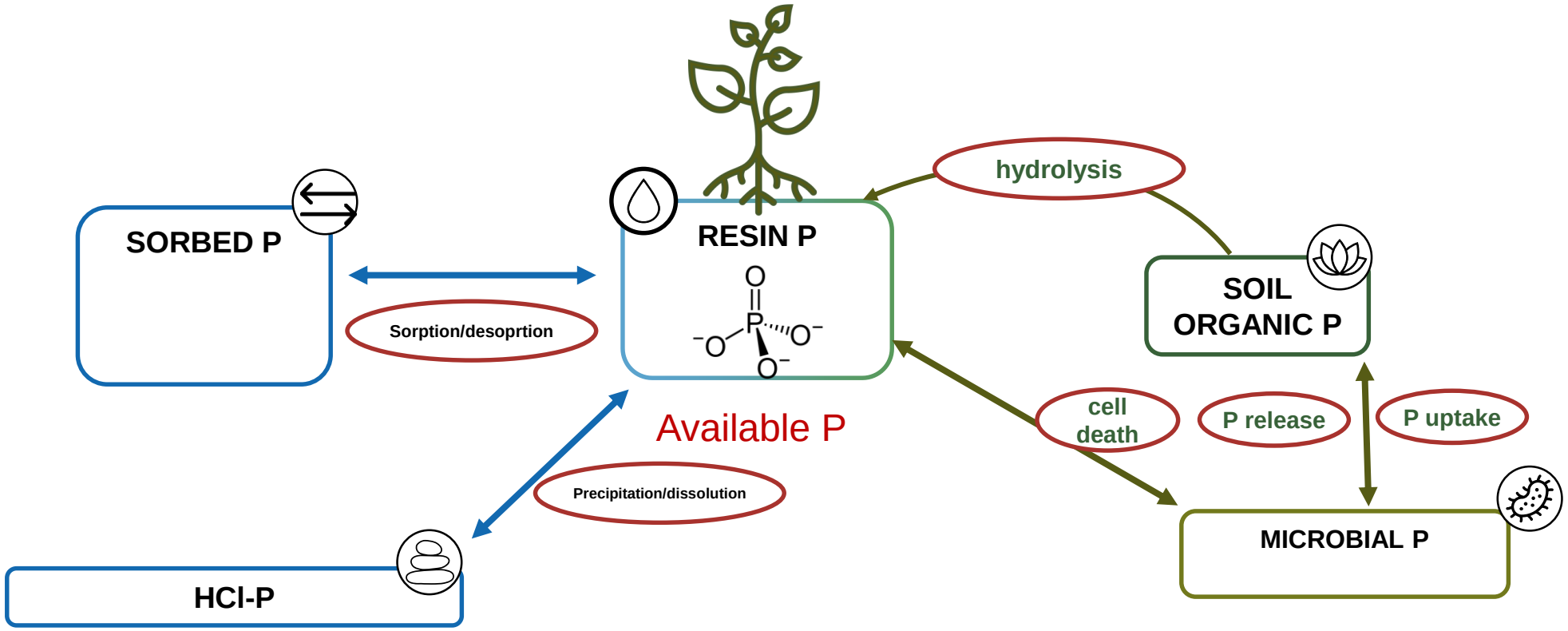
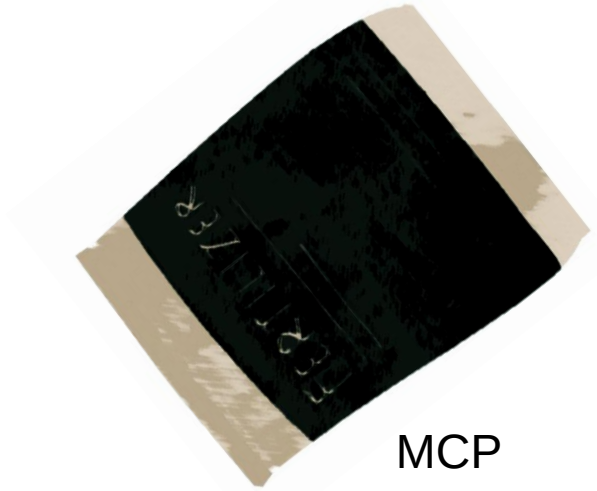


Mineral fertilizers vs organic-based

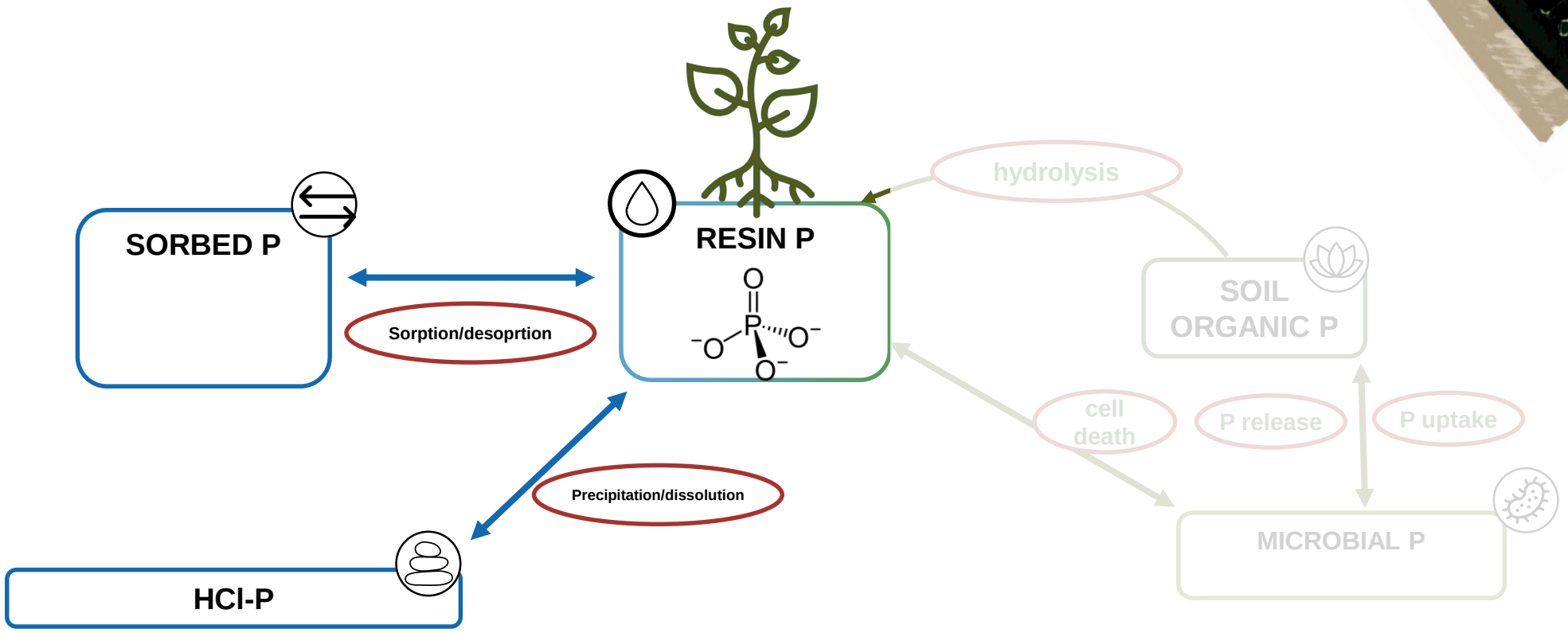


Abiotic Processes

Biotic Processes



MCP



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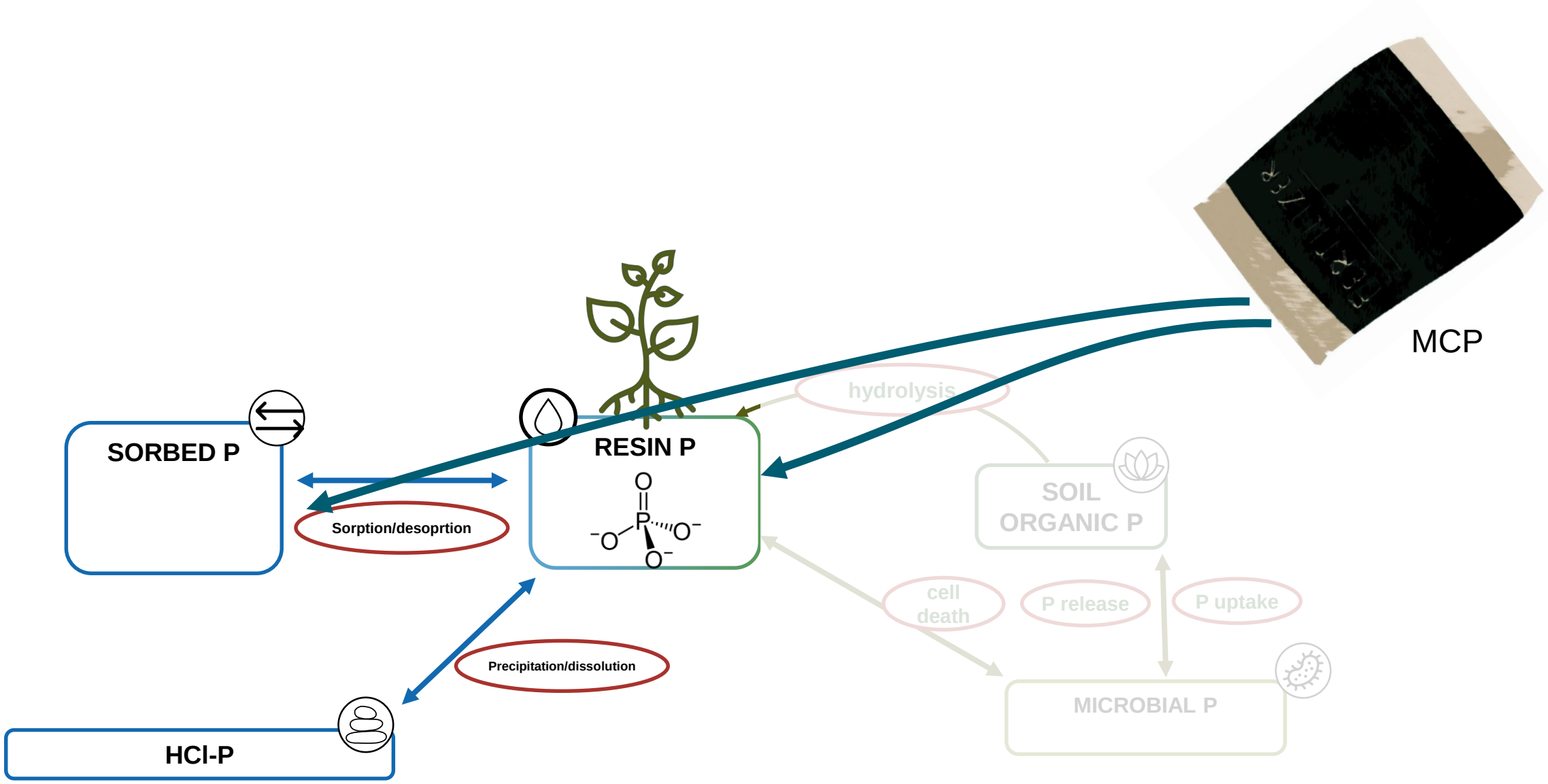

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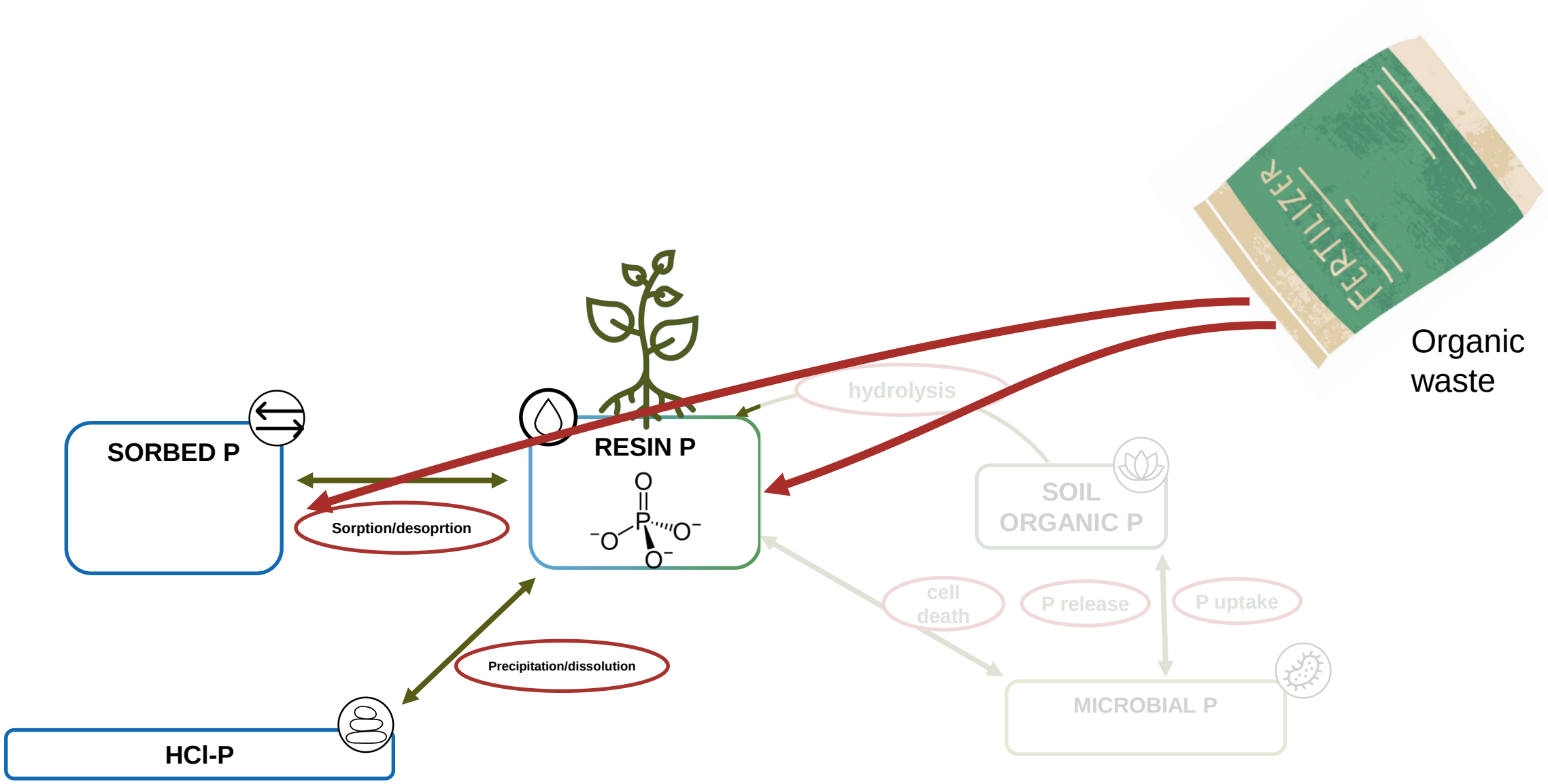
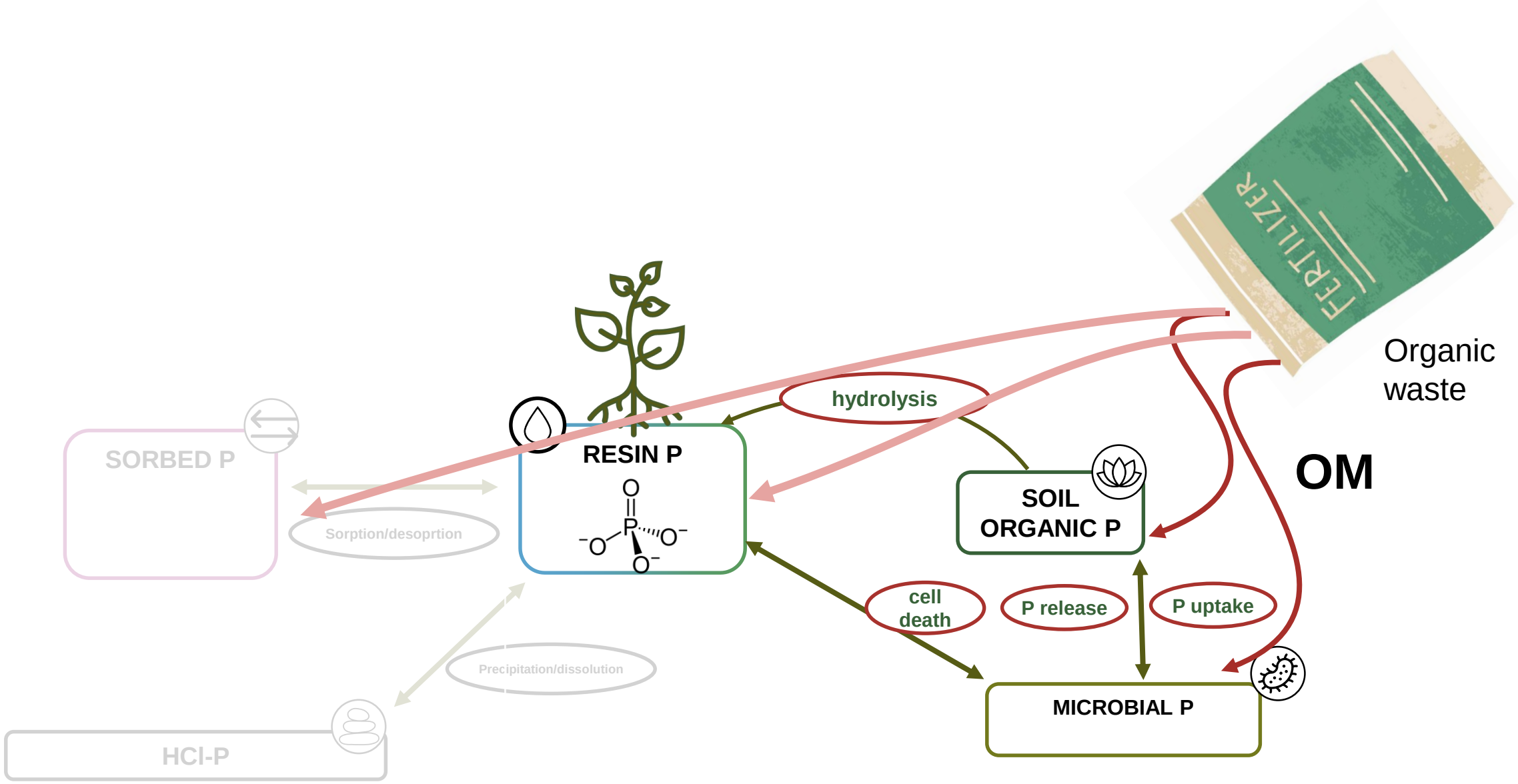
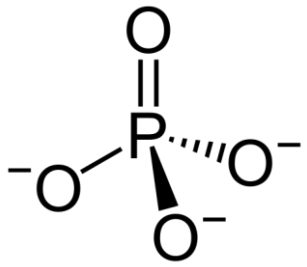
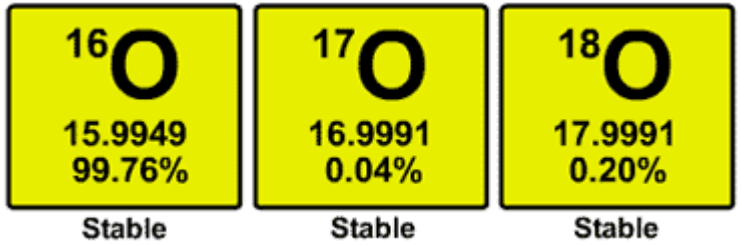
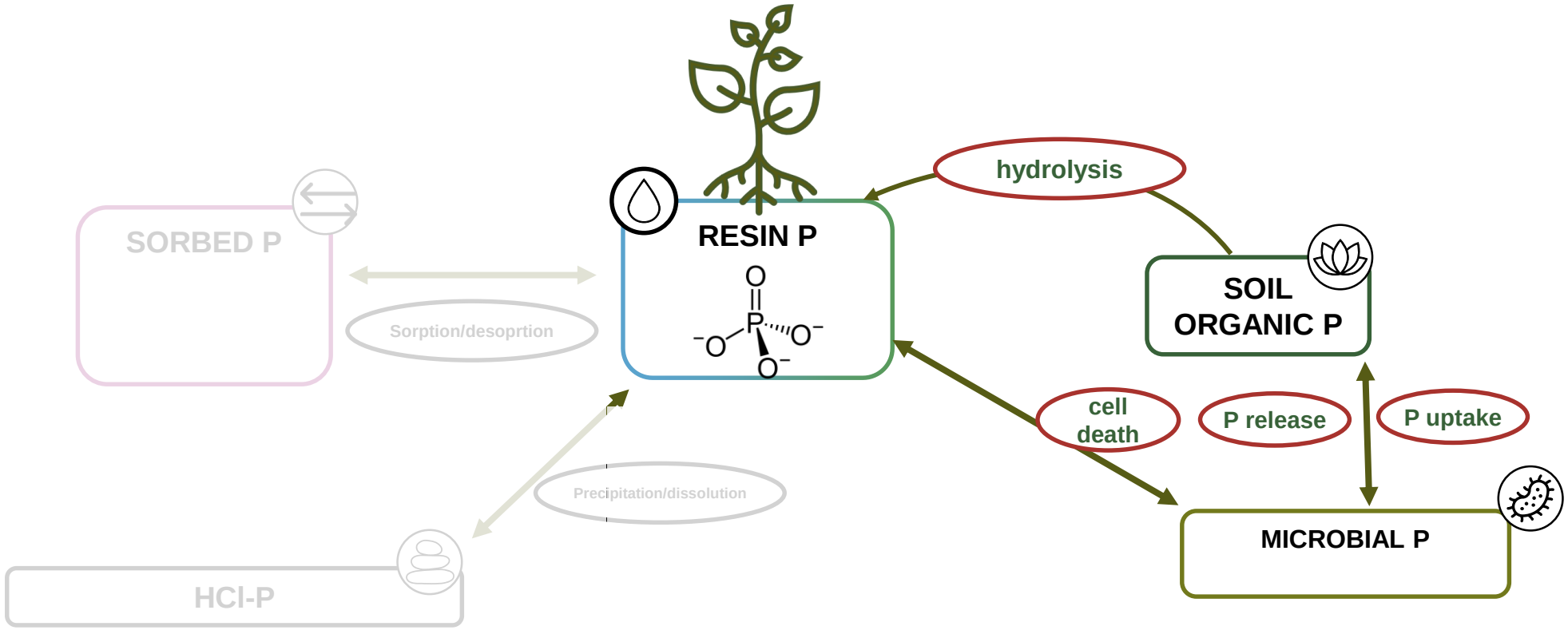


Abiotic Processes


FERTILIZER
Organic waste
OM
SORBED P
Sorption/desoprtion
RESIN P
hydrolysis
SOIL ORGANIC P
cell death
P release
P uptake
MICROBIAL P
Precipitation/dissolution
HCl-P
Abiotic Processes
Biotic Processes

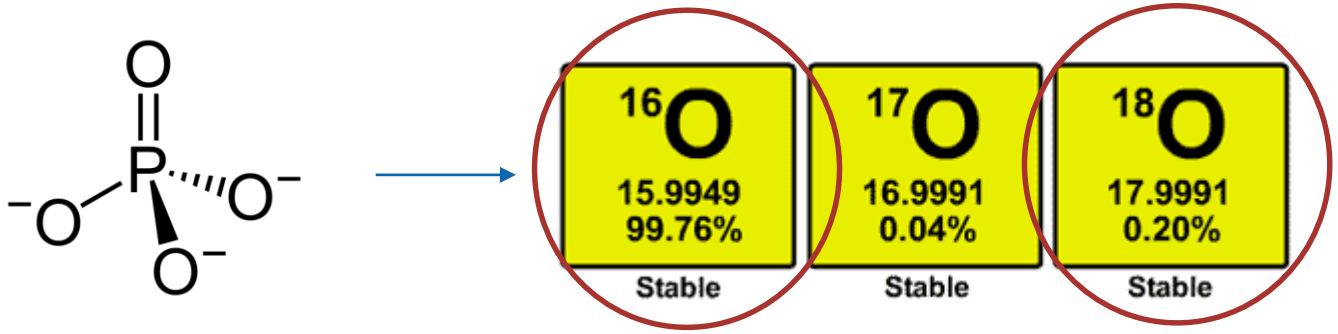




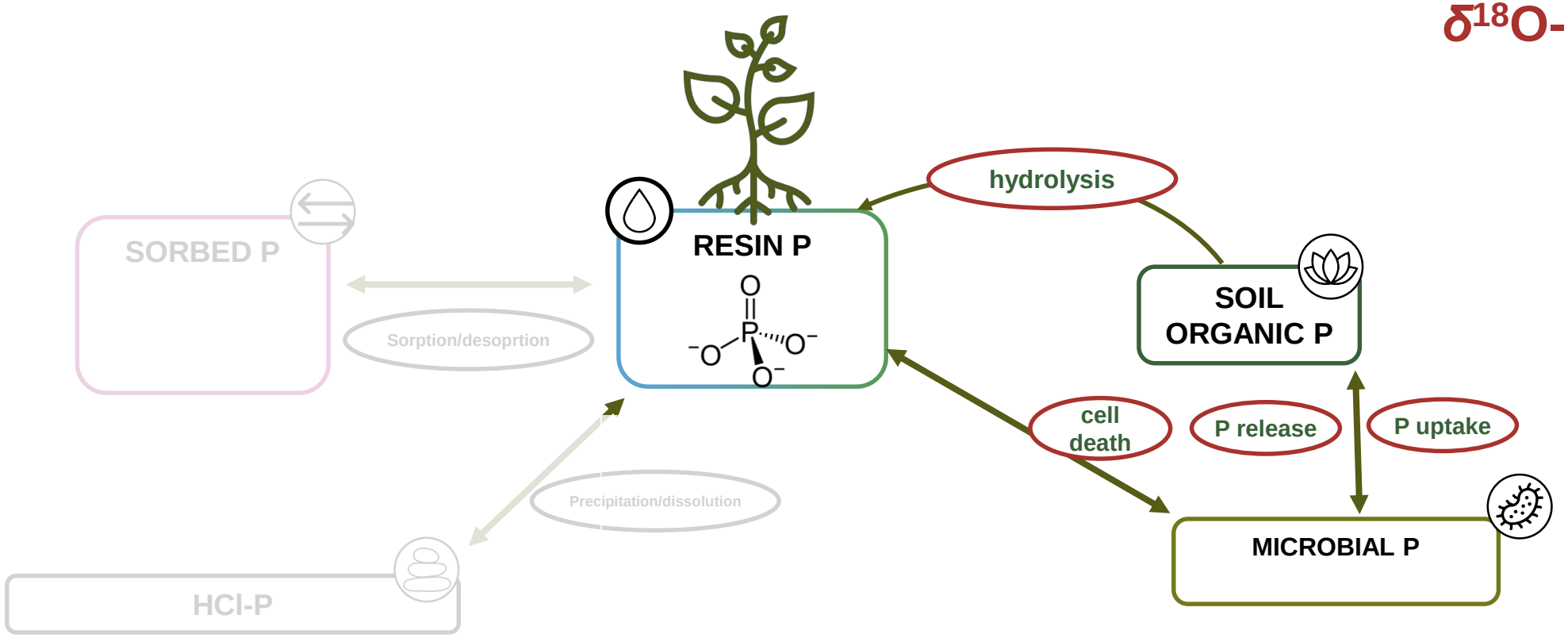


Abiotic Processes

Biotic Processes



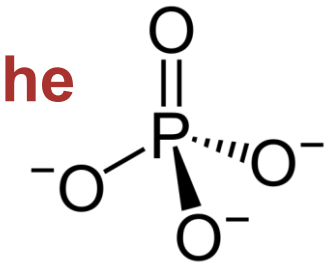
$\delta^{18}O\text{-}P$

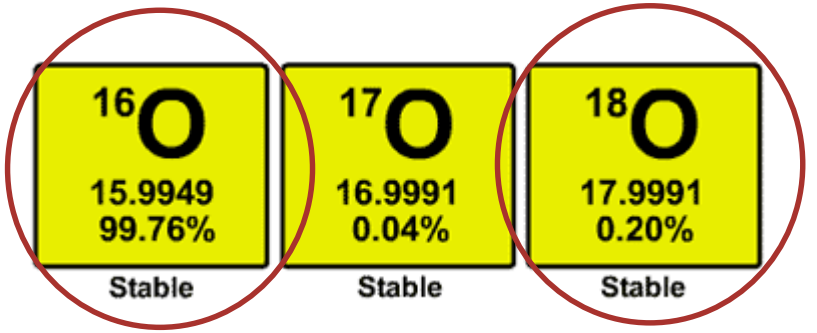


Abiotic Processes

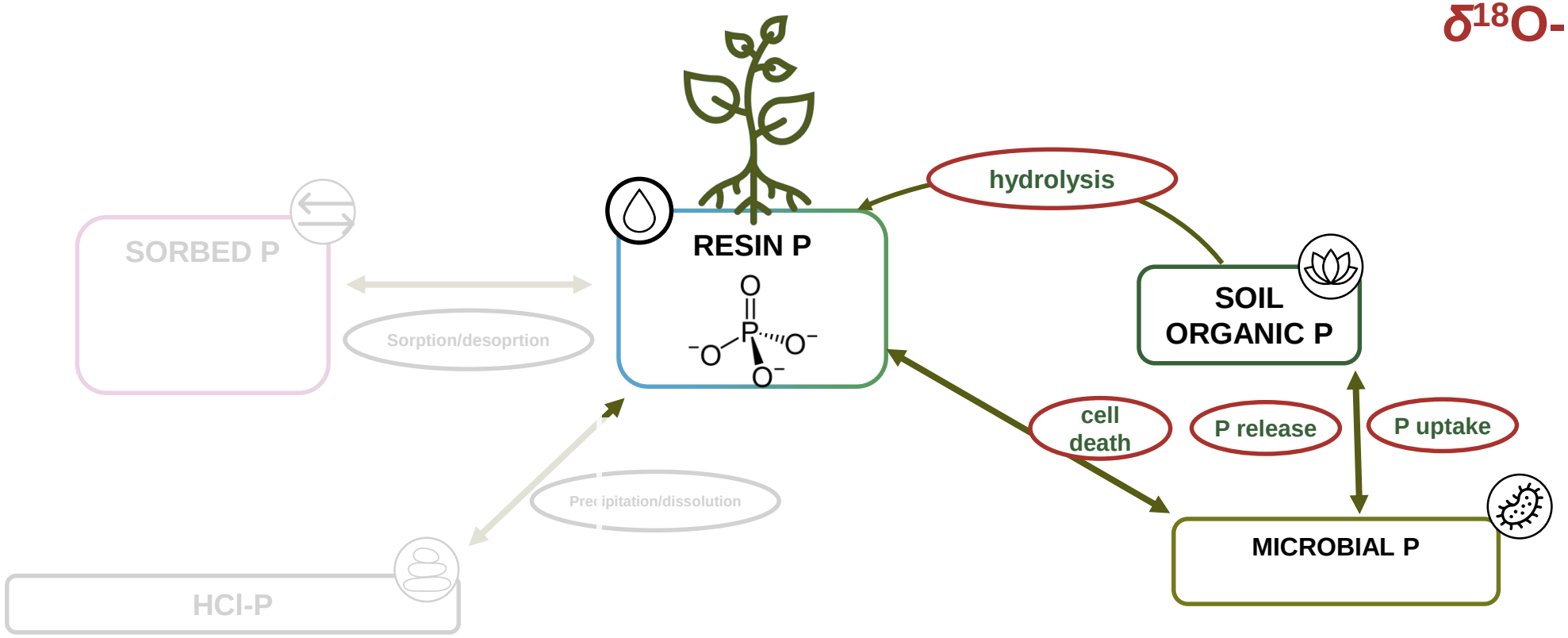
Biotic Processes

Microbial processes can “Overwrite” the δ^{18}O-P of the source.





δ^{18}O-P

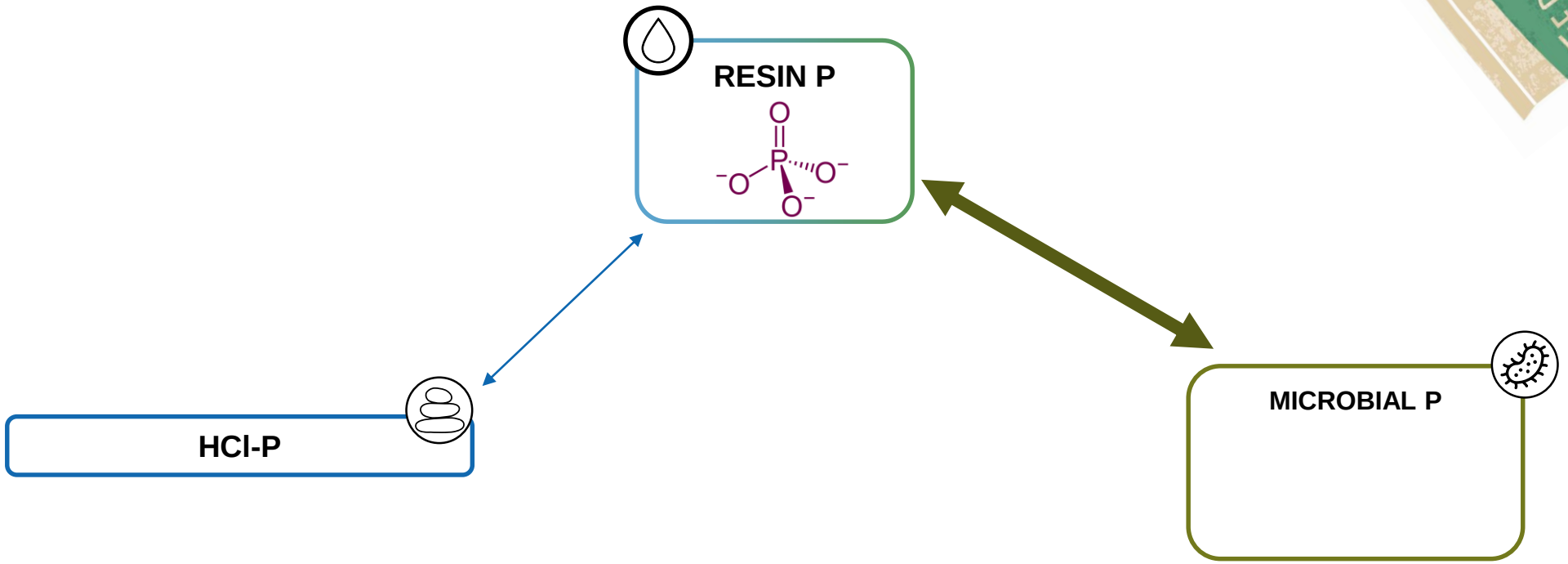


Abiotic Processes

Biotic Processes

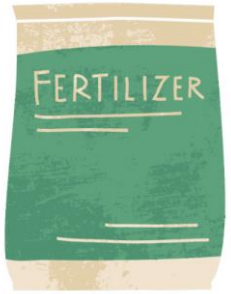
Hypothesis

Fertilizer $\delta^{18}O$-P signal in the Resin-P (available fraction) of the soil will be overwritten by microbial processes but found in the more recalcitrant pools.



Method:

We determined $\delta^{18}O$-P signals in the Resin-P fraction in the fertilizers. In soils, Resin-P, Microbial-P and HCl-P



RESIN P

Years: 2008, 2018, 2019, 2020,2021

RESIN P

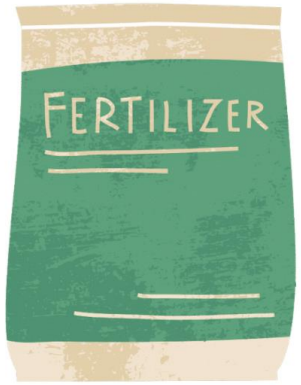
MICROBIAL P

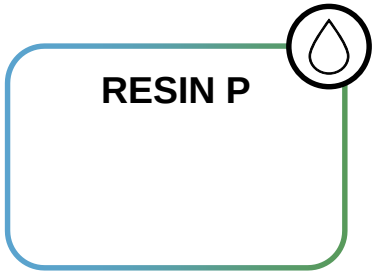
HCl-P

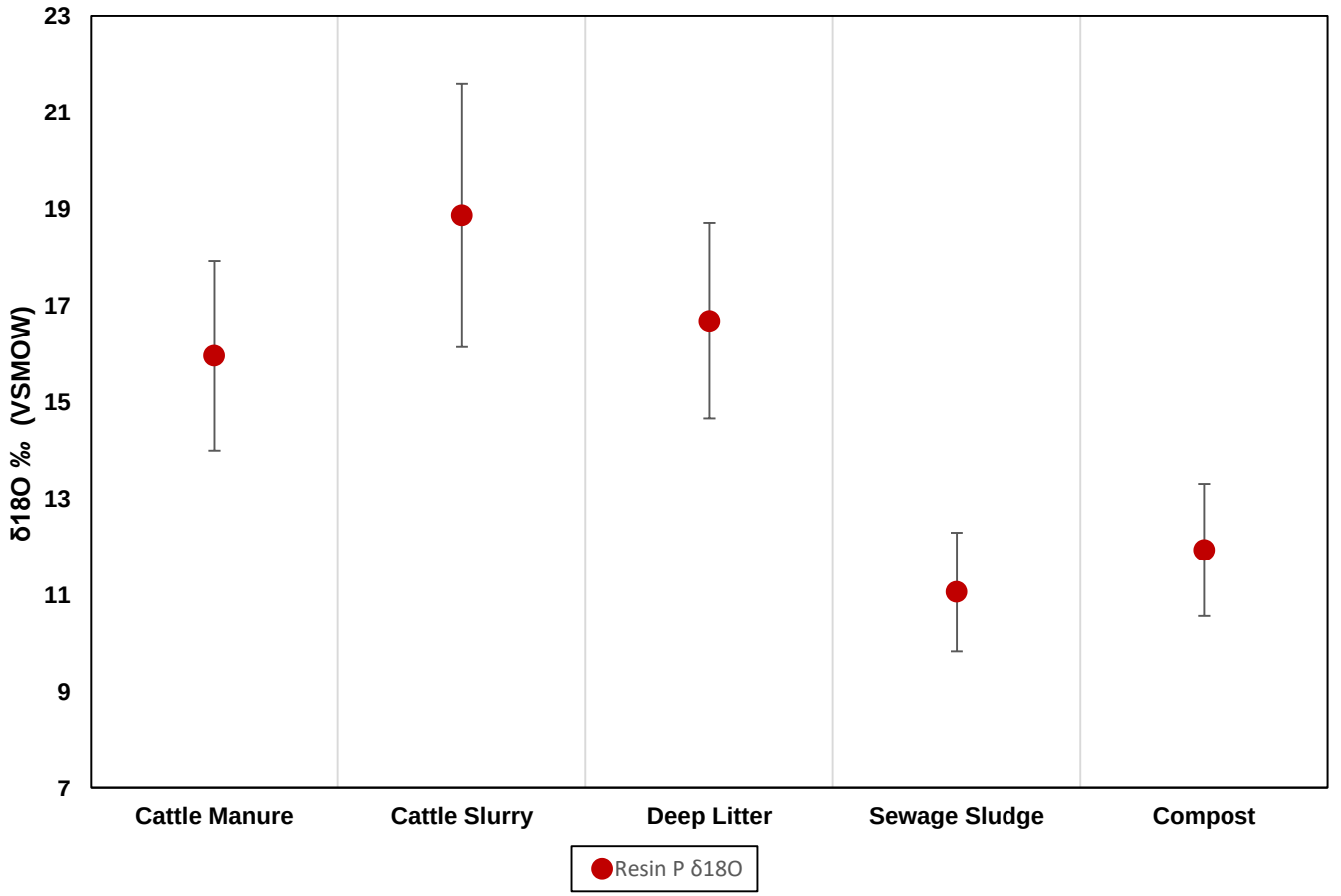
Years: March 2021 (Before the yearly fertilization), June 2021 (After the yearly fertilization)

Results:

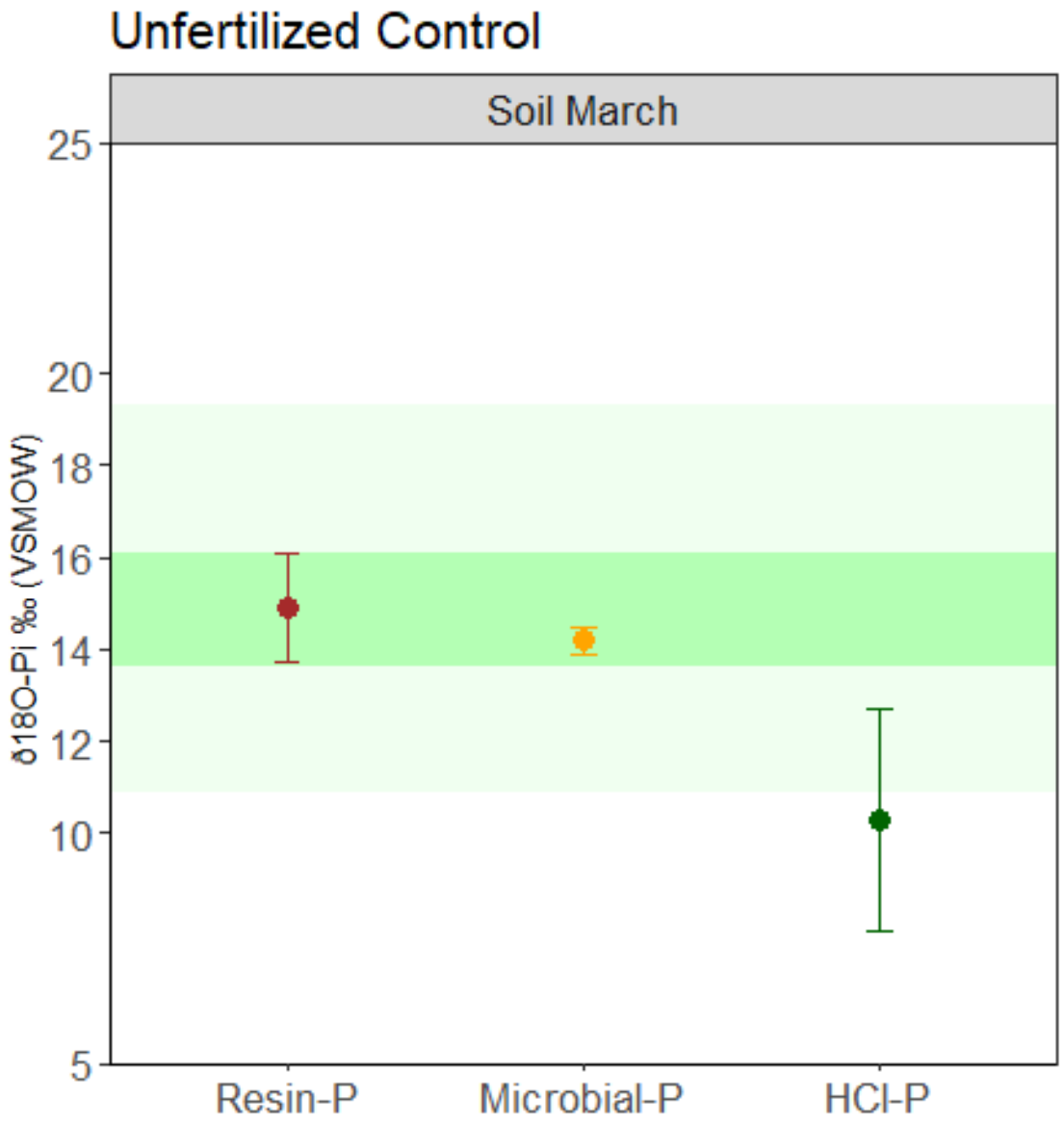
Fertilizers have distinct ranges of δ^{18}O-P signals in the Resin-P. Cattle-derived fertilizers are clearly differentiated from Sewage Sludge and Compost





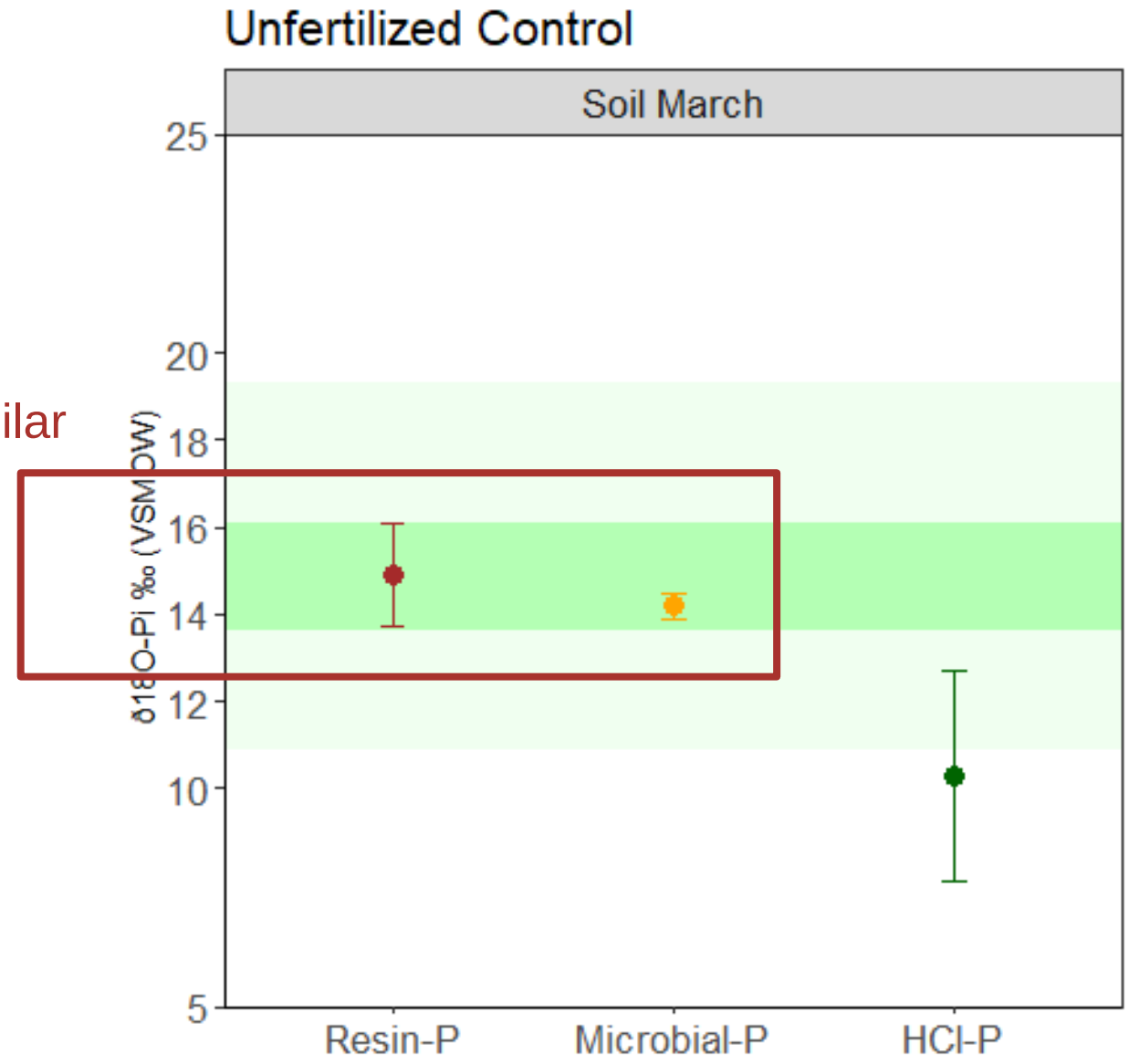


Unfertilized control soil



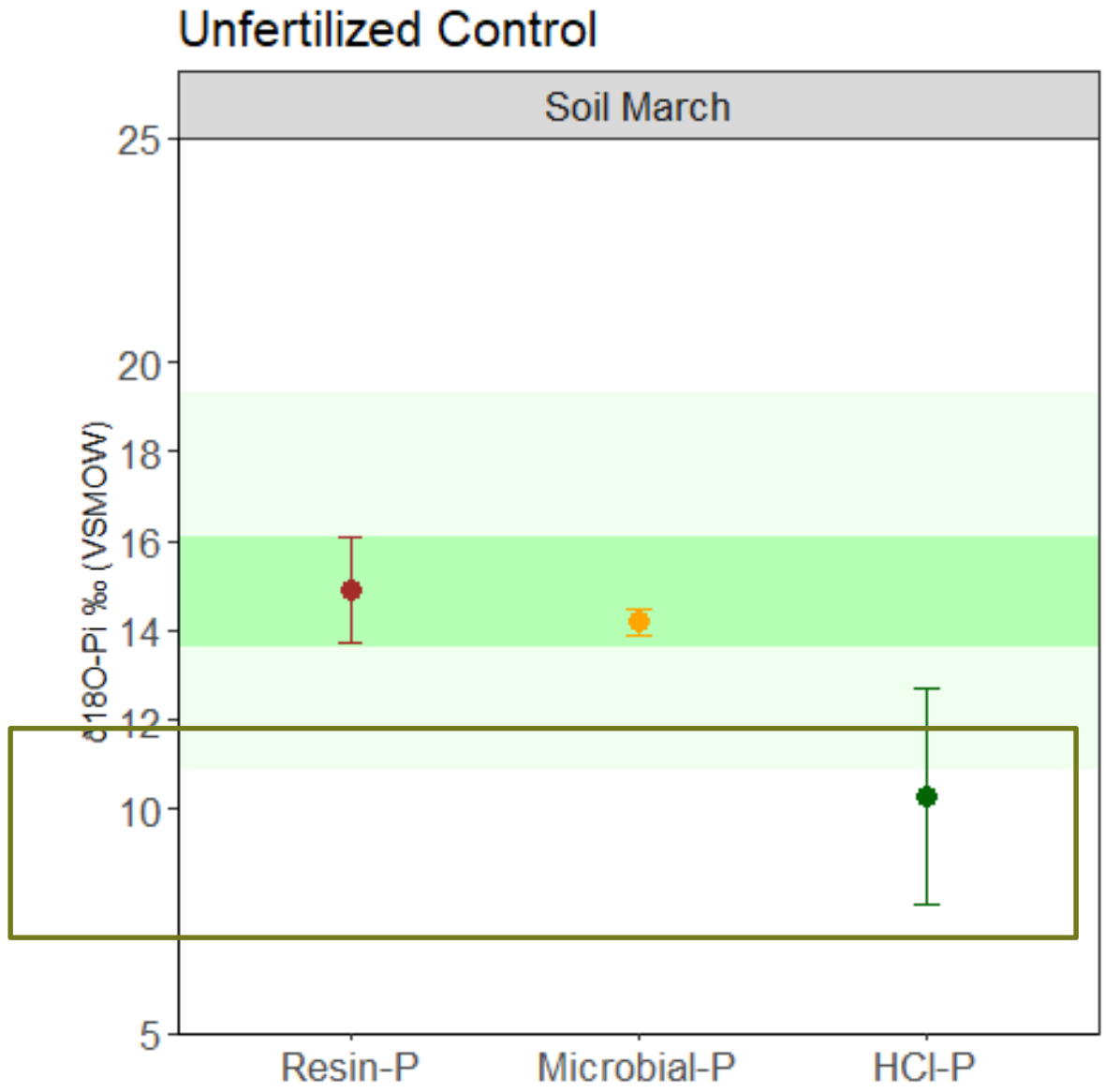
Unfertilized control soil

Resin-P
and Microbial-P
δ^{18}O-P signal is similar



Unfertilized control soil

HCl-P is clearly different from the microbial $\delta^{18}O$-P.




Cattle Slurry
Fertilizer
Soil March
Soil June
δ18O-Pi ‰ (VSMOW)
25
20
18
16
14
12
10
5
FERTILIZER
Resin-P
Resin-P
HCl-P
Resin-P
HCl-P

Resin-P values in soils are similar to fertilizer values

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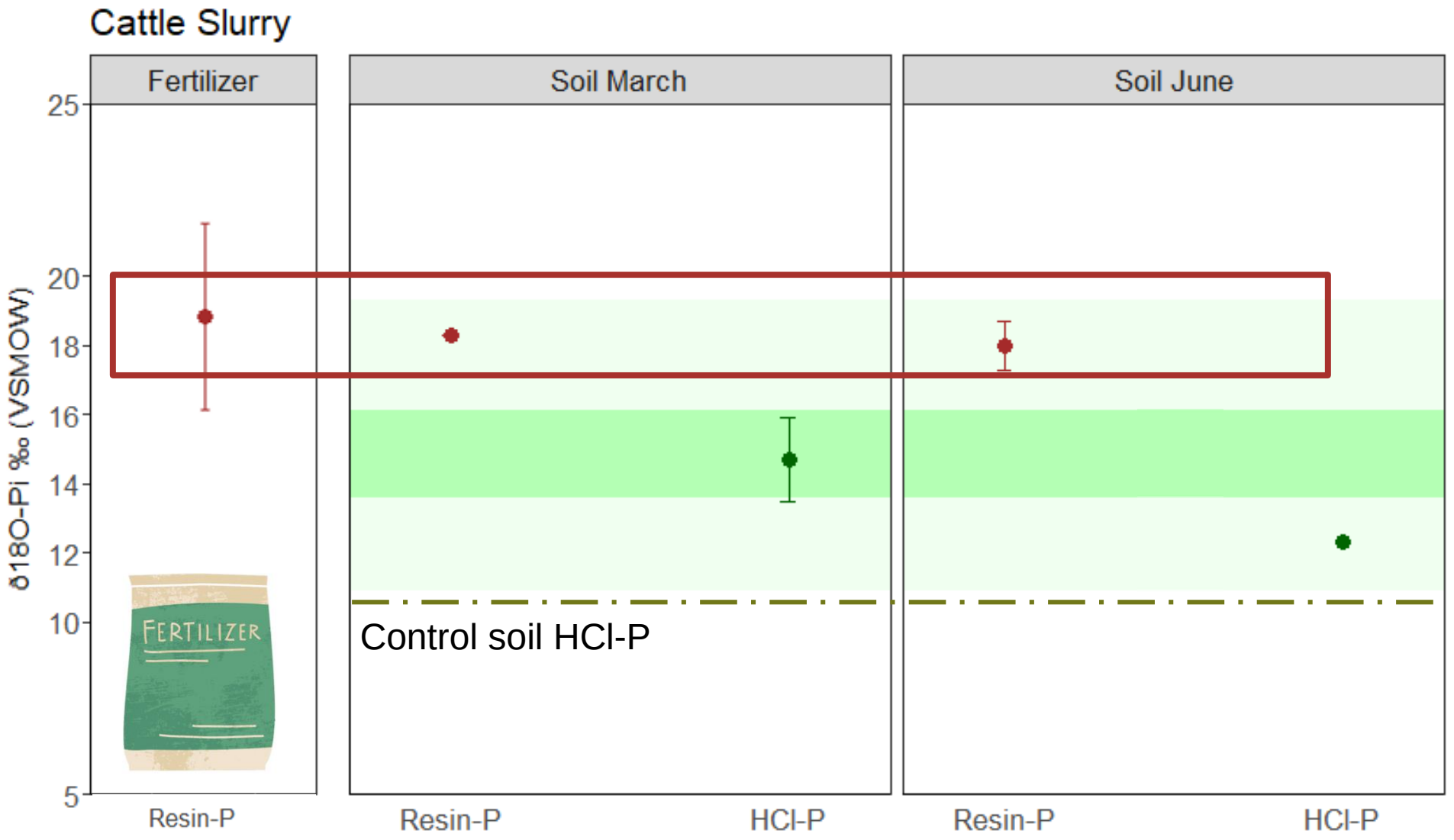
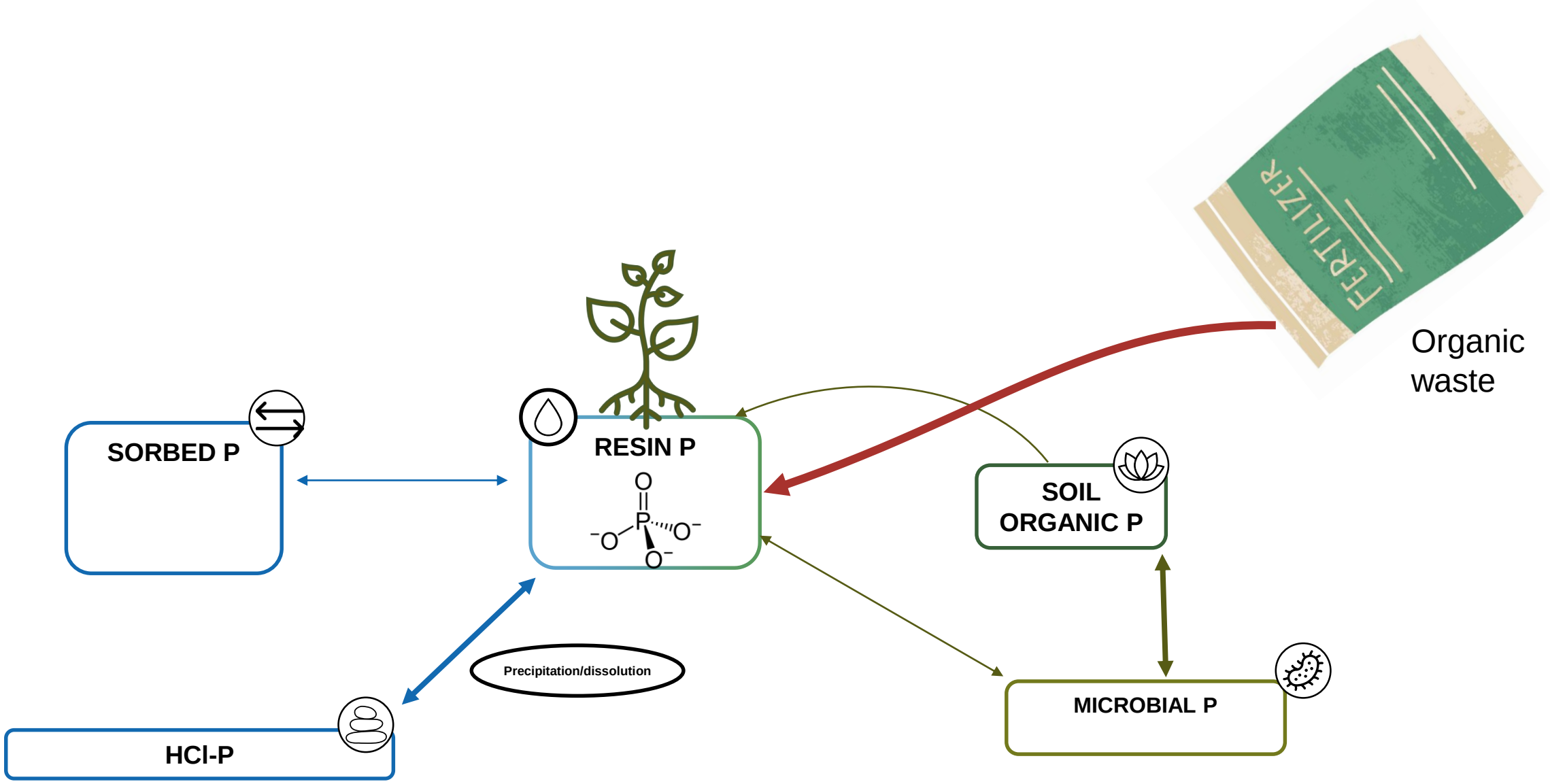
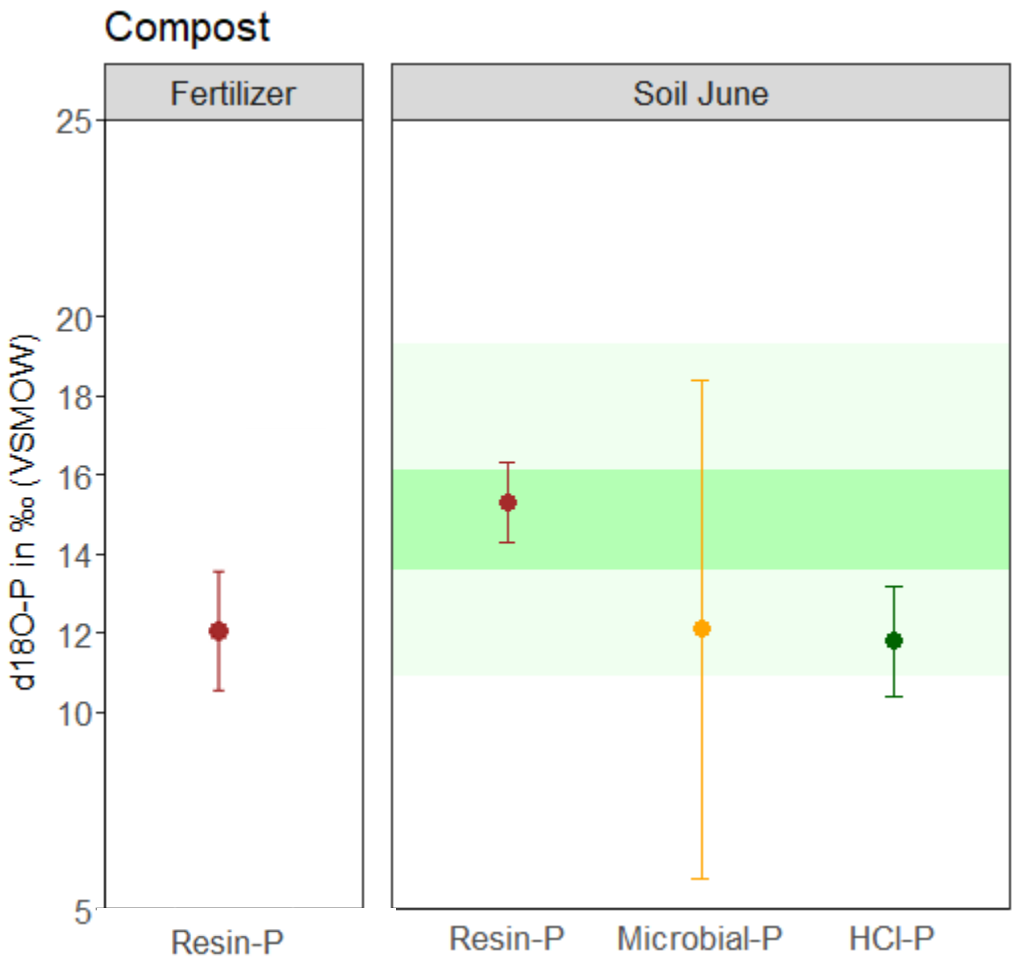
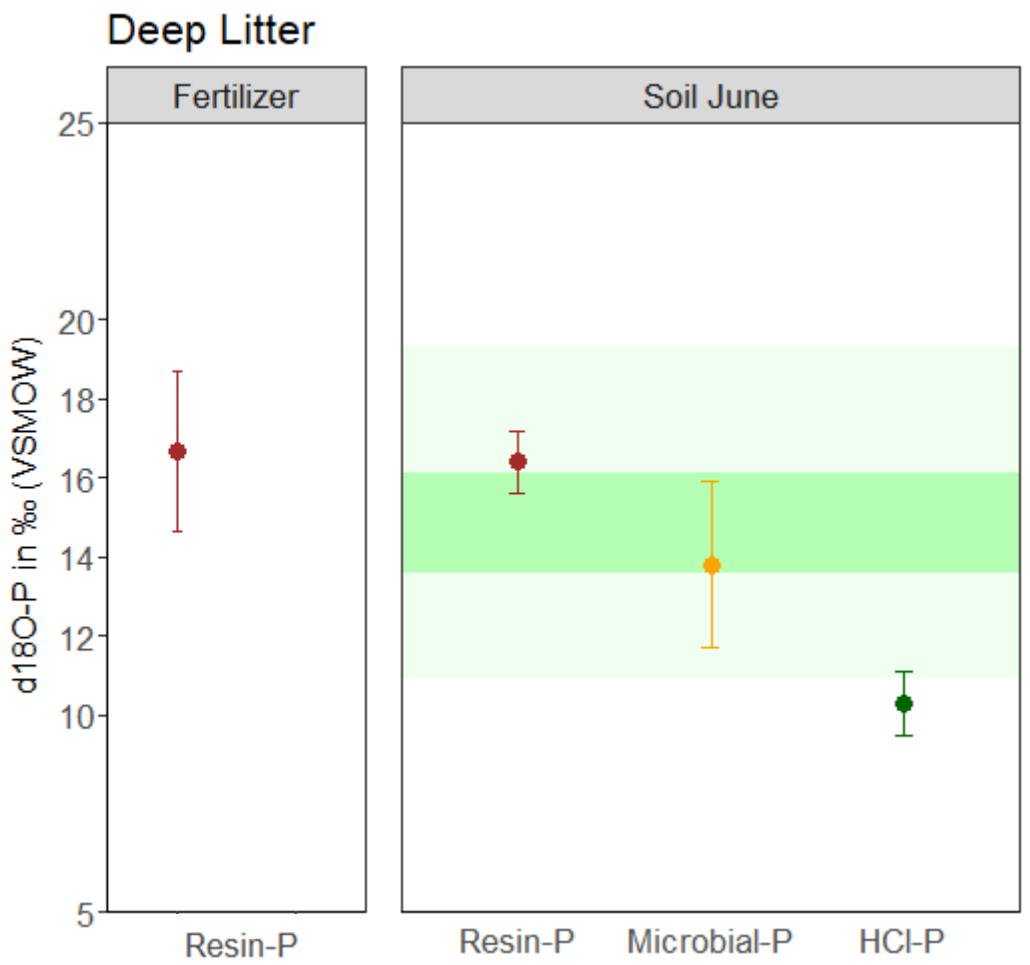


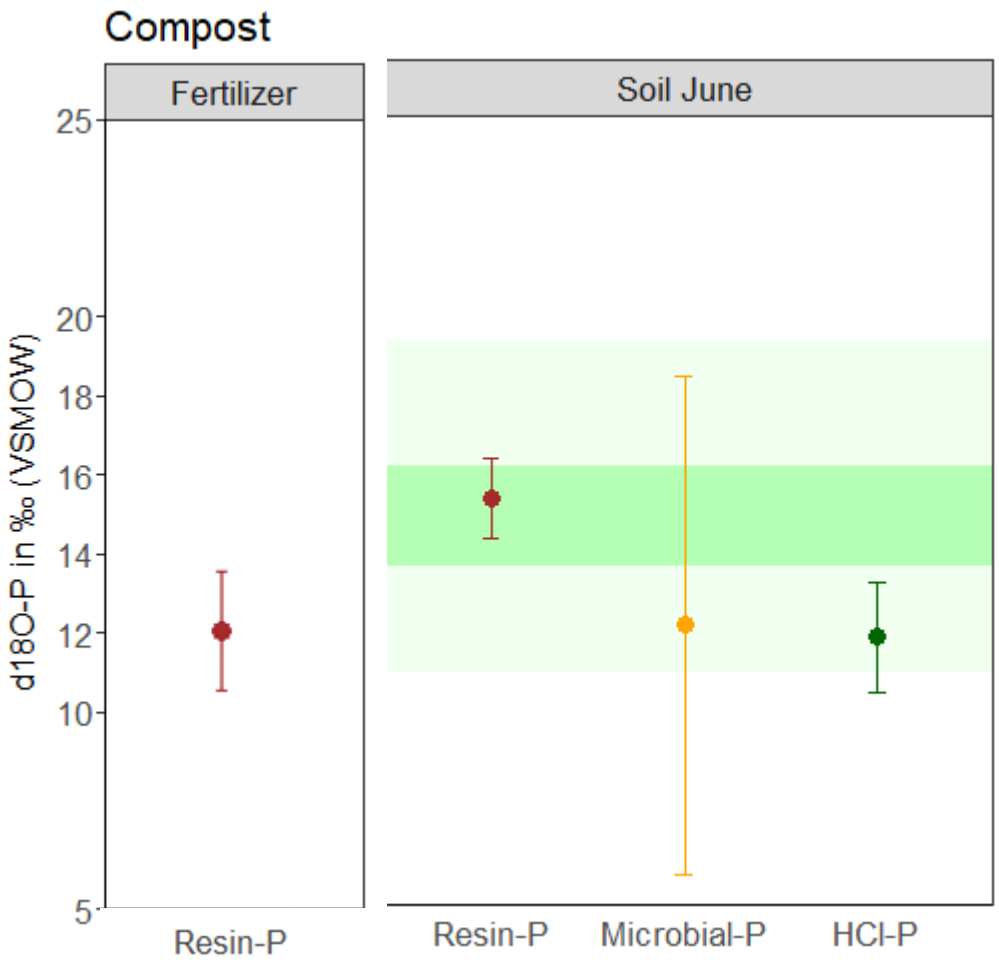


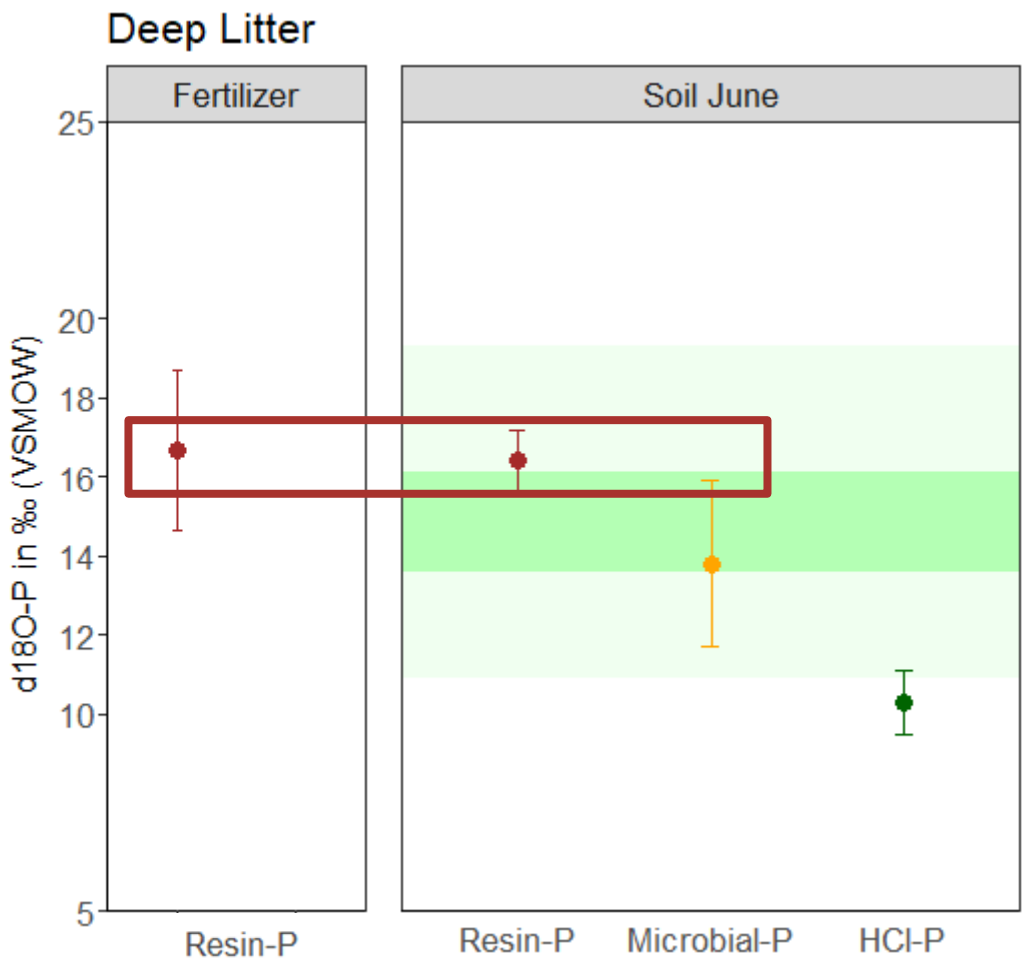
Abiotic Processes

Biotic Processes

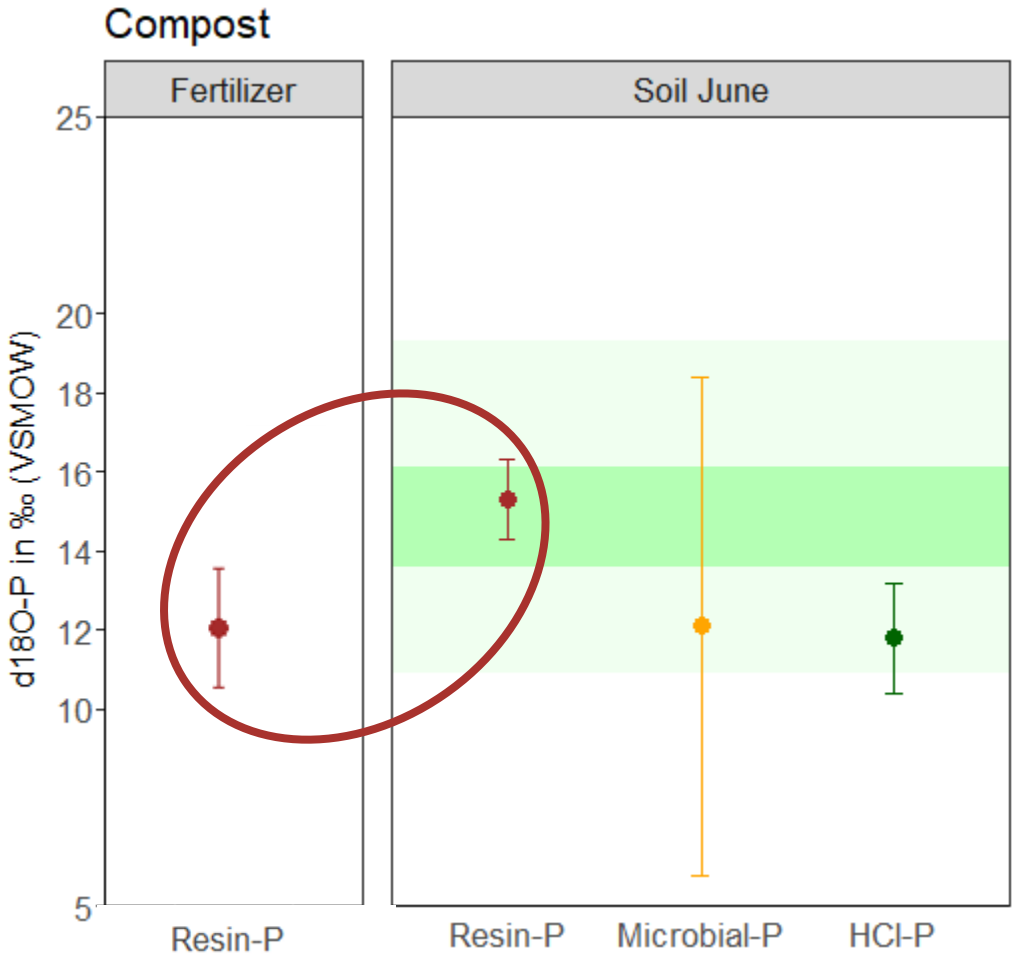

Compost
Fertilizer
Soil June
d18O-P in ‰ (VSMOW)
25
20
18
16
14
12
10
5
Resin-P
Resin-P
Microbial-P
HCl-P

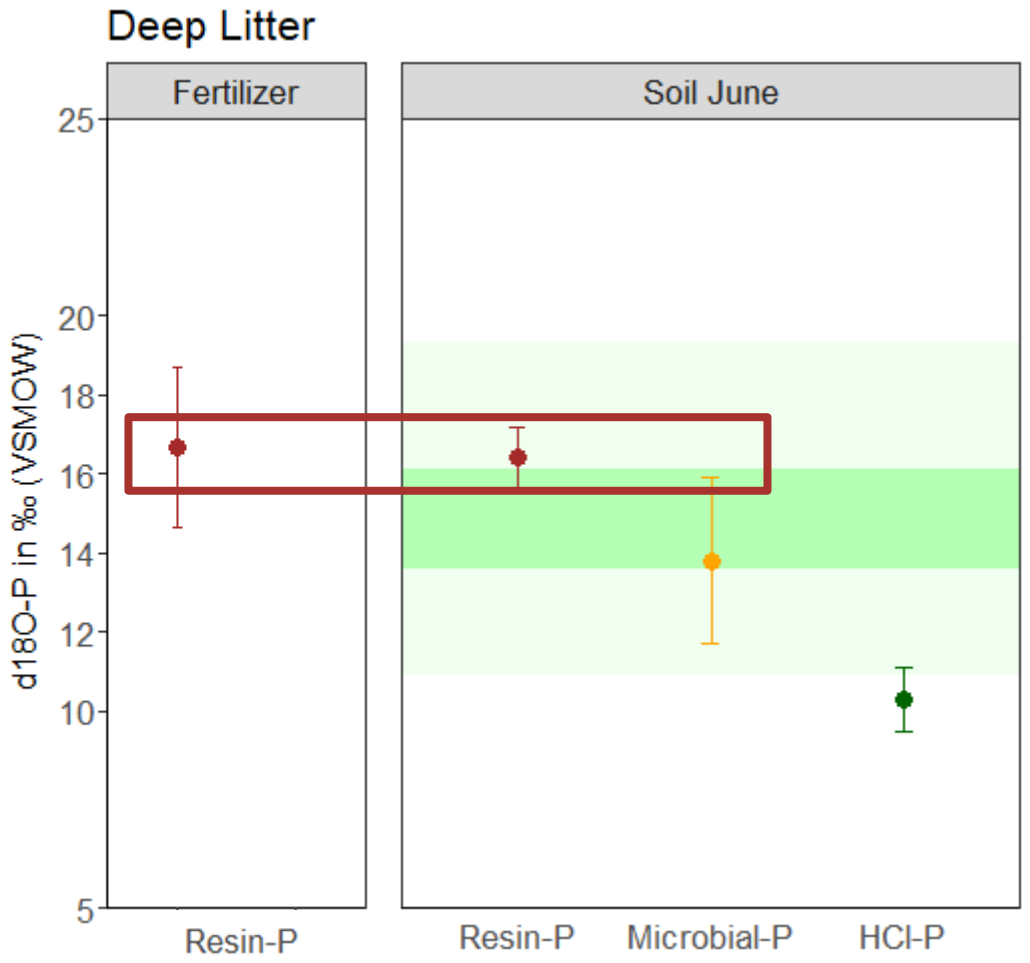

Deep Litter
Fertilizer
Soil June
d18O-P in ‰ (VSMOW)
25
20
18
16
14
12
10
5
Resin-P
Resin-P
Microbial-P
HCl-P


Compost
Fertilizer
Soil June
d18O-P in ‰ (VSMOW)
25
20
18
16
14
12
10
5
Resin-P
Resin-P
Microbial-P
HCl-P

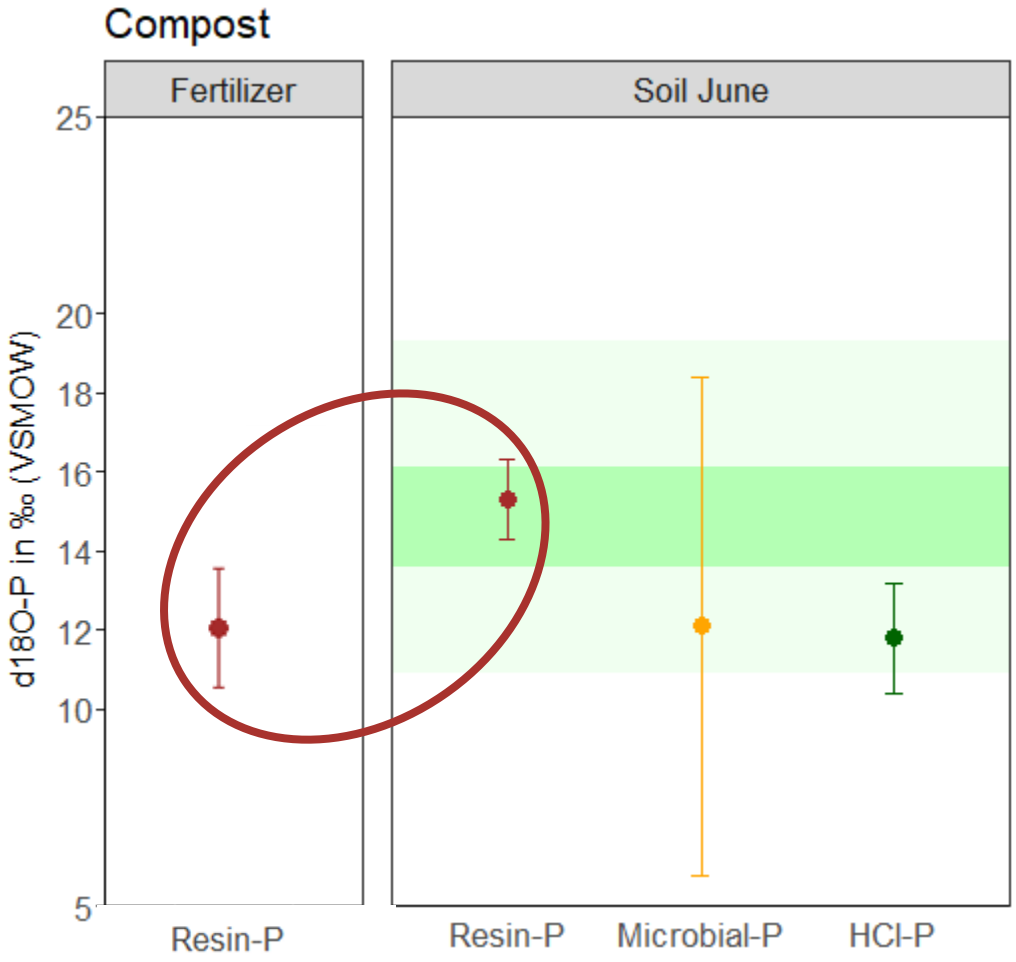

Deep Litter
Fertilizer
Soil June
d18O-P in ‰ (VSMOW)
25
20
18
16
14
12
10
5
Resin-P
Resin-P
Microbial-P
HCl-P

Effect is clearer for cattle-derived fertilizers. Deep Litter Resin-P is 40% of total P.





Compost contains a smaller proportion of Resin-P (10%).



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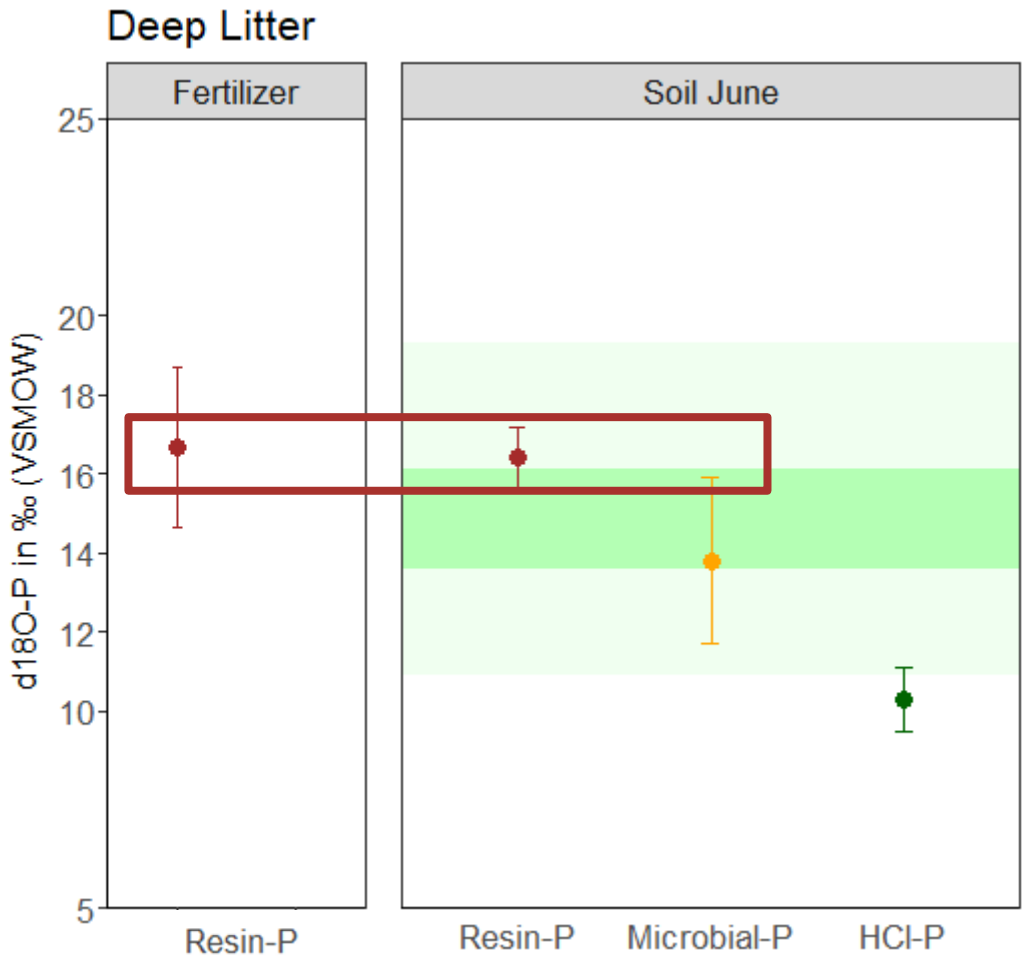

Conclusions:

- Each fertilizer will deliver specific amounts of the different P forms
- When the proportion of resin-P from fertilizer is high (30-40%) the 18O-P of the fertilizer is traceable in the soil.
- When the proportion of resin-P from fertilizer is low (10%), microbial processes will overwrite it.

- Environmental implications: Accumulated P difficult to access to microbial processes.

Funding:

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Thank you!

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	Average Yearly Applications in kg/ha * a										
Treatment	**% of Dry Matter in FM***	**Fertilizer Fresh Matter ***	**Fertilizer Dry Matter**	**P ****	**Resin P**	**Sorbed P**	**Organic P**	**HCl P**	**N ****	**C ****	**S****
Cattle Slurry	8	53000	4240	45	18.0	15.5	9.4	2.3	105	1532	25
Deep Litter	38	48000	18240	92	26.8	27.8	30.1	7.7	348	6579	69
Cattle Manure	26	89000	23140	174	72.2	26.8	67.4	7.9	580	9155	93
Sewage Sludge	31	19000	5890	219	33.9	132.7	38.8	14.5	239	1725	80
Compost	68	33000	22440	234	20.8	140.2	54.8	19.0	534	5115	84
Sewage Sludge acel.	31	52000	16120	601	92.9	363.1	106.1	39.6	654	4722	220
Compost accel.	68	100000	68000	711	63.1	424.8	165.9	57.6	1620	15500	254

AYA = Average yearly application of

FM = Fresh Matter

DM = Dry Matter

* According to Lemming 2019

** Yearly input of these elements (AVG 2008, 2018 and 2019)

Deep Litter

CRUCIAL Deep Litter consists of mainly straw bedding material soaked with urine mixed with dairy farmyard cattle feces (Lemming et al., 2019).

Deep litter is basically an in-situ compost

- Carbon-based litter material (Straw)
- Constant removal and aeration caused by animals.
- Aerobic composting

Treatment		Average yearly		
		P input	P offtake	P balance
Abbrev.	Description	(kg P ha^{-1} yr^{-1})		
GM	Unfertilized, w.green manure	0 ± 0	13.3 ± 0.8	−13.3 ± 0.8
U	Unfertilized	0 ± 0	10.7 ± 0.5	−10.7 ± 0.5
NPK-R	NPK – retired	12 ± 0	22.2 ± 0.2	−10.6 ± 0.2
NPK	NPK	16 ± 0	23.5 ± 0.3	−8.0 ± 0.3
HU	Human urine	13 ± 1	23.4 ± 0.3	−10.7 ± 1.5
CS	Cattle slurry	37 ± 4	19.9 ± 2.0	16.9 ± 5.3
DL-R	Deep litter – retired	74 ± 22	20.9 ± 0.3	53.0 ± 22
DL	Deep litter	98 ± 29	20.1 ± 0.0	77.7 ± 29
CMA-R	Cattle manure – retired	115 ± 46	22.3 ± 1.3	93.0 ± 36
CMA	Cattle manure	140 ± 61	22.9 ± 1.2	117.4 ± 48
CH-R	Compost – retired	99 ± 44	20.1 ± 0.7	78.7 ± 44
CH	Compost	131 ± 58	19.7 ± 0.7	111.4 ± 58
CHA-R	Compost accelerated – retired	298 ± 132	23.4 ± 1.6	274.6 ± 133
CHA	Compost accelerated	397 ± 176	23.3 ± 1.7	373.3 ± 177
S-R	Sludge – retired	169 ± 12	20.7 ± 1.4	148.1 ± 14
S	Sludge	224 ± 17	21.3 ± 1.1	203.0 ± 17
SA-R	Sludge accelerated – retired	466 ± 36	23.5 ± 0.4	442.9 ± 40
SA	Sludge accelerated	621 ± 47	23.6 ± 0.7	597.5 ± 49