Next Generation Dairying Workshop 2021

23 November 2021

Agronomic value of recycled nutrients from dairy processing sludge - case of the research field trials in Ireland

Dr. S.M. Ashekuzzaman, MCIWEM

Teagasc, Environment Research Centre

Johnstown Castle, Wexford, Ireland

@SM_Ashek

Teagasc

Agriculture and Food Development Authority

Nutri2Cycle

Transition towards a more carbon and nutrient efficient agriculture in Europe

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Context: Dairy processing sludge?

Journal of Cleaner Production 230 (2019) 1266–1275
Contents lists available at ScienceDirect
Journal of Cleaner Production
journal homepage: www.elsevier.com/locate/jclepro

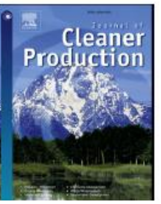
Dairy industry derived wastewater treatment sludge: Generation, type and characterization of nutrients and metals for agricultural reuse

S.M. Ashekuzzaman[*,1], Patrick Forrestal, Karl Richards, Owen Fenton
...asc, Environment Research Centre, Johnstown Castle, Co. Wexford, Ireland

Influ
BOD
COD:
TN: 83
TP: 280
SS: 4500

Effluent quality:
BOD: 16 mg L^{-1}
COD: 125 mg L^{-1}
TN: 5–25 mg L^{-1}
TP: 2–5 mg L^{-1}
SS: 30 mg L^{-1}

Facts & Figures: Volume generation and disposal?



Dairy processing sludge and co-products: A review of present and future re-use pathways in agriculture

W. Shi [a,b], M.G. Healy [b], S.M. Ashekuzzaman [a], K. Daly [a], J.J. Leahy [c], O. Fenton [a,b,*]

[a] Teagasc, Environmental Research Centre, Johnstown Castle, Co., Wexford, Ireland
[b] Civil Engineering and Ryan Institute, College of Science and Engineering, National University of Ireland Galway, Galway, Ireland
[c] Chemical and Environmental Science, University of Limerick, Limerick, Ireland

Journal of Cleaner Production 314 (2021) 128035

frontiers in Sustainable Food Systems

SYSTEMATIC REVIEW
published: 10 November 2021
doi: 10.3389/fsufs.2021.763020

Systematic Review of Dairy Processing Sludge and Secondary STRUBIAS Products Used in Agriculture

Yihuai Hu [1], Olha Khomenko [2,3], Wenxuan Shi [2,4], Ángel Velasco-Sánchez [5,6], S. M. Ashekuzzaman [2], Nadia Bennegadi-Laurent [5], Karen Daly [2], Owen Fenton [2*], Mark G. Healy [4], J. J. Leahy [3], Peter Sørensen [7], Sven G. Sommer [1], Arezoo Taghizadeh-Toosi [8] and Isabelle Trinsoutrot-Gattin [5]

DPS generation (per unit volume/mass of processed milk) and disposal pathways in different countries.

Region	Water consumption	Effluents loads	DPS volume	Method of Disposal
EU	0.2–11 L/L processed milk	0.3×10^6–3×10^6 L (in a factory with capacity:10^6L milk/day)	1-3t dry matter sludge (in a factory with capacity: 10^6L milk/day)	Wastewater: drained to river sludge: land spread
EU	0.8–60 m^3/t processed milk	0.9–60 $m3^3$/t processed milk	0.2–30 kg sludge/t processed milk	–
Sweden	0.96–4.0 L/L processed milk	0.86–4.3 L/L processed milk	–	Landfill, compost, irrigation, biogas production. In Denmark, 2/3 sludge from dairies is irrigated on cultivated land and the rest is utilized in biogas production.
Denmark	0.60–1.9 L/L processed milk	0.75–1.5 L/L processed milk	–	
Finland	1.2–4.6 L/L processed milk	1.2–3.9 L/L processed milk	–	
Norway	2.5–6.3 L/L processed milk	2.0–3.3 L/L processed milk	–	
Ireland	2.3 m^3/m^3 processed milk	2.71 ± 0.9 L/L processed milk	15–19.7 kg sludge/m^3 milk processed	Sludge: land spread (63%), compost (13.6%), or removed by licensed contractors (23.4%)
Australia	0.07–2.90 L/L milk	–	31 kg organic waste/t product	Compost, fertiliser, stockfeed and recovery of marketable products.
United States	–	0.10–12.4 kg/kg milk	–213	Effluent: discharge into municipal sewage treatment system or irrigate on the land
United States	–	170–2081 m^3/d	–	
UK	1.8 L/kg product	1–5 L/L processed milk	–	Sludge: landfilling ?

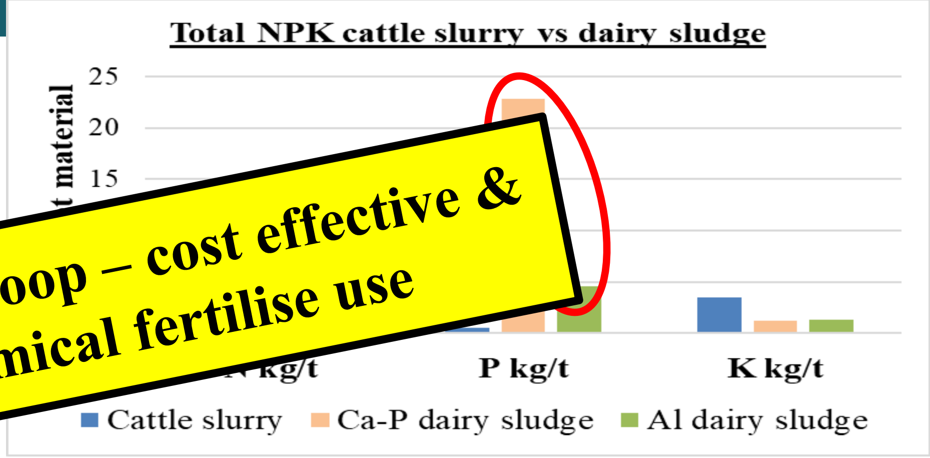
- **EU Figure (2020) – 2.45 million tons** from 144.6 million tons of milk production
- **Ireland - 126,700 tons per year** (39% of increase between 2012 and 2017) (abolition of European milk quotas in 2015)
- **EU -** Total recyclable **phosphorus 12,840 tons**
- **EU -** Total recyclable **nitrogen 17,490 tons**

Regulations & Policy Drivers: Disposal management to increase nutrient recycling

- ❖ **NAP Regulation (SI 31 2014):** Good Agricultural Practice for Protection of Waters

- ❖ **Teagasc Nutrient Advice:** Greenbook (**no information on dairy sludge presently**)

Agricultural ... nutrient rec...



Closing Nutrient Loop – cost effective & reducing chemical fertilise use

Dairy sludge samples are high in N & P when compared to cattle slurry.**

- **The new European Union (EU) Fertilising Products Regulation (EU, 2019) has expanded its scope to enable the use of recovered and bio-based fertilising products in line with EU Circular Economy Package goals adopted in December 2015 (EC, 2015)**

- **European Green Deal - 'Farm to Fork Strategy for Sustainable Food'**

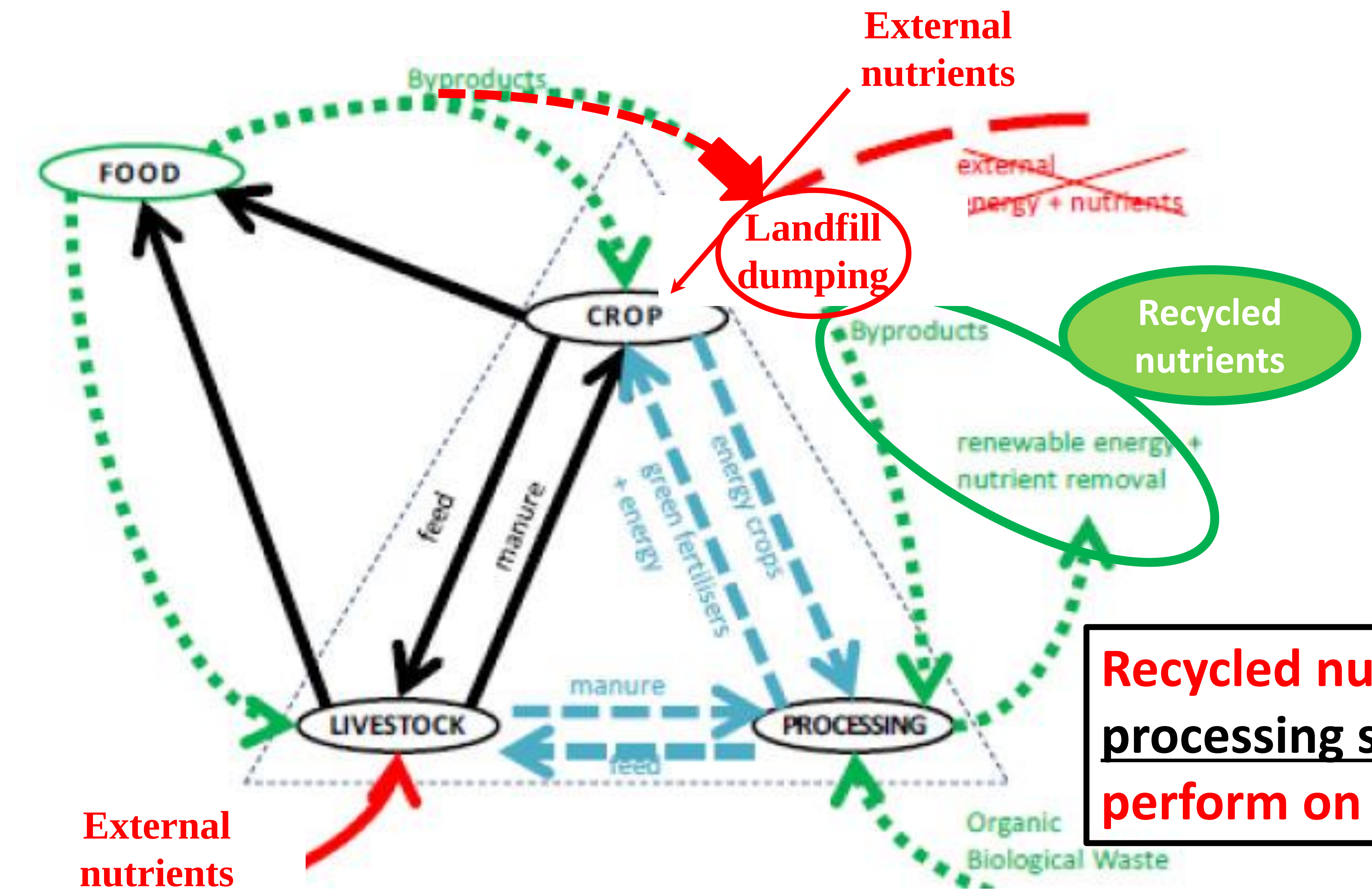
The **excess of nutrients** in the environment is a major source of air, soil and water pollution, negatively impacting biodiversity and climate. The Commission will act to:

✓ **reduce nutrient losses by at least 50%**, while ensuring no deterioration on soil fertility.

✓ **reduce fertilizer use by at least 20%** by 2030.

- **Driving towards a circular, resource-efficient economy – processing nutrients from waste materials and prevents their losses**

Nutri2Cycle Approach: Closing carbon and nutrient loop in the agro-production system



Triangle model for reconnecting nutrient and carbon flows between conventional agro-pillars (Nutri2Cycle Concept)

Recycled nutrients from dairy processing sludge – how they perform on crops and soil?

Nutri2Cycle

Transition towards a more carbon and nutrient efficient agriculture in Europe

www.nutri2cycle.eu
#Nutri2Cycle

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

Experiment: Materials used to recycle nutrients

Integrating recycled nutrients into fertilizer application programme

How recycled nutrients perform on crops and soil?

(decrease)

Product	Sample	Chemical composition	Source/Feedstock
Super phosphate (SP)		$Ca(H_2PO_4)_2$, 44-51% P_2O_5 (16%P)	phosphate rock
Calcium ammonium nitrate (CAN)		$5Ca(NO_3)_2 \cdot NH_4NO_3 \cdot 10H_2O$ (27%N)	atmospheric N_2, natural gas, limestone
Muriate of Potash (MOP)		KCl (50%K)	Potash mining
Sulfate of potash (SOP)		K_2SO_4 (42%K, 18%S)	Potash mining, H_2SO_4, Brine

(increase)

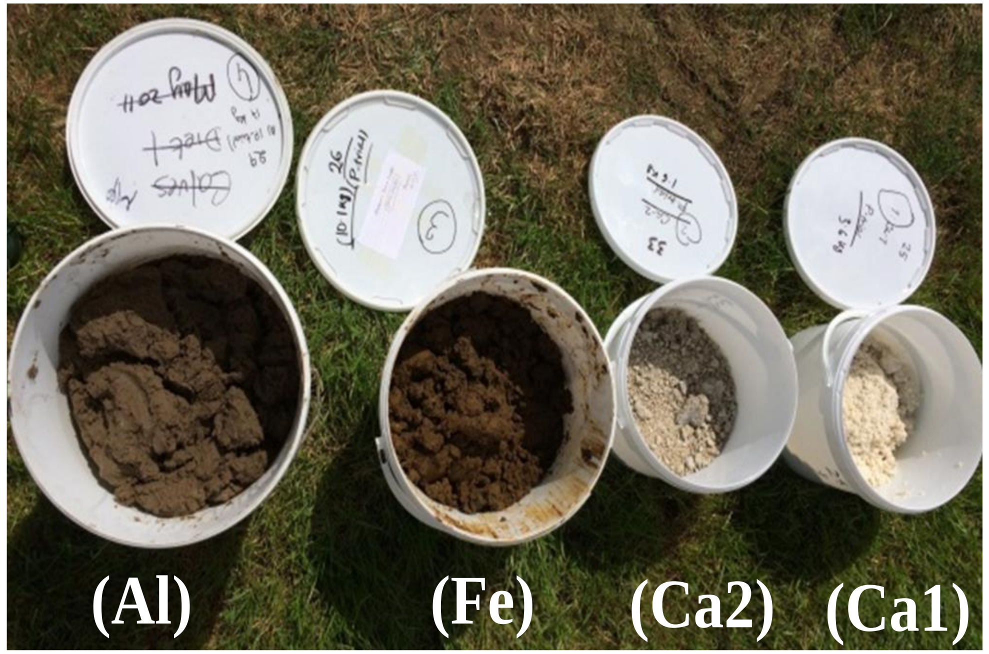
Product	Sample	Chemical composition	Source/Feedstock
Cattle slurry		0.6%P, 4.3%K, 0.4%S (dry basis)	Livestock animals
Dairy sludge (Al-precipitated)		4.6%P, 6%N, 3%Ca, 3%Al, 1.6%K, 0.6%S (dry basis)	Dairy food processing wastewater
Dairy sludge (Ca-precipitated)		8.1%P, 1.8%N, 24%Ca, 0.4%K, 0.3%S (dry basis)	Dairy food processing wastewater

- **Less C footprint**
- **Saving €**
- **Increase local nutrient recycling**

Agronomic trial: Nutrient composition & availability?

4 dairy sludge: Ca1, Ca2, Al and Fe

(two activated sludge - Al-DPS and Fe-DPS, and two lime-stabilised sludge - Ca_1- and Ca_2-DPS)



Sample	DM	N	P	K	S	Ca	Al	Fe
	%	kg/t dry weight						
DAF - **Ca1**	22	36.5	**79.6**	3.9	2.9	**238**	0.6	0.5
DAF - **Ca2**	31	19.3	**128**	4	3.2	**278**	0.9	3.8
AC - **Fe**	20	38.5	31.6	5.5	3.3	107	0.8	**161.8**
AC - **Al**	11	42.5	34.1	5.7	4.3	33	**58.1**	4.1
Cattle slurry	6.3	38.1	7.9	**55.6**	4.8	- -	- -	- -

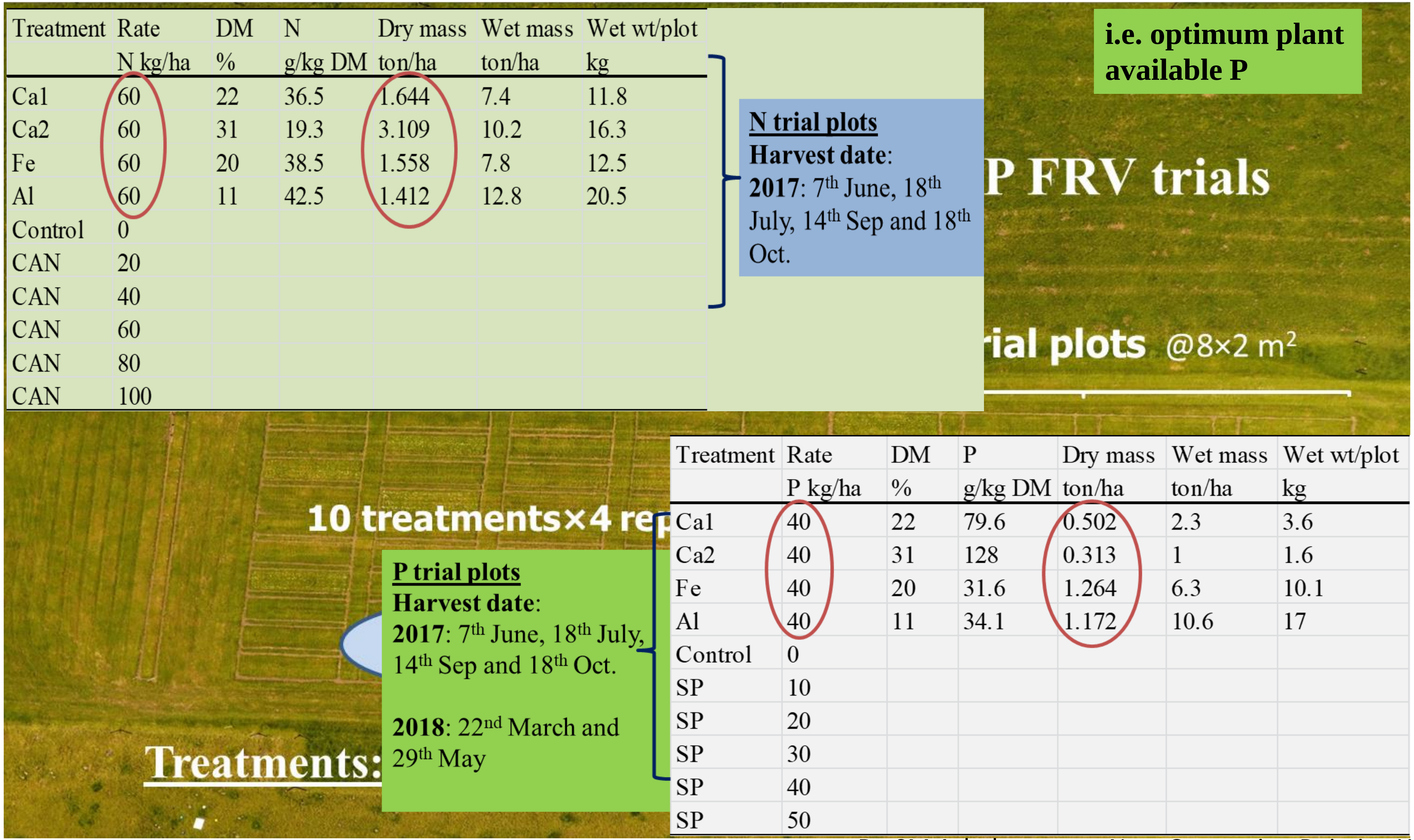
Cattle slurry samples from Irish farms (Berry et al., 2013)

N and P Availability for crop uptake?

Agronomic trial: Set-up and layout

Soil: light textured clay loam with a soil P test (STP) of 7.6 mg L^{-1} (P Index 3)

i.e. optimum plant available P



Treatment	Rate N kg/ha	DM %	N g/kg DM	Dry mass ton/ha	Wet mass ton/ha	Wet wt/plot kg
Ca1	60	22	36.5	1.644	7.4	11.8
Ca2	60	31	19.3	3.109	10.2	16.3
Fe	60	20	38.5	1.558	7.8	12.5
Al	60	11	42.5	1.412	12.8	20.5
Control	0					
CAN	20					
CAN	40					
CAN	60					
CAN	80					
CAN	100					

N trial plots
Harvest date:
2017: 7th June, 18th July, 14th Sep and 18th Oct.

P trial plots
Harvest date:
2017: 7th June, 18th July, 14th Sep and 18th Oct.

2018: 22nd March and 29th May

Treatment	Rate P kg/ha	DM %	P g/kg DM	Dry mass ton/ha	Wet mass ton/ha	Wet wt/plot kg
Ca1	40	22	79.6	0.502	2.3	3.6
Ca2	40	31	128	0.313	1	1.6
Fe	40	20	31.6	1.264	6.3	10.1
Al	40	11	34.1	1.172	10.6	17
Control	0					
SP	10					
SP	20					
SP	30					
SP	40					
SP	50					

Results: Efficiency of recycled N & P bioavailability

N & P bioavailability: Computational method (example for P)

Apparent P Recovery (APR)

$$APR(\%) = \frac{P_{treatment} - P_{control}}{P_{applied}} \times 100$$

APR compares crop P uptake in an amended treatment with that in an unamended control treatment assuming amount of P provided by the soil is the same among plots

APR represent P uptake is due solely to the treatment

Relative P Effectiveness (RPE)

$$RPE(\%) = \frac{APR\ (\%)_{biosolids}}{APR\ (\%)_{mineral}} \times 100$$

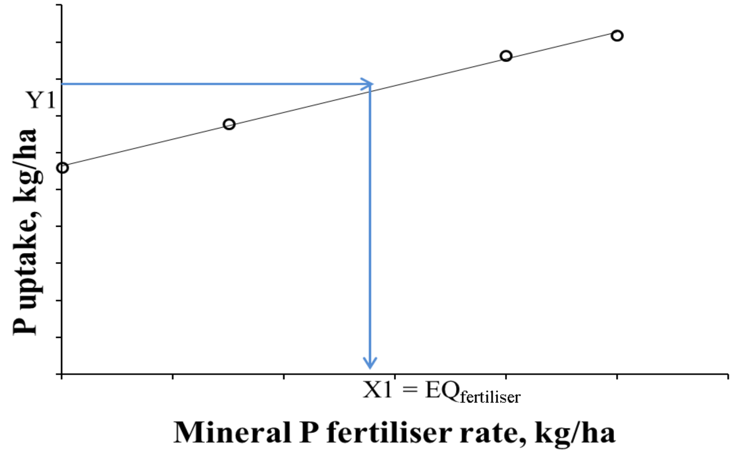
RPE allows comparison of the potential of the RDF treatment to provide bioavailable P with respect to mineral fertiliser

Fertilizer Phosphorus Equivalence (FPE)

$$FPE(\%) = \frac{EQ_{fertilizer}}{P_{applied}} \times 100$$

This method also provides % of P availability of RDF treatment by comparing crop response (P uptake or yield) with that of mineral fertiliser.

P Fertiliser Replacement Value (FRV)



Agronomic trial: N and P FRV


Sustainable Production and Consumption 25 (2021) 363–373

Contents lists available at ScienceDirect

Sustainable Production and Consumption

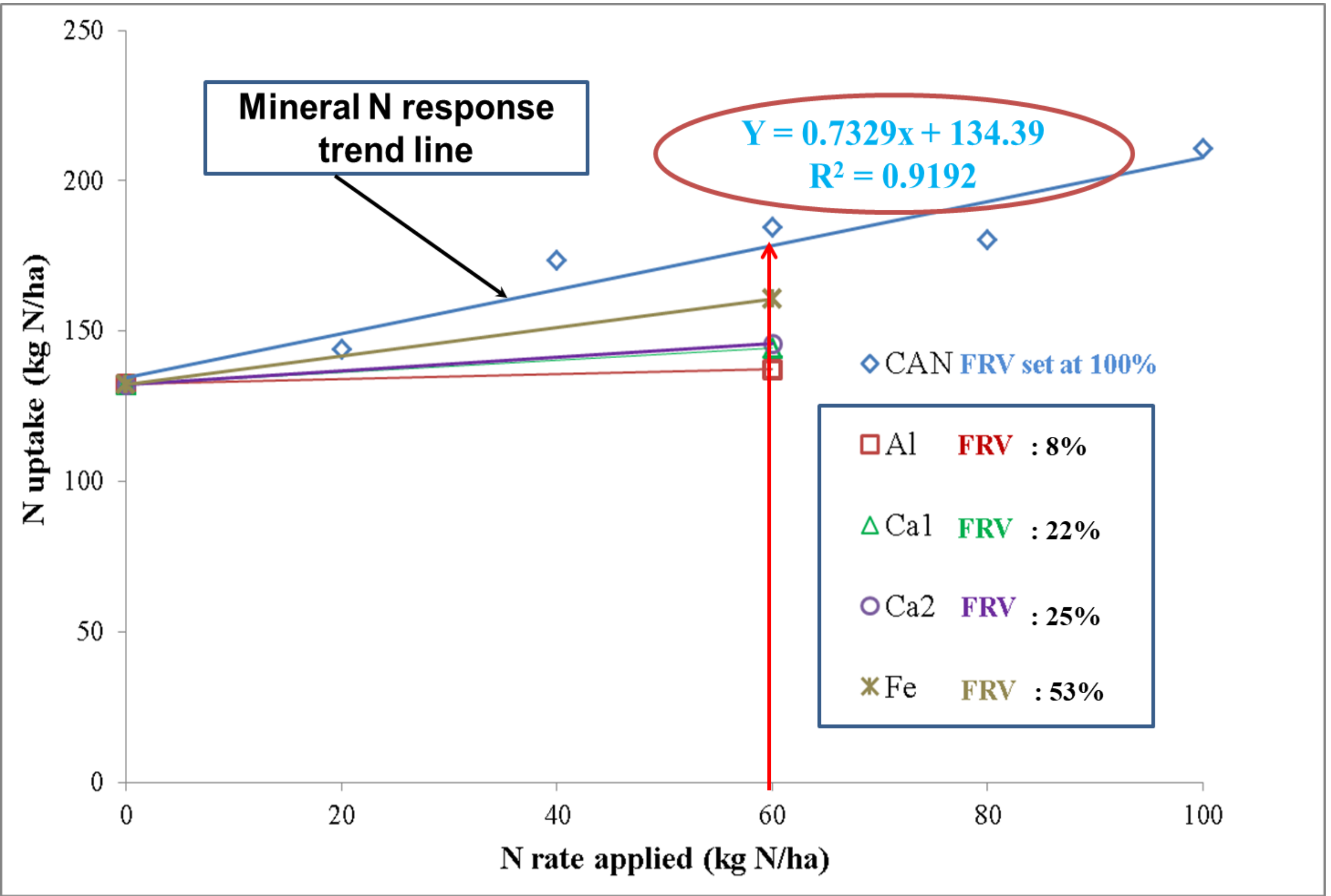
journal homepage: www.elsevier.com/locate/spc

ELSEVIER

Grassland Phosphorus and Nitrogen Fertiliser Replacement value of Dairy Processing Dewatered Sludge

S.M. Ashekuzzaman*, Patrick Forrestal, Karl G. Richards, Karen Daly, Owen Fenton

Teagasc, Environment Research Centre, Johnstown Castle, Co. Wexford, Ireland

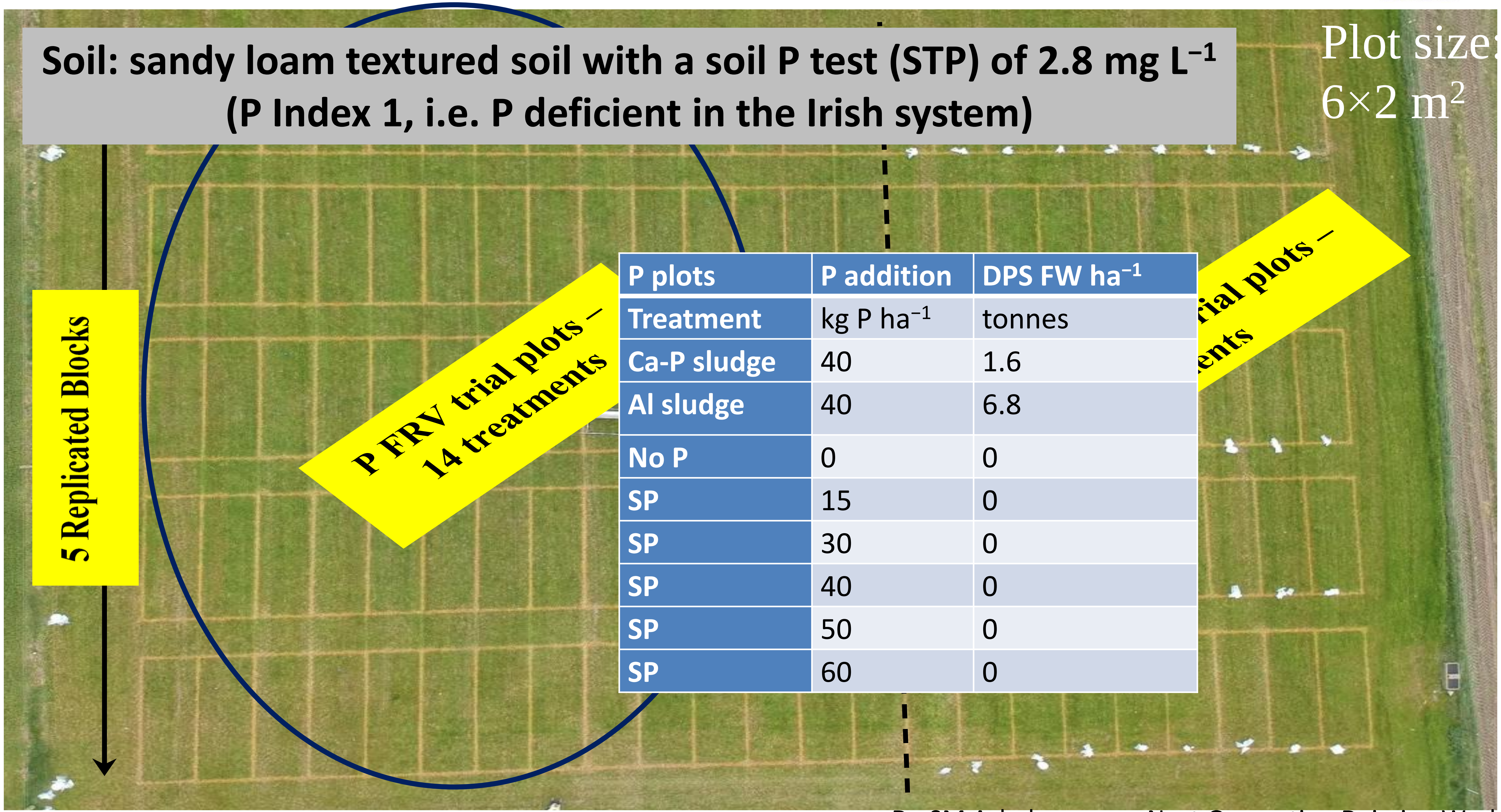


- **The N FRV of tested dairy sludge samples varied a great deal**.
- Delay in N mineralisation and NH_3 volatilisation losses are likely to cause low available N pool in sludge. The **exceptionally low N FRV of Al-sludge can be related to the poor sludge stabilization processes**.
- **Influence of upstream wastewater and sludge treatment processing on plant available N**, an important finding for their appropriate incorporation into fertiliser programmes
- All dairy sludge and mineral P treatments produced **similar yields and uptake, and crop P was not affected by sludge applications** despite the presence of high Al, Ca and Fe.

Experiment progressing: Field plots and set-up

- **Randomized Complete Block Design**

Soil: sandy loam textured soil with a soil P test (STP) of 2.8 mg L^{-1} (P Index 1, i.e. P deficient in the Irish system)



P plots	P addition	DPS FW ha^{-1}
Treatment	kg P ha^{-1}	tonnes
Ca-P sludge	40	1.6
Al sludge	40	6.8
No P	0	0
SP	15	0
SP	30	0
SP	40	0
SP	50	0
SP	60	0

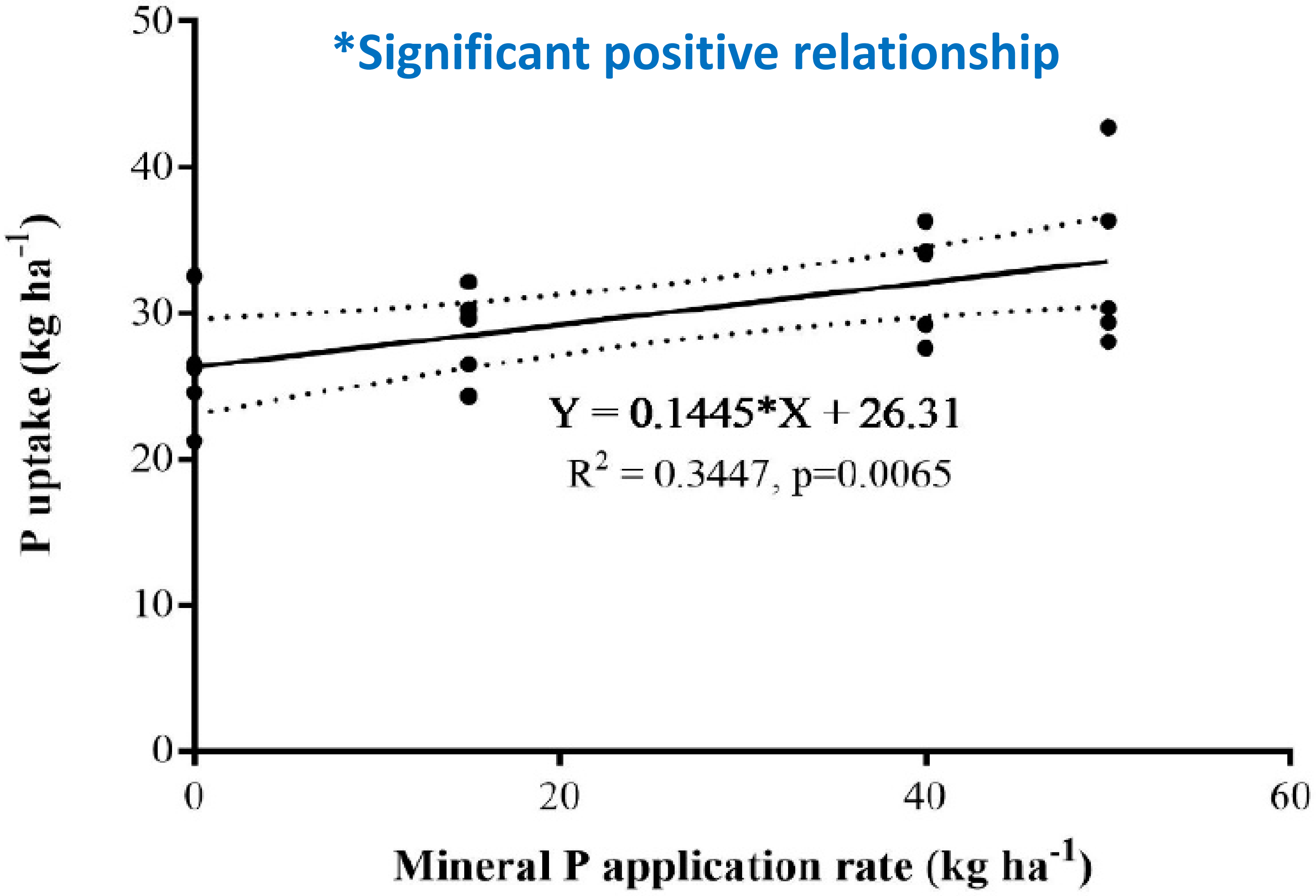
Sample

Mineral SP, CAN, MOP, SOP

Al sludge

Ca-P sludge

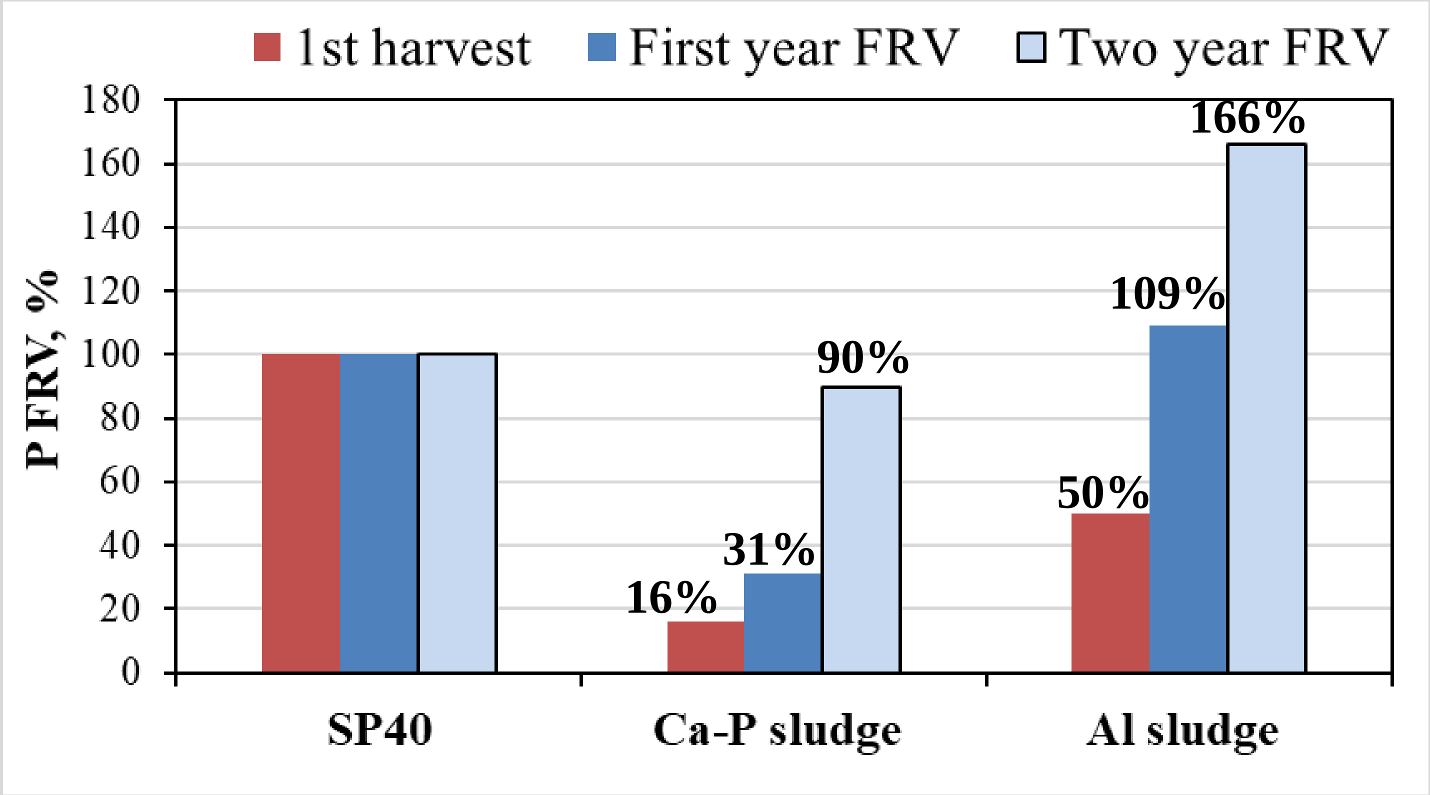
Results: P uptake response



- Clear evidence of positive P uptake response with increasing mineral P application rate (suitable for P availability assessment)
- P uptake is more sensitive to treatment differences by taking into account of crop P concentration and biomass yield

❖ **What is P fertiliser replacement value (P FRV) of dairy sludge products?**

Results: P FRV: Al- and Ca-P sludge varied greatly



agronomy

Agronomy **2021**, *11*, 427. https://doi.org/10.3390/agronomy11030427

MDPI

Article

Differing Phosphorus Crop Availability of Aluminium and Calcium Precipitated Dairy Processing Sludge Potential Recycled Alternatives to Mineral Phosphorus Fertiliser

S.M. Ashekuzzaman [1,*], Owen Fenton [1], Erik Meers [2] and Patrick J. Forrestal [1]

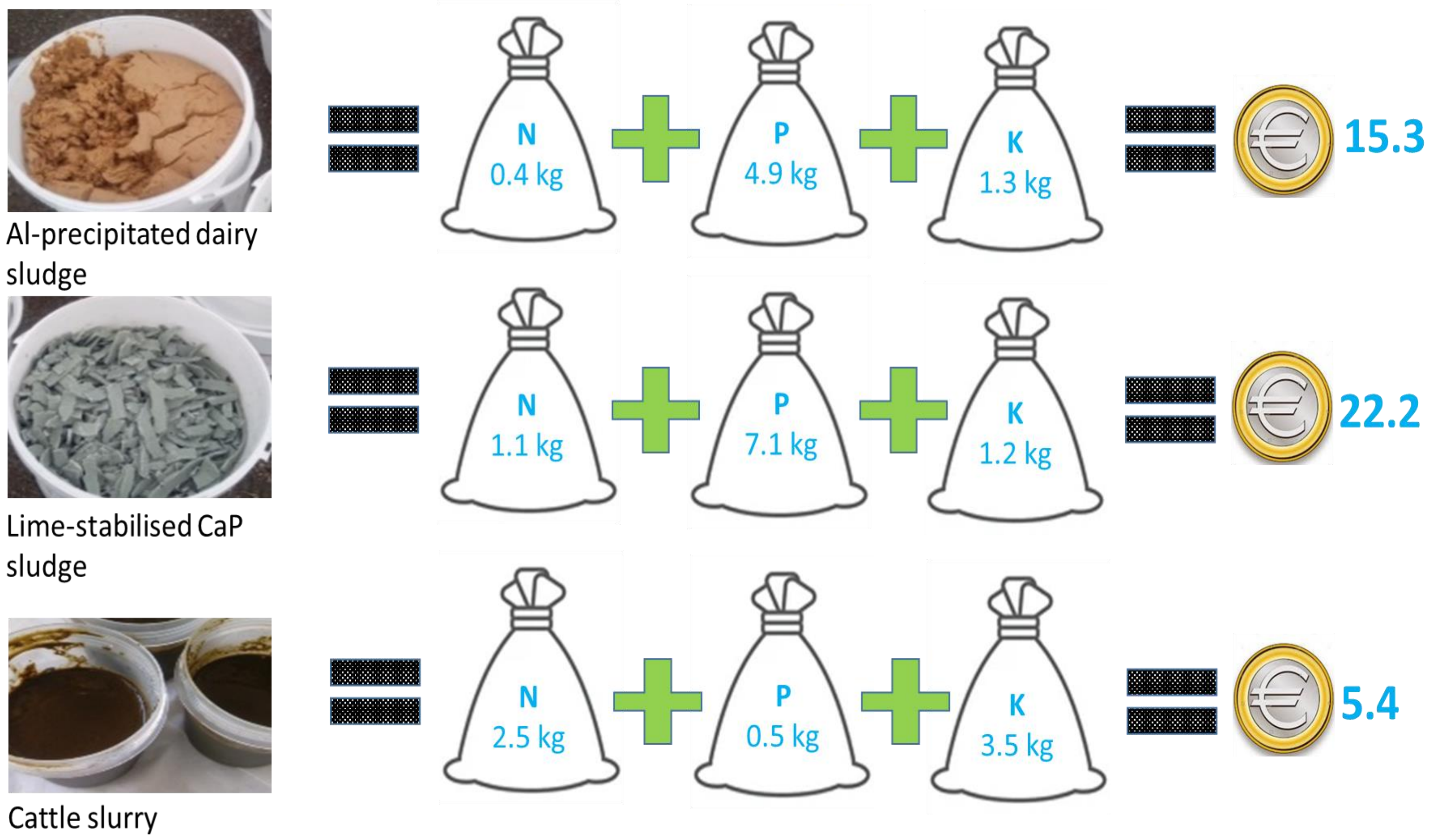
1 Teagasc, Environment Research Centre, Johnstown Castle, Co., Y35 Y521 Wexford, Ireland; owen.fenton@teagasc.ie (O.F.); patrick.forrestal@teagasc.ie (P.J.F.)
2 Department of Green Chemistry and Technology, Faculty of Bioscience Engineering, Ghent University, Coupure links 653, 9000 Ghent, Belgium; Erik.Meers@UGent.be
* Correspondence: sm.ashekuzzaman@teagasc.ie; Tel.: +353-(0)-53-9171232

- Ca-P sludge provided very limited P supply for plant uptake in the first-year but potential for residual P availability
- Al-sludge demonstrated high P availability and are promising options to replace mineral P from first-year

Ca-P sludge has Ca/P = 1.84 and pH 7.7 - High Ca content and Ca/P molar ratio likely to cause low soluble Ca-P compounds formation

Agronomic implications: Fertiliser value (€)

Nutrient Recycling by Dairy Processing sludge from milk factory
(One tonne equivalent supply of nutrients) *



*Based on first year N and P availability for grass uptake

Farmers Benefit: Grassland N-P-K maintenance

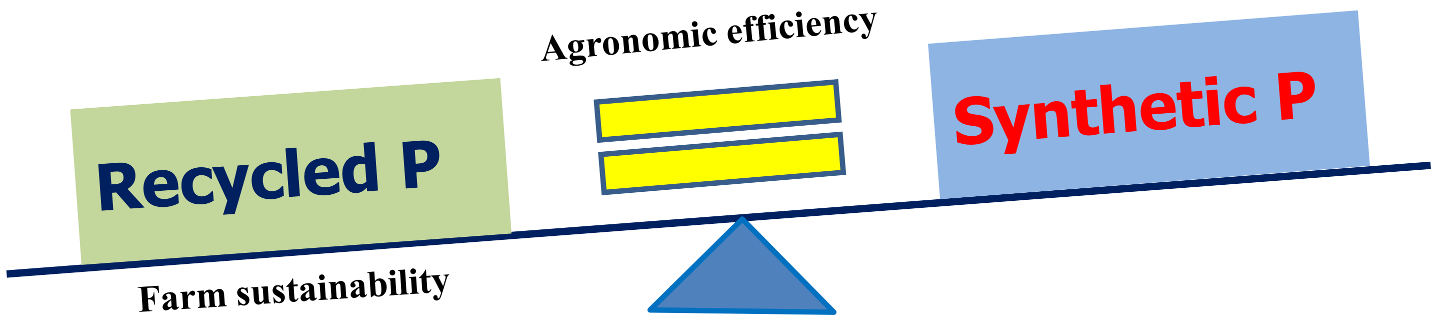
- **More € value in dairy sludge than in slurry dictated by high P content**
- **High P content in sludge controls application rate which with high availability can replace chemical P input fully**
- **Potential of 16-18% fertiliser cost saving by dairy sludge**

Summary & management implications:

- **The fertiliser efficiency of recycled P from Al-sludge is equivalent to synthetic P-fertilisers and as such highly potential to replace mineral P from first-year application.**

- **Feedstock composition and the length of the plant growing season need careful consideration to assess recycled P availability (e.g. Ca-P sludge provided very limited P supply for plant uptake in the first-year but potential for residual P availability) - More study is needed to assess effect on soil P build up through multiple applications per year in a medium-long-term trial.**

- **Limited land bank and closed period over Winter – this opens opportunity to convert dairy sludge as feedstock to produce more viable and refined fertilizer products such as STRUBIAS (struvite, biochar and ash) to supply of sufficient recycled P products locally and thereby, reduce dependency on mined and synthetic P-fertilisers.**



Acknowledgement

Thanks to all lab/field staffs and involved placement students for the dedicated support on the work done and in-progress.

Funding from EU H2020 Nutri2Cycle project

Nutri2Cycle
Nurturing the Circular Economy

Project Team: S.M. Ashekuzzaman, Cathal Redmond, Martin Bourke, John B Murphy, Mark Plunkett, Patrick Forrestal (PI)

eagasc
AGRICULTURE AND FOOD DEVELOPMENT AUTHORITY

Nutri2Cycle
Transition towards a more carbon and nutrient efficient agriculture in Europe

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773682.

@SM_Ashek