Programme
Conference Circular@wur

11-13th April 2022
Venue: WICC
Wageningen

WAGENINGEN UNIVERSITY & RESEARCH

www.wur.eu/circular-at-wur-conference

The Anaerobic Digestions as Key Factor in Proposing the Recovery of Renewable Fertilizers in a Circular Economy Frame

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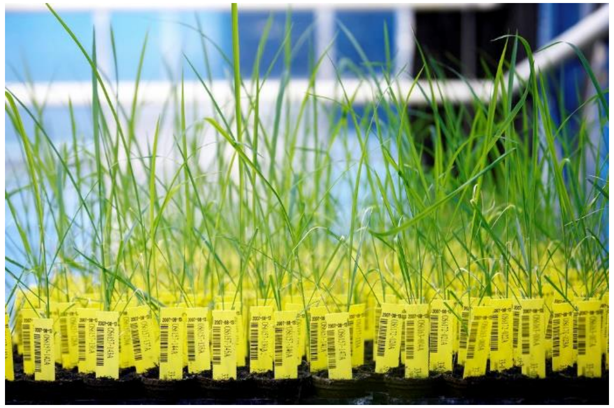
THE GREEN REVOLUTION

Started on 1944 in Mexico

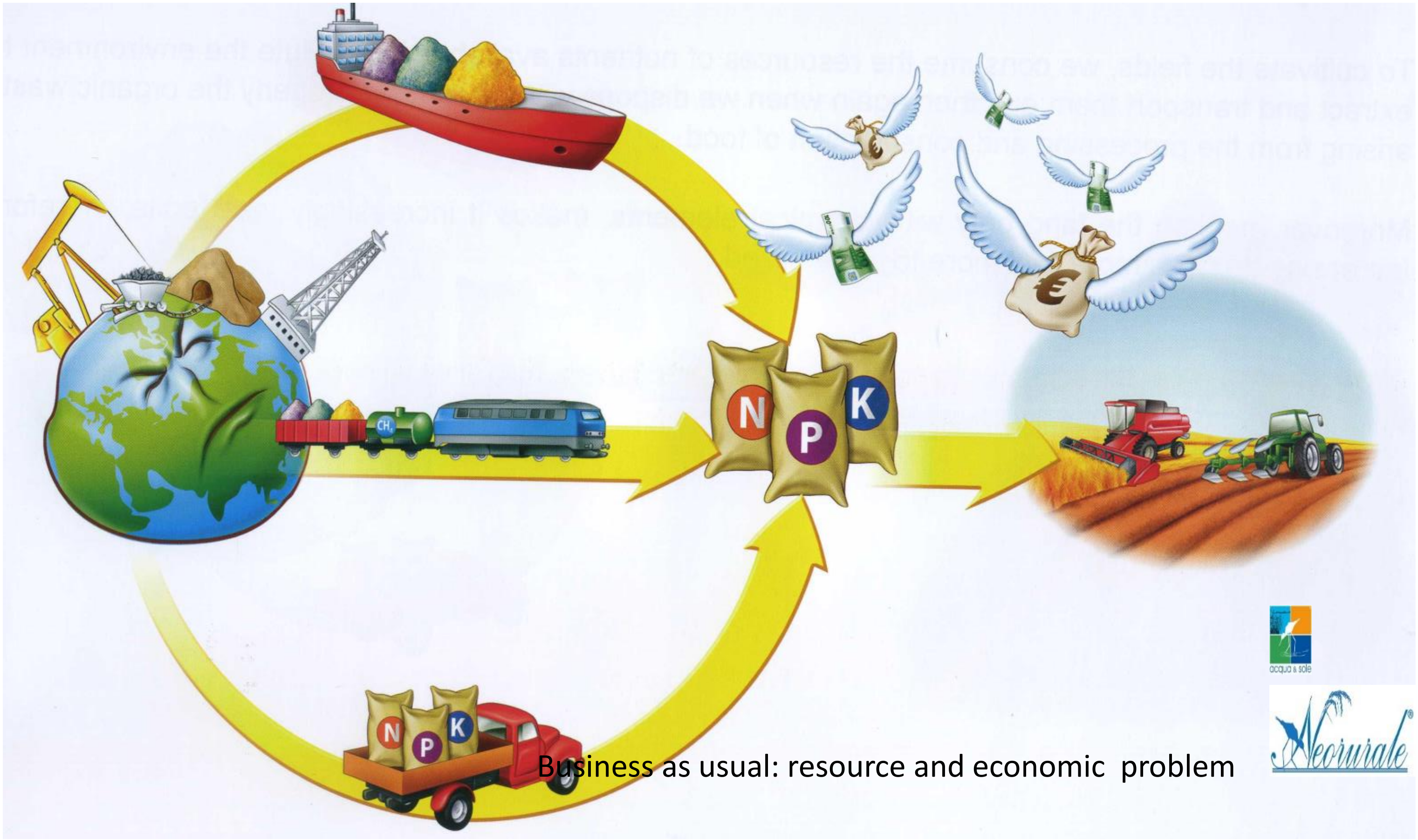
GREEN REVOLUTION:



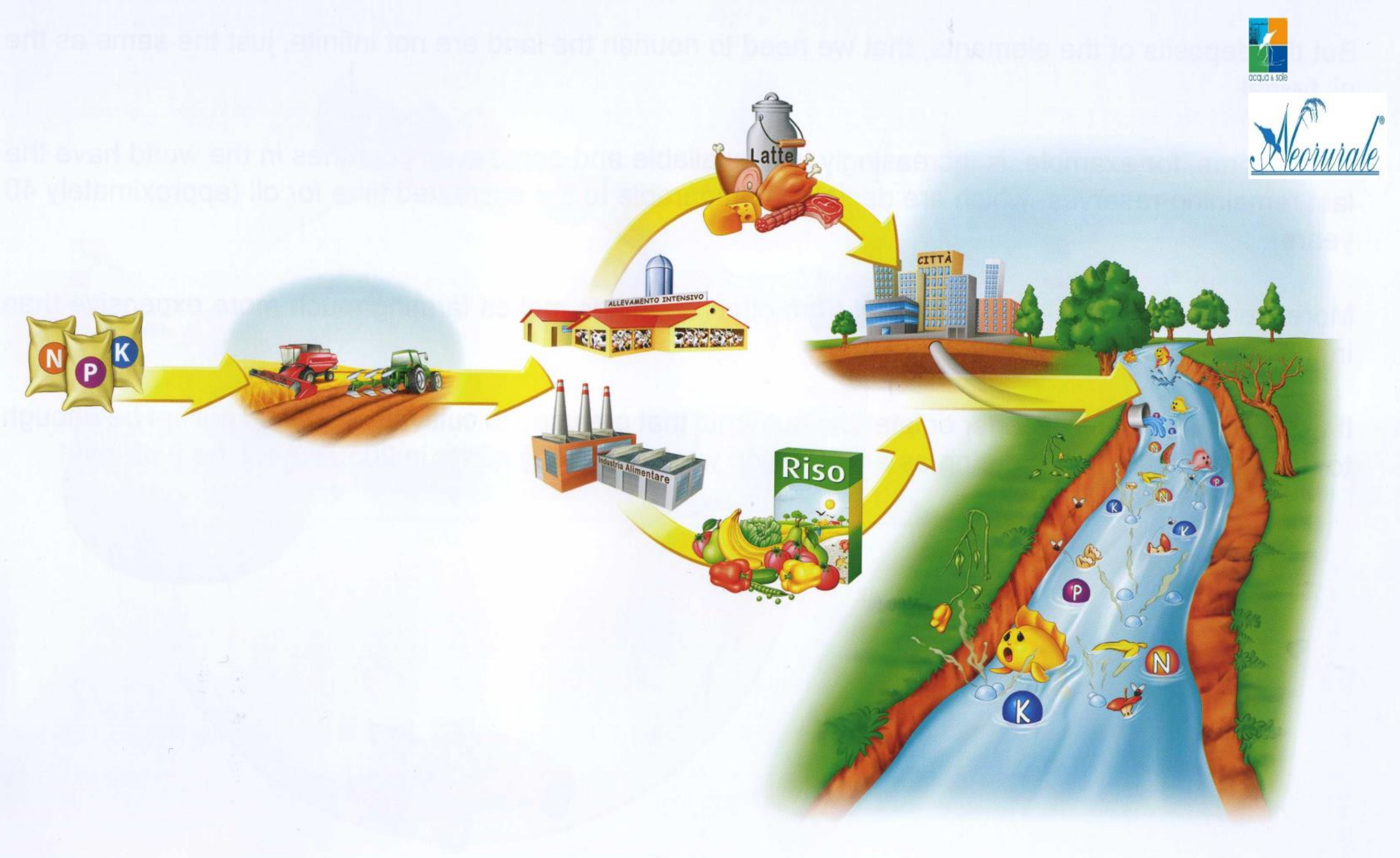
Genetic improvement

Massive use of fertilizers and pesticide

Agriculture mechanization



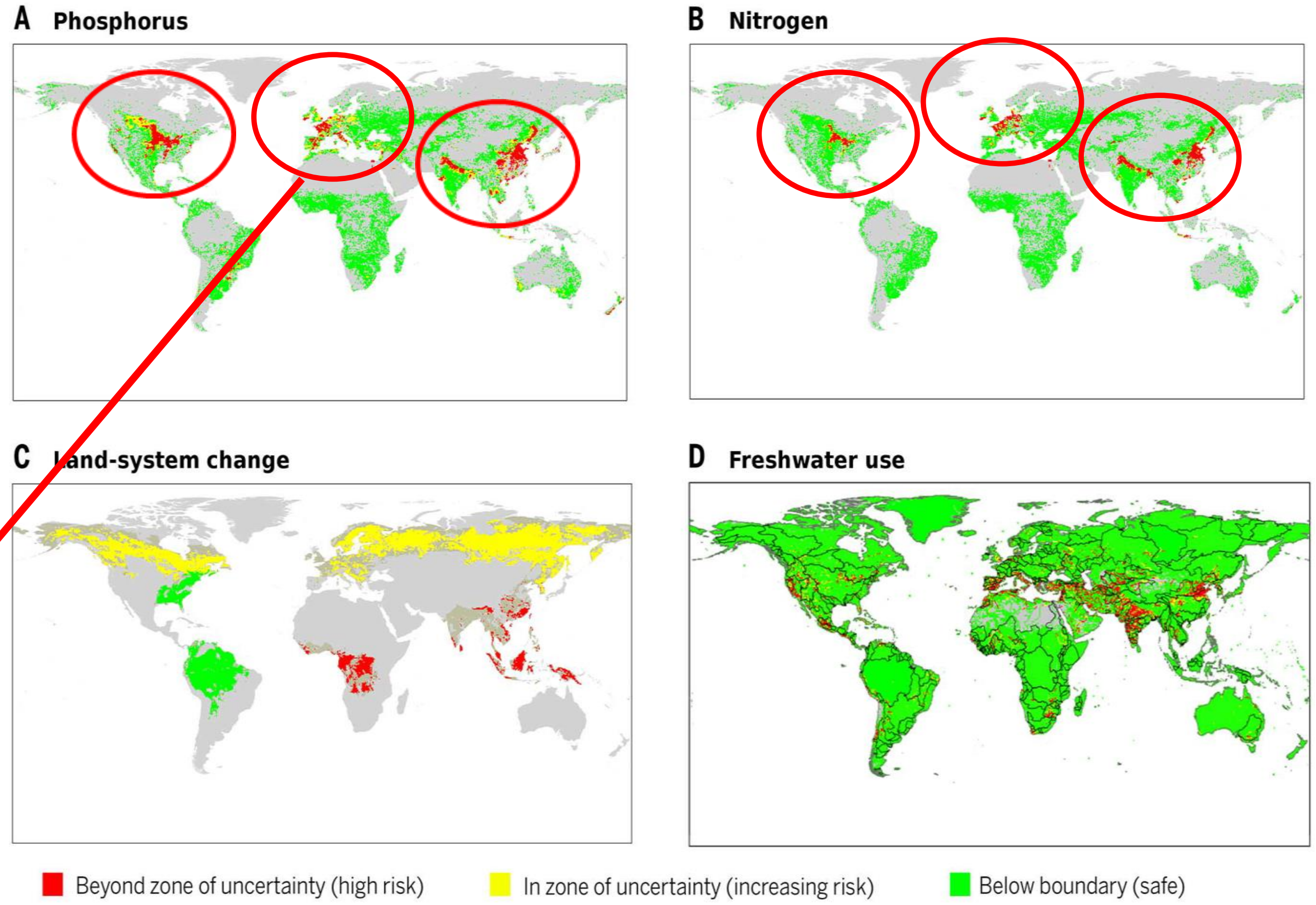
Fertilizers production and use in agriculture : linear economy



Business as usual: environmental problem

Environmental problems

N and P are over planet boundary



Steffen et al., 2015
Science

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NITROGEN EXCESS IN EU

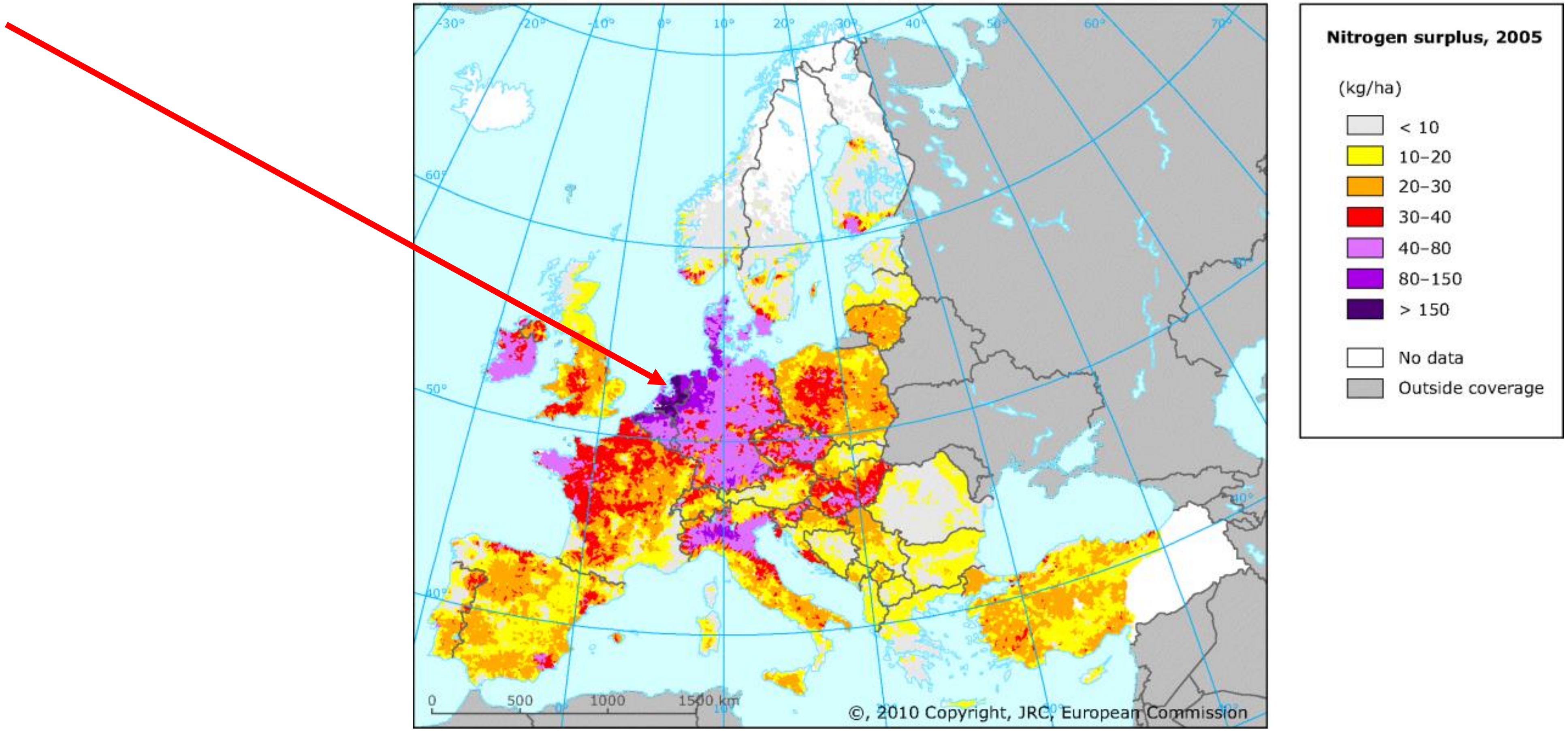


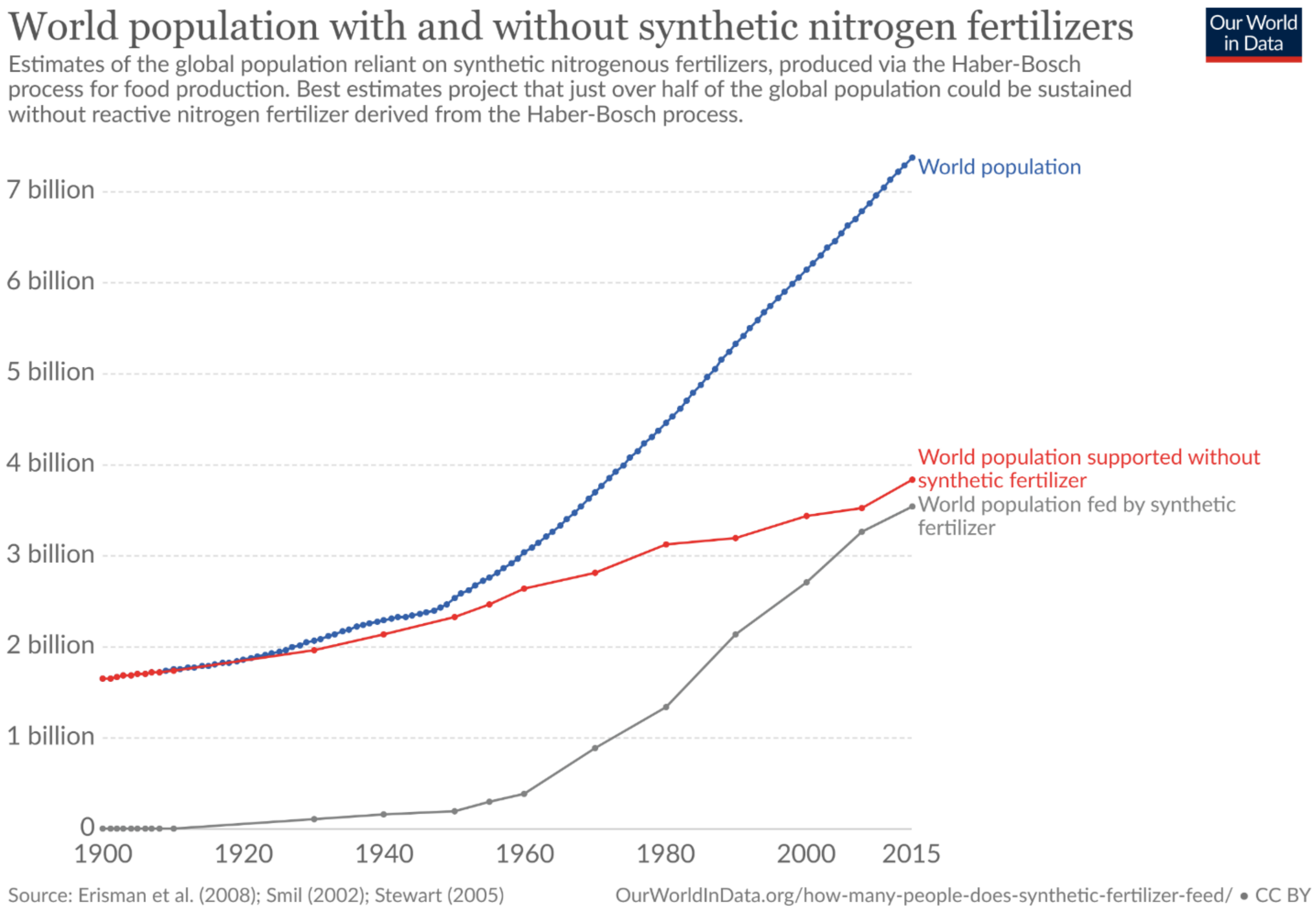
Table 1. The updated control variables and their current values, along with the proposed boundaries and zones of uncertainty, for all nine planetary boundaries. In the first column, the name for the Earth-system process used in the original PB publication (R2009, reference 1) is given for comparison.

Earth-system process	Control variable(s)	Planetary boundary (zone of uncertainty)		Current value of control variable
Biogeochemical flows: (P and N cycles) (R2009: Biogeochemical flows: (interference with P and N cycles))	*P Global*: P flow from freshwater systems into the ocean	11 Tg P yr^{-1} (11–100 Tg P yr^{-1})	<<	~22 Tg P yr^{-1}
	P Regional: P flow from fertilizers to erodible soils	6.2 Tg yr^{-1} mined and applied to erodible (agricultural) soils (6.2-11.2 Tg yr^{-1}). Boundary is a global average but regional distribution is critical for impacts.		~14 Tg P yr^{-1}
	N Global: Industrial and intentional biological fixation of N	62 Tg N yr^{-1} (62–82 Tg N yr^{-1}). Boundary acts as a global 'valve' limiting introduction of new reactive N to Earth System, but regional distribution of fertilizer N is critical for impacts.	<<	~150 Tg N yr^{-1}

Steffen et al., 2015 Science

HOWEVER, FERTILIZERS USE WILL INCREASE WORLDWIDE

Food Production issues



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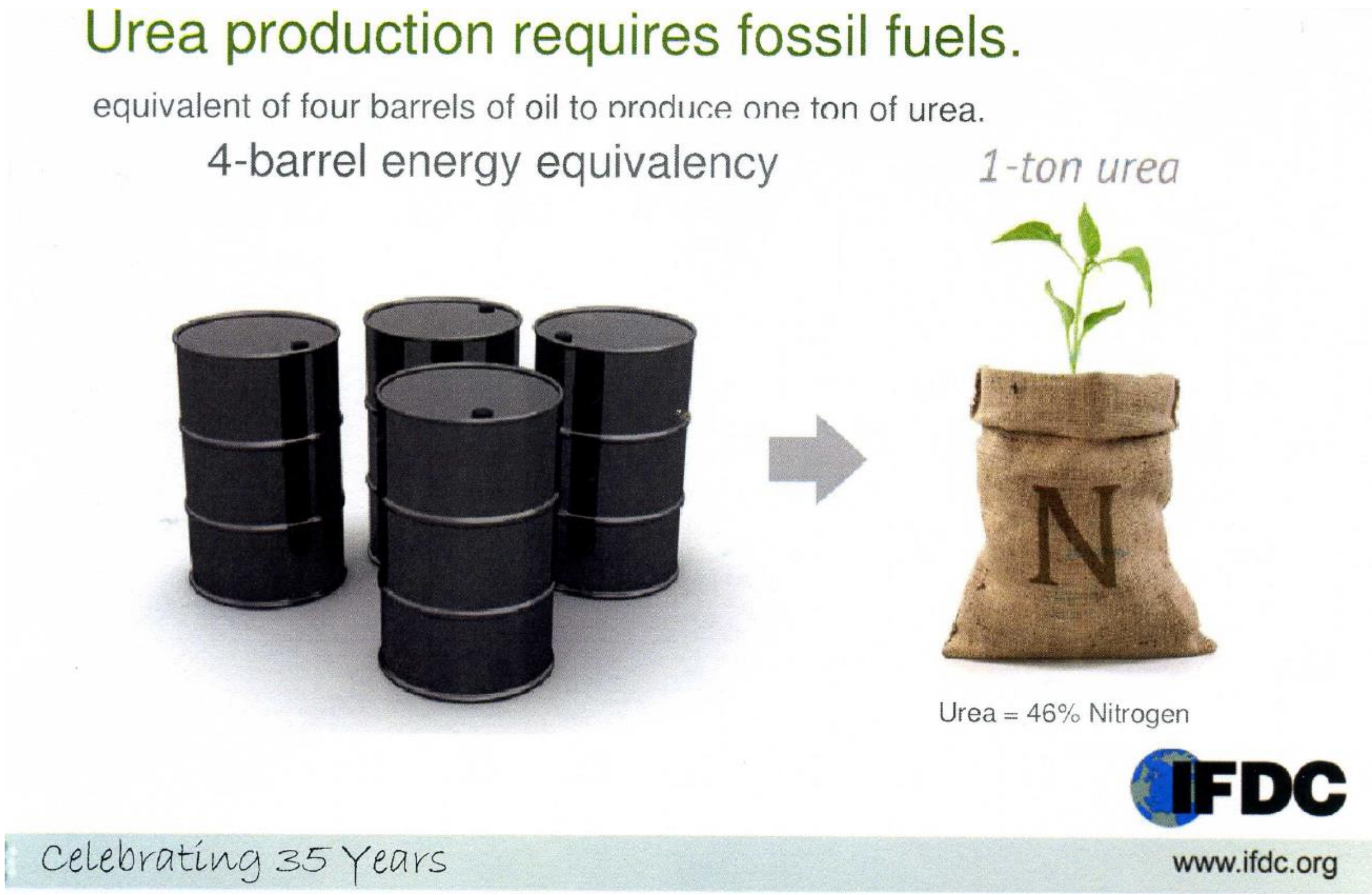
Fertilizers are finite source and require large amount of energy to be produced

N


Urea production requires fossil fuels.
equivalent of four barrels of oil to produce one ton of urea.
4-barrel energy equivalency
1-ton urea
N
Urea = 46% Nitrogen
IFDC
Celebrating 35 Years
www.ifdc.org

Nitrogen fertilizers are produced starting from N_2

The fertilizers manufacturing industry consumes about **3-5 %** of the world's energy supply

The total annual demand of fertilizers will increase of 25% by 2030 of which 62% of N

FIMechE, 2013

P

Phosphorus Containing Fertilizers Are Produced from Mined Phosphate Rock

A Non –Renewable Finite Resource

| NATURE | VOL 478 | 6 OCTOBER 2011

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PHOSPHORUS IS A NO-RENEWABLE RESOURCES

A broken biogeochemical cycle

Excess phosphorus is polluting our environment while, ironically, mineable resources of this essential nutrient are limited. **James Elser** and **Elena Bennett** argue that recycling programmes are urgently needed.

Phosphate is mined to produce fertilizers for crops, but phosphorus leaching into water supplies is an environmental hazard.

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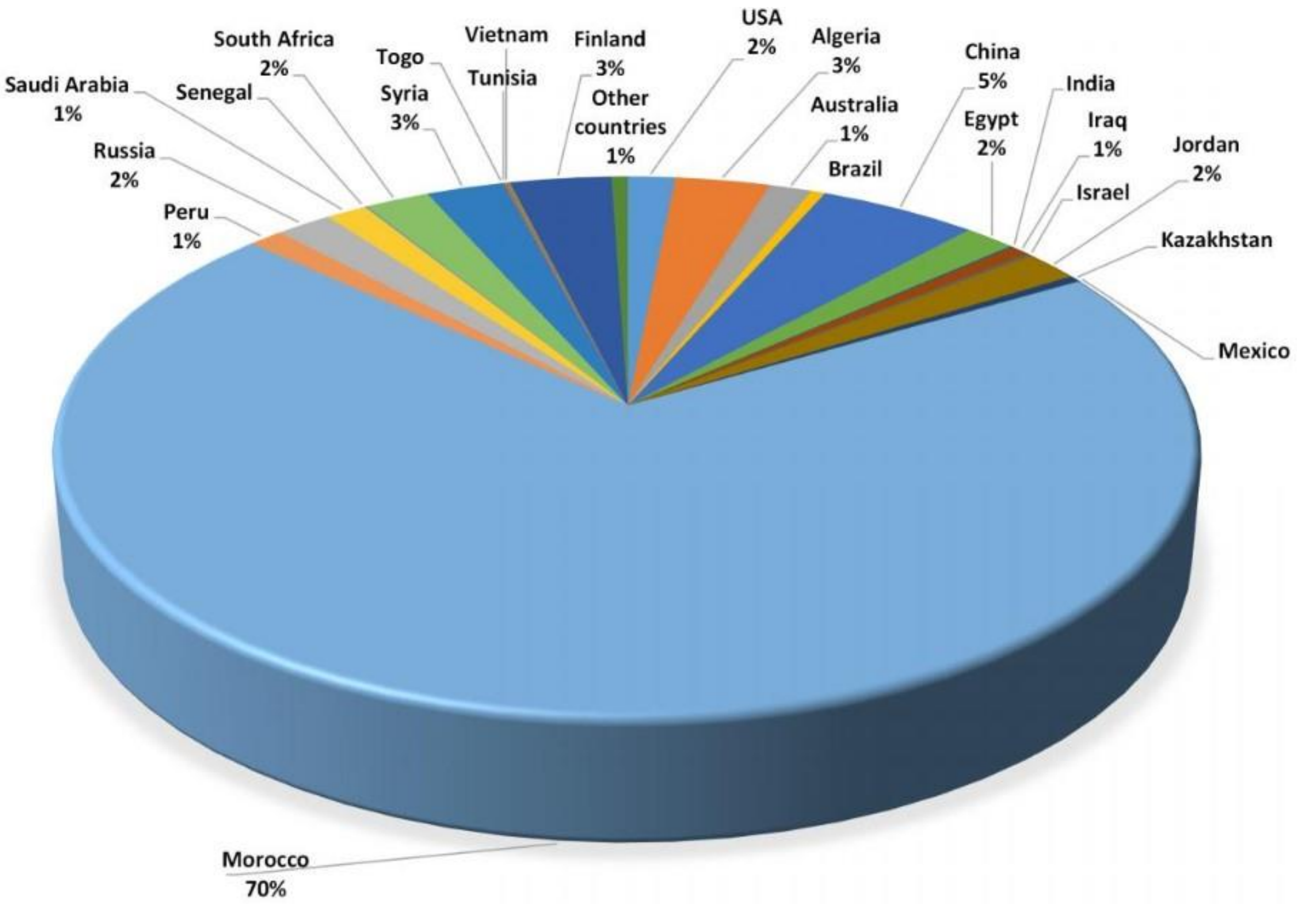
P…CONCENTRATED IN FEW PLACES…



World reserve 71 Gton

Commercial Reserves P-Rock 2016

Country	Gigatons of P-rock	% of global
Global	71	100
Morocco	50	70
China	3.7	5
Finland	2.4	3
Algeria	2.2	3
Syria	1.8	3
South Africa	1.5	2
Jordan	1.3	2
Russia	1.3	2
USA	1.1	2
Australia	1	1
Saudi Arabia	0.96	1

USGS 2016; GTK, 2015

94% in 11 countries

SEI

Political issues ?

USGS Phosphate Rock Statistics and Information

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Potassium-Containing Fertilizers Are Produced from Mined Potassium Salts

A Non–Renewable, Finite Resource

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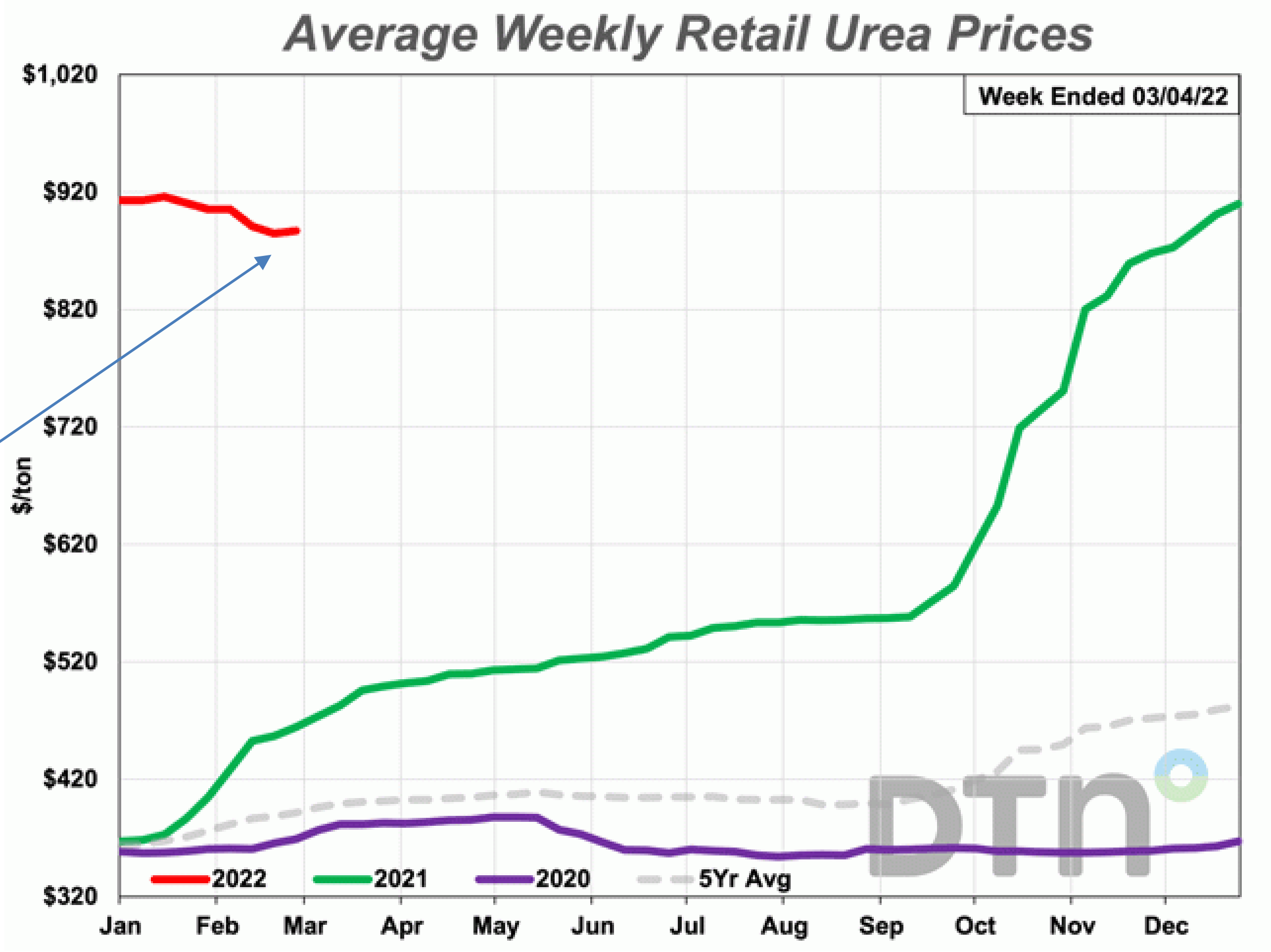
DTN Retail Fertilizer Trends
Most Retail Fertilizer Prices Resume Climb at Beginning of March



Russ Queen 3/09/2022

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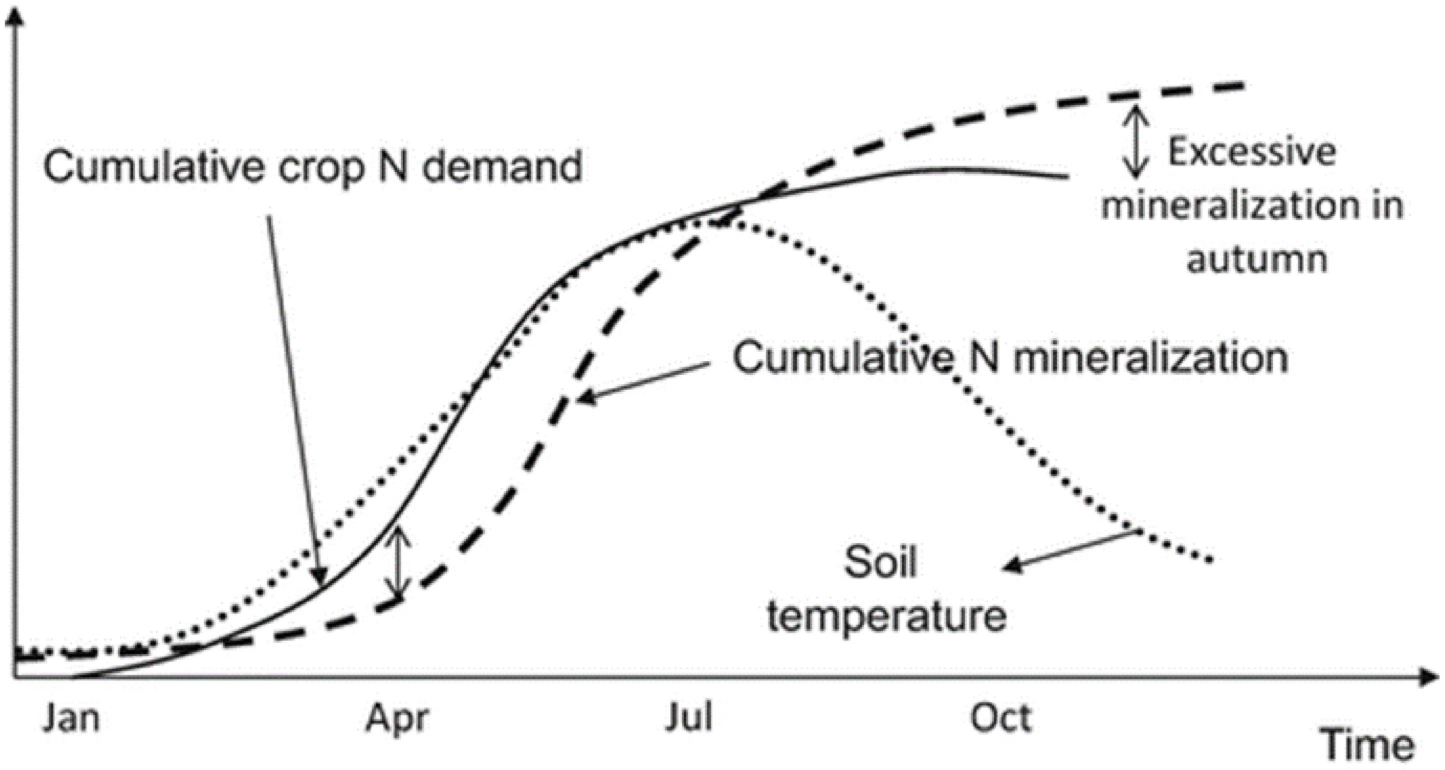
Organic waste is «gold»

The Peepoo biodegradable bag captures human excreta and can be used as fertilizer.

Bio-Fertilizers should be able replacing mineral fertilizers



Da *Organic Matter Mineralization as a Source of Nitrogen*, 2017

Courtesy by Geromel, 2020

From biomasses to fertilizers:

What we need ?

We need technologies able to produce renewable fertilizers able to substitute synthetic fertilizers.

……………*circular economy*

e.g. : ANAEROBIC DIGESTION transforms biomass into

BIOFUELS

……and more……….

renewable fertilizers ®

Renewable fertilizers®

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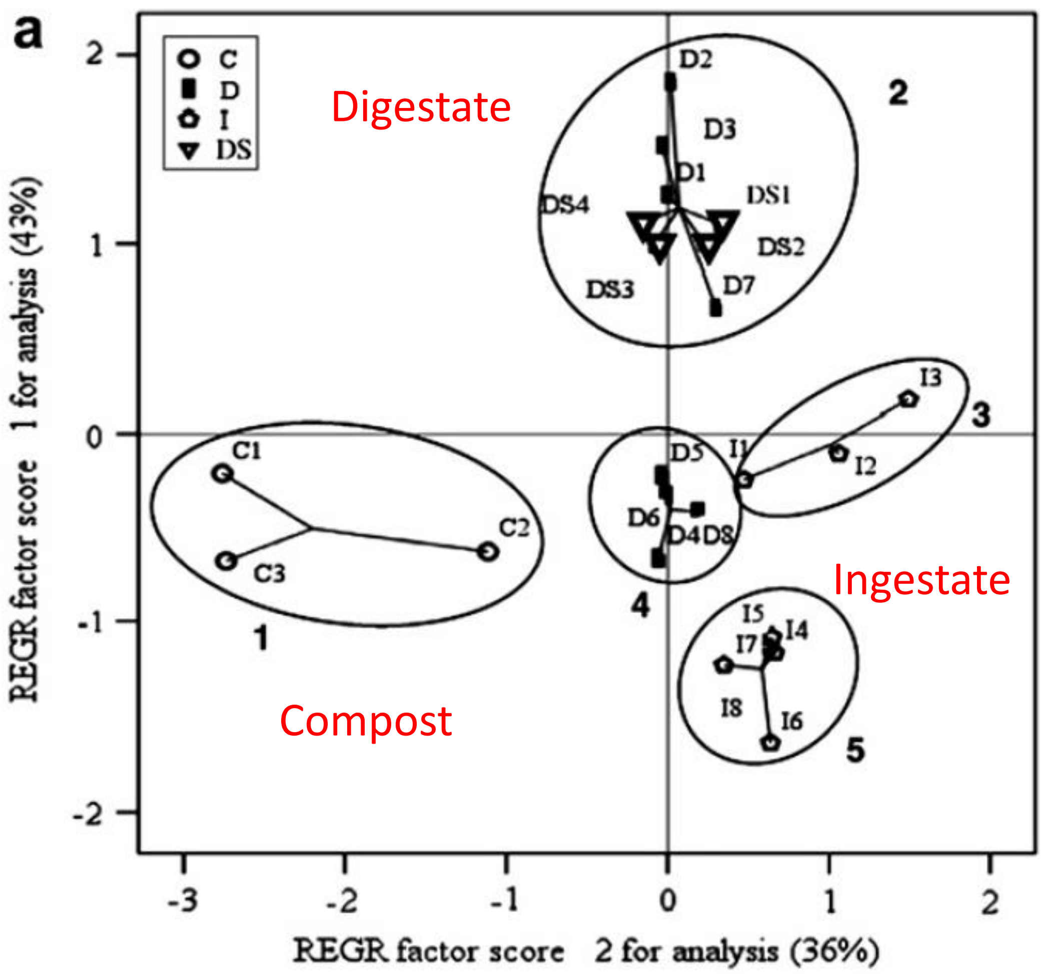
Anaerobic digestion: modification of both elements and organic matter contained ……

Biological stability = OC stability

Compost = digestate >> ingestate

Good amendment properties (soil fertility)



Tambone et al., 2010

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What about mineral fraction……..?

Digestate is different for ingestate and compost.

Good fertilizers replacing synthetic mineral fertilizers

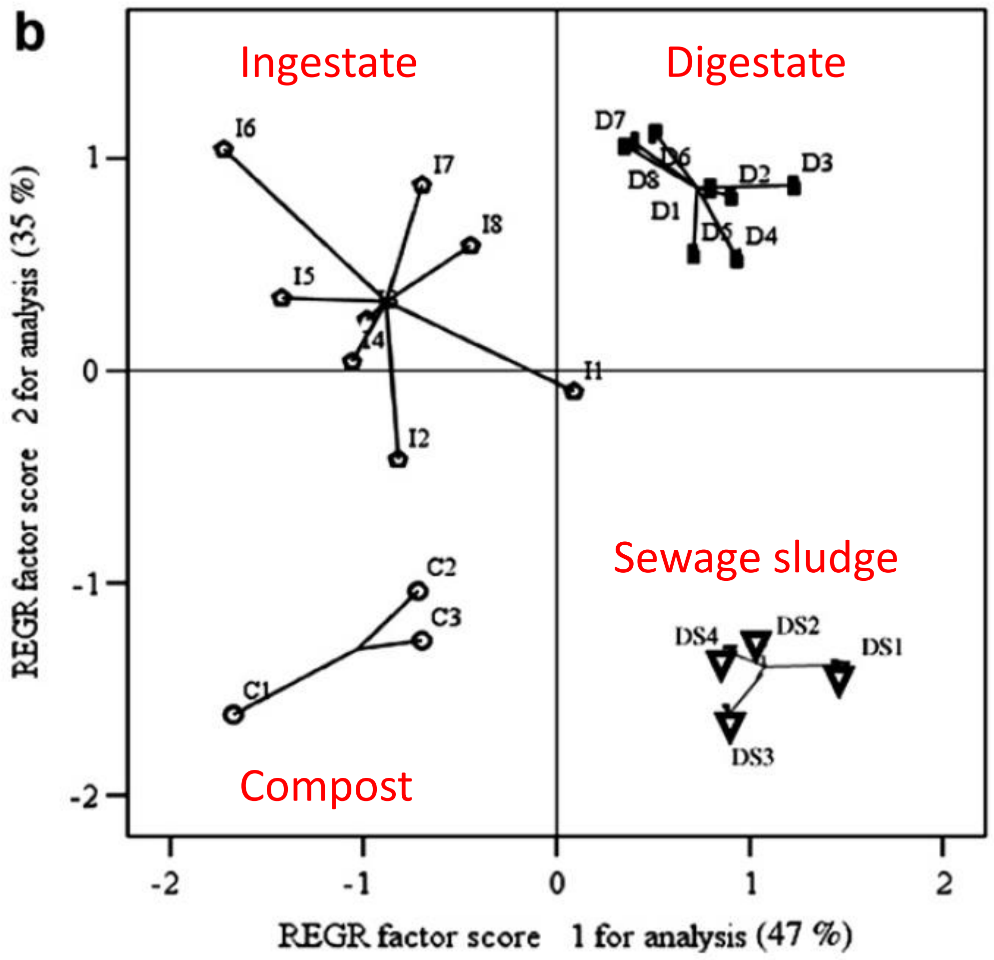


Fig. 1. PCA plots for amendment properties (a) and fertilizer properties (b).

Agronomic use of liquid separated fraction of digestate

Moreover: anaerobic digestion makes digestate suitable to be transformed in mineral fertilizers if nutrient exceeded plant request.. ……….

..REcovered Nitrogen from manURE (RENURE)

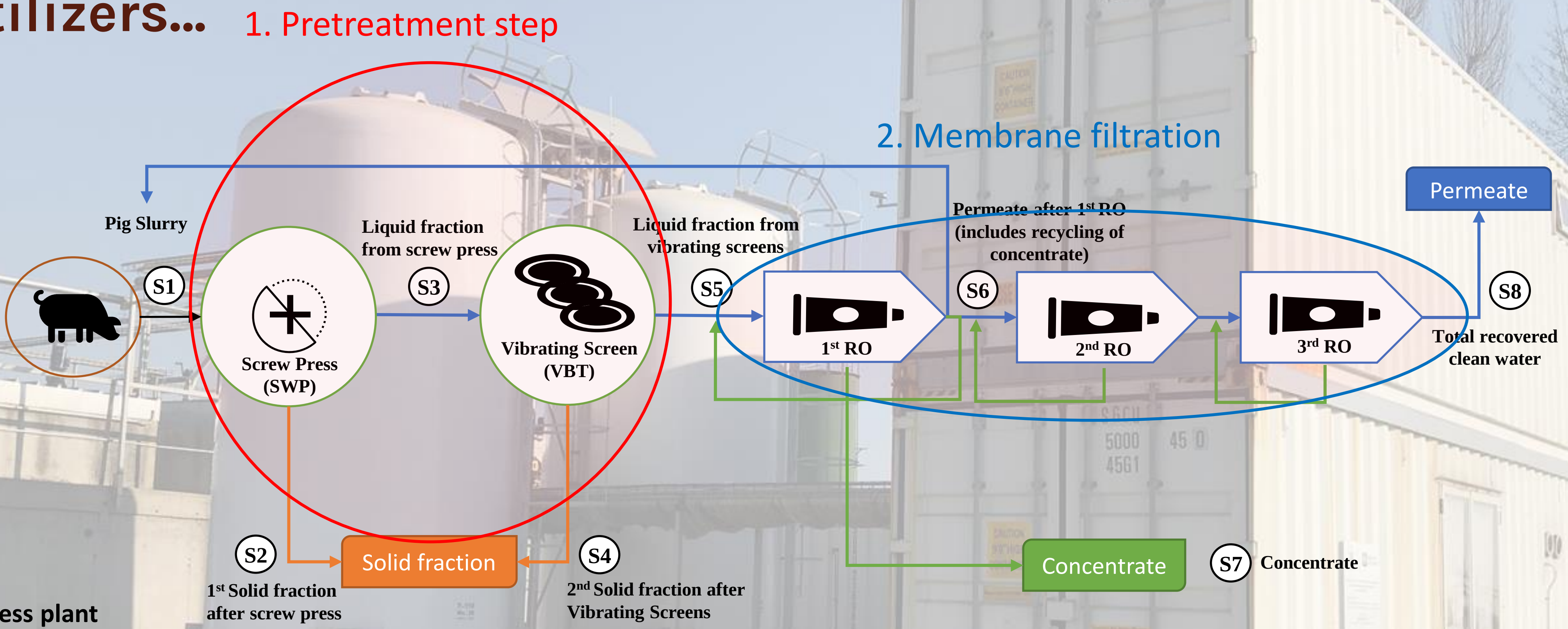
total organic carbon to total N ≤ 3 or a mineral N to total N ratio ≥ 90%

Ammonia sulfate production by NH_3 stripping for export

Po valley, Italy

Cortesia Eliopig

Pig manure refinery into mineral fertilizers...



Full scale – TRL 9

Pre-assembled process plant

Mechanical treatments of separation and concentration

Volume reduction and concentration of nutrients

Recovery of clean water

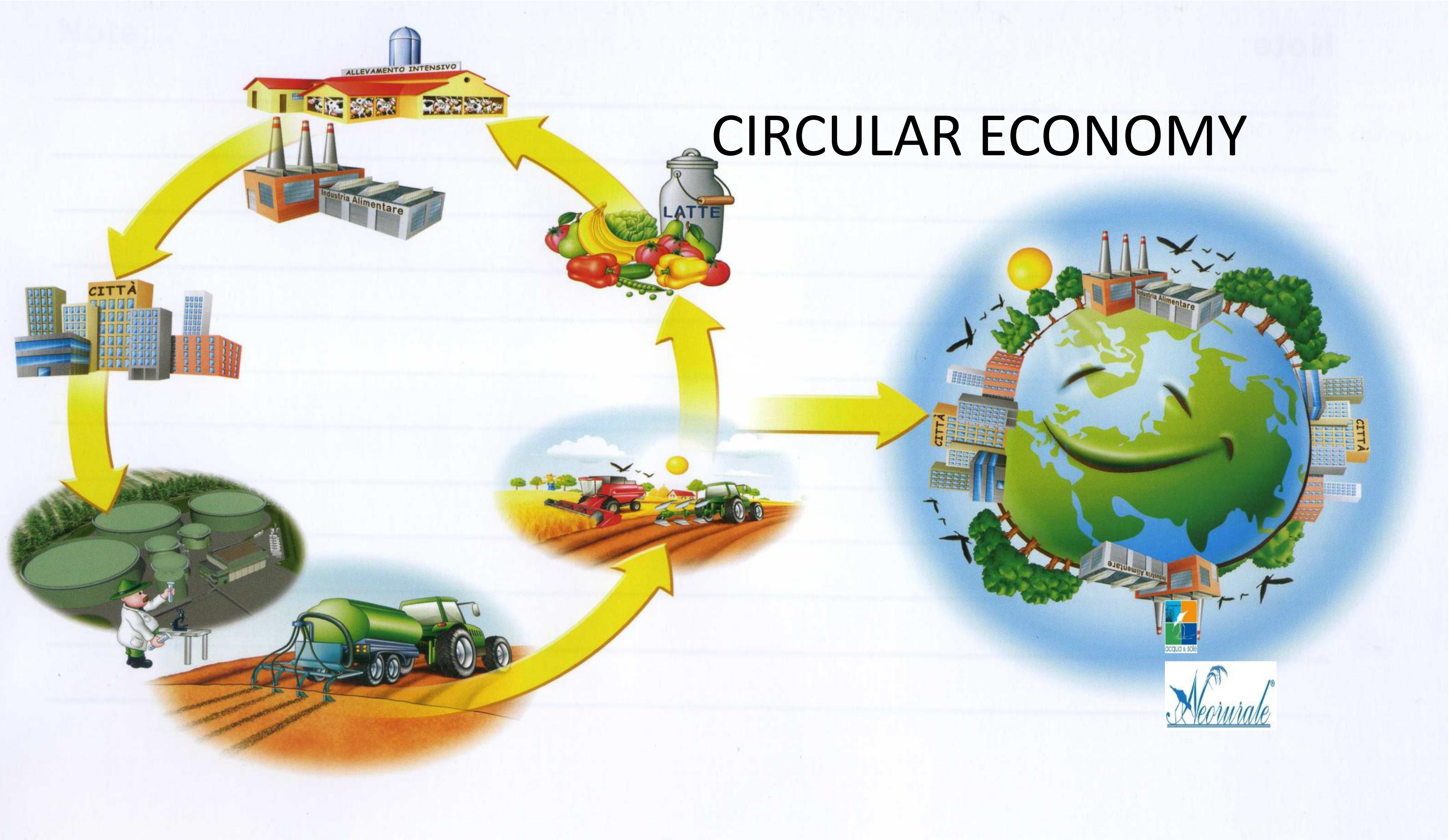
Concentration of N, favoring its displacement in places where is required

Monitored remotely

Po Valley, Italy

OB-Slurless

CIRCULAR ECONOMY



Digestato equiparato **(Digestate equivalent)** ai fertilizzanti chimici: stabilite nuove agevolazioni! Pubblicato in Gazzetta il D.L. 21 marzo 2022, n. 21

"1. In order to promote the spread of ecological practices in the biogas production phase and reduce the use of chemical fertilizers, increase the supply of organic matter in the soils and limit production costs, the Agronomic Utilization Plans referred to in article 5 of the decree of the Minister of Agricultural, Food and Forestry Policies of 25 February 2016, published in the ordinary supplement to the Official Gazette of the Italian Republic no. 90 of 18 April 2016, provide for the replacement of synthetic chemical fertilizers with equivalent digestate referred to in Article 52, paragraph 2-bis, of the decree-law of 22 June 2012, no. 83, converted, with modifications, by the law 7 August 2012, n. 134, as amended by paragraph 2 of this article.

2. In article 52, paragraph 2-bis, of the decree-law no. 83 of 2012, converted, with amendments, by law no. 134 of 2012, the second sentence is replaced by the following: "The digestate referred to in this paragraph is considered equivalent to fertilizers of chemical origin when it is obtained from the anaerobic digestion of substances and materials alone or mixed with each other, pursuant to provided for by article 22 of the decree of the Minister of Agricultural, Food and Forestry Policies of 25 February 2016, published in the ordinary supplement to the Official Gazette of the Italian Republic no. 90 of 18 April 2016, used in a low-emissivity and high-efficiency mode of nutrient recycling and in compliance with the requirements and characteristics defined by the decree referred to in the third period of this paragraph, for products that act on the soil of chemical origin. The characteristics and methods of use of the equivalent digestate are defined by decree of the Minister of Agricultural, Food and Forestry Policies, in agreement with the Minister of Ecological Transition, to be adopted within thirty days from the date of entry into force of this provision. "

3. Letter o-bis) of paragraph 1 of article 3 and Chapter IV-bis of Title IV of the decree of the Minister of Agricultural, Food and Forestry Policies of 25 February 2016, as introduced by article 1, paragraph 527, of the law 27 December 2019, n. 160, are repealed.

ACS Sustainable Chemistry & Engineering
pubs.acs.org/journal/ascecg Research Article

Environmental Performance in the Production and Use of Recovered Fertilizers from Organic Wastes Treated by Anaerobic Digestion vs Synthetic Mineral Fertilizers

Axel Herrera, Giuliana D'Imporzano,* Massimo Zilio, Ambrogio Pigoli, Bruno Rizzi, Erik Meers, Oscar Schouman, Micol Schepis, Federica Barone, Andrea Giordano, and Fabrizio Adani*

Cite This: ACS Sustainable Chem. Eng. 2022, 10, 986−997 Read Online

RF = Recovered fertilizers (digestate)

RS = Synthetic mineral fertilizers

Table S6. Average maize productions yield in grain for the three years of experiments (mean ± SD; n=9). Table modified from Zilio et al., 2021.

Fertilizer	Grain yield dw[a] (Mg Ha^{-1})
Unfertilized	10.4 ± 3.5 (a)[b]
Synthetic fertilizer	17.4 ± 1.2 (b)
Recovered fertilizer	18.1 ± 2.9 (b)

[a]dw: dry weight

[b]Letters are referred to One-way ANOVA analysis (Tukey post-test, $p < 0.01$; n=9).

Herrera et al., 2022, ACS Sustainable Chem. Eng. 2022, 10, 986−997

GHG, NH_3 and NO_3^- emissions

RF = recovered fertilizers (digestate)

RF = Synthetic mineral fertilizers

Table S4. Comparison between emissions (Ammonia, GHG and Nitrate leaching) and grain production measured from experimental soils fertilized with digestate and urea during the agronomic season (maize) (RF = Recovered Fertilizers and SF = Synthetic Fertiliser). The column "unfertilized" refers to the control plots set during the experimental design.

Parameter	Unit	RF	SF	Unfertilized
NH_3[a]	$kgN\ ha^{-1}$	25.6 ± 9.4(a)[b]	24.8 ± 8.3(a)	Undetectable[c]
N_2O[d]	$kgN\ ha^{-1}$	7.59 ± 3.2(ab)	10.3 ± 6.8(b)	1.71 ± 1.1(a)
CO_2[d]	$kgC\ ha^{-1}$	6216 ± 1160(a)	6144 ± 1491(a)	5698 ± 935(a)
CH_4[d]	$kgC\ ha^{-1}$	0036 ± 0.03(a)	0.053 ± 0.04(a)	0.066 ± 0.06(a)
NO_3^-[e]	$mgN\ kg^{-1}$	6.45 ± 7.6(a)	7.24 ± 8.6(a)	6.23 ± 7.1(a)
Grain Yield	$Mg\ ha^{-1}$ DM[f]	18.1 ± 2.9(b)	17.4 ± 1.2(b)	10.4 ± 3.5(a)

[a]Cumulative emissions measurements carried out up to 90 hours after spreading (n = 9). The measures were repeated for three consecutive years (2018-2019-2020). Total N dosed: 370 $kgN\ ha^{-1}$ (Digestate), 185 $kgN\ ha^{-1}$ (Urea) (from Zilio et al., 2021)

[b]Letters in brackets are referred to One-way ANOVA analysis carried out for each of the emission source reported in the table (Tukey post-test, $p < 0.05$; $n = 3$).

[c]Ammonia emission in unfertilized plots did not differ from background.

[d]Cumulative emissions measurements carried out from 28/05/2020 (spreading) to 17/03/2021 (293 days, n = 36). Total N dosed: 370 $kgN\ ha^{-1}$ (Digestate), 185 $kgN\ ha^{-1}$ (Urea)

[e]Average concentration of NO_3^- in the soil at 1-meter depth. The measurements were carried out in 3 moments of the season (before spreading in pre-sowing, 20 days after spreading and after harvesting). n for each measure = 3. Total N dosed: 370 $kgN\ ha^{-1}$ (Digestate), 185 $kgN\ ha^{-1}$ (Urea)

[f]DM = dry matter

Herrera et al., 2022, ACS Sustainable Chem. Eng. 2022, 10, 986−997

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RF = recovered fertilizers (digestate)

RF = Synthetic mineral fertilizers

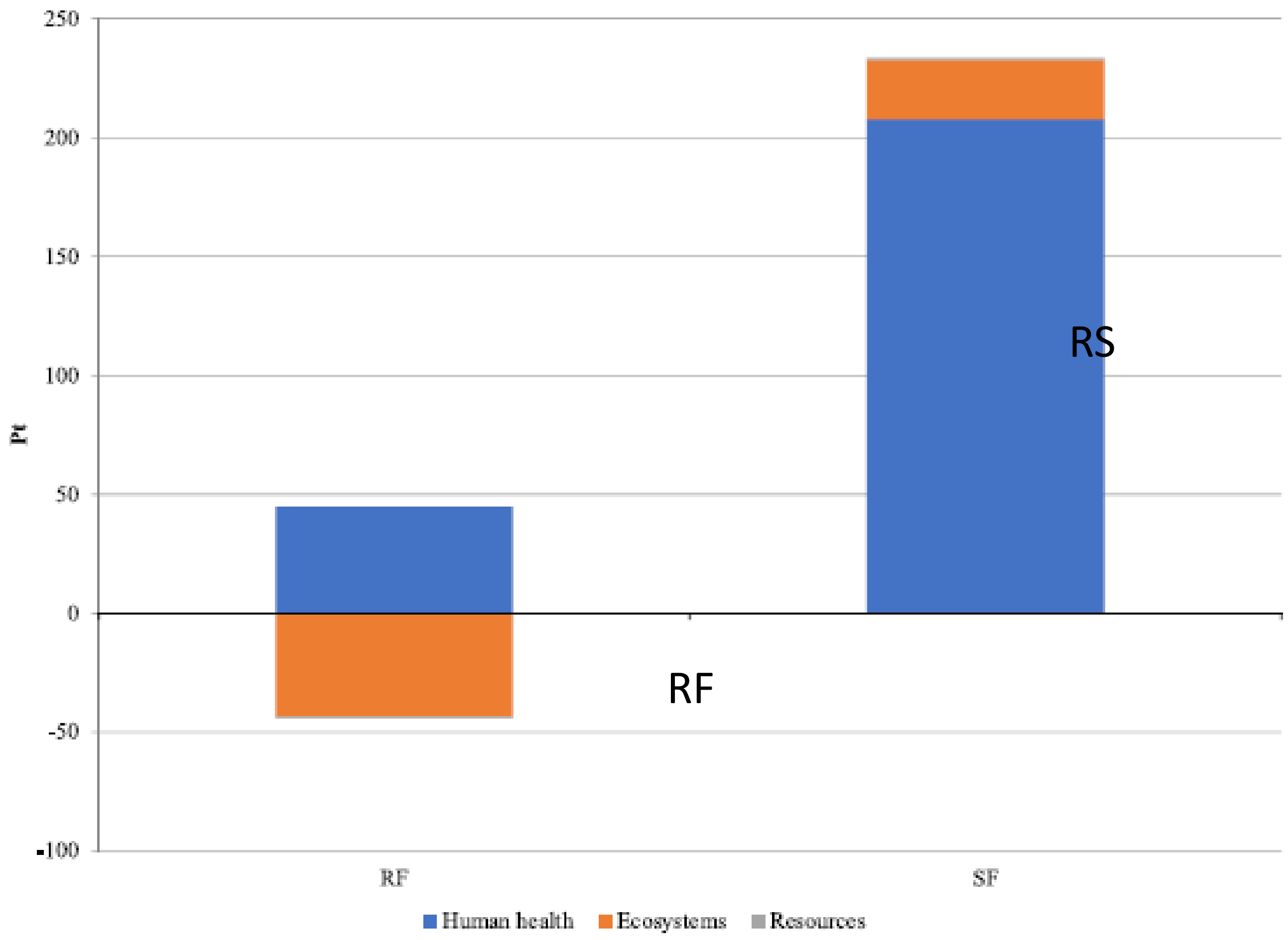

Figure 2. Comparative environmental results for Scenarios Recovered Fertilizers (RFs) and Synthetic Fertilizers (SFs). Impact assessment (Ecopoint—Pt) calculated according to the ReCiPe 2016 end point (H) V 1.03 impact assessment method.

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Herrera et al., 2022, ACS Sustainable Chem. Eng. 2022, 10, 986−997

Definition Circular Economy

A Circular Economy is an industrial system that is restorative or regenerative by design. It replaces the ‘end-of-life’ concept with restoration, shifts towards the use of renewable energy, eliminates use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models.

Circular economy is not recycling but it must include the review of production processes to allow a real and safe use of waste as feedstock to produce “Renewable Fertilizers”.

- E.g. Reducing chemicals (antibiotics) in animal slurries = review animal breeding;

- E.g. Reducing pollutant and inert in OFMSW = door to door separate collection and bioplastics as substitute of plastic;

- E.g. Reducing pollutant, micro plastics etc. in sewage sludge = redesign goods limiting the presence of pollutant and microplastics and redesign wastewater treatment plant.

Circular responsibility

Real example of Circular economy under investigation in two H2020

Nutri2Cycle
Nurturing the Circular Economy

NUTRI2CYCLE: Transition towards a more carbon and nutrient efficient agriculture in Europe

Call: H2020-SFS-2016-2017: Sustainable Food Security – Resilient and resource-efficient value chains

Nutri2Cycle
Nurturing the Circular Economy

SYSTEMIC aspires to produce fertilizers that are up to standard compared to synthetic products. In order to realize this ambition, product quality will be monitored and optimized in order to meet the criteria of the end users, who are naturally closely involved in the whole process. This iteration process ensures that *demonstration plants* will produce user-specific products that can be applied in the nearby region.

Systemic
Circular solutions for biowaste

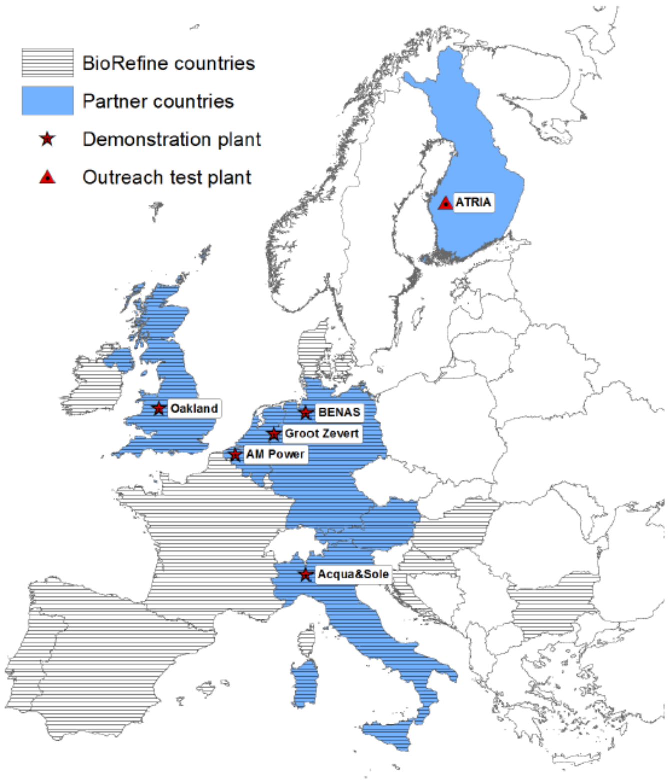

Figure 2 Location of SYSTEMIC's large scale demonstration plants for the demonstration of novel nutrient recovery technologies for biowaste valorisation.

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PRODUZIONE, TERRITORIO, AGROENERGIA

THANK YOU FOR YOUR ATTENTION

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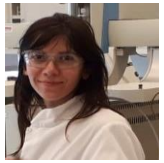

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