

## **Edited Chat from ESPP webinar on Legacy Phosphorus 2<sup>nd</sup> February 2022**

Co-organised by ESPP and Boku

Slides and recording of the webinar will be available here [www.phosphorusplatform.eu/LegacyP](http://www.phosphorusplatform.eu/LegacyP)

Also, ESPP will produce a [SCOPE Newsletter](#) special summarising this webinar and presenting also recent scientific publications and reports relevant to Legacy Phosphorus. **Please send any relevant publications for consideration to [info@phosphorusplatform.eu](mailto:info@phosphorusplatform.eu)**

Ed Weinberg: Q for A. Sharpley: Andrew I have your textbook on the subject matter from the 90's. It showed the US map with N and P regions impaired by nutrient pollution in black. In terms of legacy P, have the impaired regions gotten bigger, smaller or the same now that more attention is being paid to conservation practices since you generated that map image?

Andrew Sharpley: I do not believe these maps have been updated, but others with NRCS or IPNI may have a better idea. However, I suspect the "impaired regions" still exist but have not increased to any great degree. In some areas of the U.S., I believe the areas of "impairment" have decreased due to the adoption and implementation of conservation strategies on agricultural lands.

Laura Johnson: Link to Rich McDowell's paper <https://www.frontiersin.org/articles/10.3389/fenvs.2020.00006/full>

Chris Thornton: Question to Achim. You mention precision application of fertilisers (and manure). It seems there is more progress for precision application for N. Do you see developments of precision application of P?

Arno Rosemarin: Q for Andrew. How does P offtake compare between grasslands and cereals? That is, their relative P mining capacity.

Romek Postma: With respect to precision application of P: placement and/or row application of P are quite common and effective precision application techniques, after my opinion

Arno Rosemarin/SEI: for Phil. Phil: How large is the global stored/legacy P in agric. soil compared to fertilizer P used since the green revolution?

Phil Haygarth: @Arno that is an excellent question and of course very difficult to answer. Having done some initial thinking about this, it is my opinion that this is of at least a similar magnitude to the stores of global P reserves. With colleagues, we are working on a paper on this at the moment and we hope to publish more details soon.

Rachid Mrabet PhD INRA MOROCCO: thank you for these highly appreciated presentations. How do plant-soil feedbacks affect P legacy in soils and then on residual P? How can climatic stress particularly water scarcity be studied?

Arno Rosemarin/SEI: FYI. Phosphorus Flows, Surpluses, and N/P Agronomic Balancing When Using Manure from Pig and Poultry Farms <https://www.mdpi.com/2073-4395/11/11/2228>

Anna Jama-Rodzeńska: Waste to Phosphorus <https://www.sciencedirect.com/science/article/pii/S0301479721002978> and Phosphorus Recovery from Sewage Sludge Ash <https://www.mdpi.com/2075-163X/11/9/985>

Ranjan Bhattacharyya: How much could cover crops and buffer strips could address the issue?

Chris Thornton: Question to Inge: yield losses are very significant (20-40%) even on sandy soil. How does the end-of-decade soil P level compare to agronomic recommendations? Is the mining taking P below recommended soil levels?

Alessio Adamiano: To Inge: Is there any difference among the form of phosphorous at different depths in the soil?

Antoine Besson: Question for Inge do you have a good relation between soil P analysis results evolution an P quantity in forage (if you measure that) Thank you

Koen Desimpelaere Belgium: Concerning the presentation from Wageningen. How do you explain such quick response on crop yield with still sufficient P content in the soil? Different conclusions were made in this study:

[https://www.vlm.be/nl/themas/waterkwaliteit/Mestbank/Achtergrond/cijfers-en-studies/afgeronde\\_studies/Milieukundig-en-economisch-verantwoord-fosforgebruik/Paginas/default.aspx](https://www.vlm.be/nl/themas/waterkwaliteit/Mestbank/Achtergrond/cijfers-en-studies/afgeronde_studies/Milieukundig-en-economisch-verantwoord-fosforgebruik/Paginas/default.aspx)

Ed Weinberg: Q for Debby: are the deep P soil reserves you mentioned at a depth > or < the 50 cm depth studied?

Martin van Ittersum: Hi all, some years back we estimated the effects of soil legacy P on crop and grass yields in different parts of the world. No doubt this can be improved by now, but it gives an indication of the differences across the world and the importance for future production: Sattari et al. 2016 Negative global phosphorus budgets challenge sustainable intensification of grasslands <https://doi.org/10.1038/ncomms10696>

Andrew Margenot: Soil reserves at depth sounds like the "subsoil P supply power" concept that used to be common in agronomic recommendations in many midwestern US states. But no longer used in most states.

Chris Thornton: Andrew: why is the "subsoil supply" no longer used in many states. It seems like it might make some sense?

Debby van Rotterdam: @ Ed we measured up to 50cm depth. Not deeper

Henrique Miranda: Water treatment technology <https://better2earth.com/home/faq/> and <https://better2earth.com/applications/wt-adofpion/>

Chammi Attanayake: How important is to look into inorganic P and organic P stocks separately when balancing agronomic P and Environmentally important P losses?

Chris Thornton: Agnieszka: what is the green horizontal line in the slide ("CHANGES IN P CONTENT IN THE PLOUGH LAYER ....")

Agnieszka Rutkowska: it is the initial content of P available in soil in 2003

Hasbullah: Q for Sabina: how large was the size of the land use in this study? Thanks

Sabina Braun (SLU): Plot size of the Swedish long-term soil fertility experiments are between 108-125 m<sup>2</sup> (varies between locations)

Eugen Köhler: to Sabina Brown: in 50 years there is a much progress by breeding, so the effect of declining P content could be hidden by breeding effect?

Antoine Besson: Question for Sabina: what was the initial P-AI content? Should be high, because 50 years without P fertilization is a long time...

Anne-Kristin Løes: lower mineral concentration in cereals over 50 years may well be one explanation but how much of the crop rotation here was cereals?

Dionisios Gasparatos: A question for this section It is possible to support solely a crop by mobilizing legacy phosphorus?

Brad Bass: Did any of the speakers look at the mycorrhizae. The presence of absence of a healthy fungal population, that maintains attachment to the plant roots would be an important factor in mobilizing legacy P.

Jakob Magid: In our long-term depletion experiment we saw clear yield decreases in 'bad' years with cold weather in spring - but no effect in 'good' years

Dionisios Gasparatos: Thank you Jakob, I understand that pedoclimatic conditions play crucial role in these experiments

Andrew Sharpley: Legacy soil P can support crop P requirements, however, time is critical in that legacy soil P built up in the soil can transition from plant available to less labile forms and eventually not supply sufficient P. This would depend on soil properties and its' capacity to sorb P. Hope this helps.

Hasbullah: Q to Sabina, what is the "push" factor making the yield not declining despite no P fertiliser for long period?

Sabina Braun (SLU): For more information about our LTEs, please download our "Guide to the trials" from this page: <https://www.slu.se/en/departments/soil-environment/research/soil-nutrient-cycling/slu-field-research-plant-nutrition/>

Antoine Besson: To have a better idea is maybe better to systematically make to extracts (intensity and quantity) so we have the apparent buffer capacity

Brad Bass: The last presentation mentioned the impact of cooler soils on P uptake. This phenomenon is well-known by cold-climate researchers. Did any other speakers measure soil temperature?

Kari Ylivainio: Soil moisture status has a clear effect on utilization of soil P reserves as well as P from fertilizers, <https://doi.org/10.1111/jac.12241>

Lars Stoumann Jensen: @Brad Bass: We documented the effect of low soil temp effects on soil P stress based on a long-term nutrient depletion trial <http://dx.doi.org/10.1016/j.eja.2017.02.006>

Свилен Смиленов: Can microorganisms be used to mineralize and reduce the input of phosphorus fertilizers without reducing the yield

Chris Thornton: Amy: for how many years does the "manure carry over" benefit crop yields?

Amy Shober: Chris, we don't quite know. We saw the yields begin to drop about 2 years after the M3P dropped below that agronomic critical level, but they were still above the no manure P. We will have more data this season

Andrew Sharpley: Chris - soil test sampling depths have historically been from 4 to 10 inches, depending on ag production system. there would likely be some benefit to measure subsoil P but the additional work and cost in analysis would in most cases be prohibitive to the ag community. Also, there would need to be an effort on plant uptake to determine response etc. and develop reliable recommendations.

Torsten Müller: The annual application rates in the experiments reported are extremely high and not very realistic

Hannah Walling: A question for Nicole - With regard to the potential manure carry over effect seen in soybean; is it possible that the interaction between P&N, particularly due to soybean BNF, may have impacted this - if so how could this be accounted for in the study?

Andrew Sharpley: Additional after thought. I do not believe subsoil P levels have been used in the past in the US. Other attendees may have a more information on this.

Kari Ylivainio: Low soil temperature effect on labile soil P content, <https://doi.org/10.23986/afsci.6389>

Maarten van Doorn: @Emileigh, how did you derive the soil phosphorus storage capacity?

Emileigh Lucas: Hi @Maarten, I used the equation from Dr. Nair's 2020 paper: Nair, V.D., Sollenberger, L.E., Harris, W.G., Sharpley, A.N., Freitas, A.M., Dubeux, J.C.B., et al., 2020. Mining of soil legacy phosphorus without jeopardizing crop yield. *Agrosyst. Geosci. Environ.* 3 (1) <https://doi.org/10.1002/agg2.20056>

Hannah Walling: For Amy - With regard to the potential manure carry over effect seen in soybean; is it possible that the interaction between P&N, particularly due to soybean BNF, may have impacted this - if so how could this be accounted for in the study?

Amy Shober: Torsten, manure applications in our study were applied over 4 years in equal amounts to get to the total P rate. This was to build soil test to concentrations that were consistent with what we see in our region of the US.

Chris Thornton: To Amy, Emileigh, is the 0.15 environmental risk threshold using the same measurement as the 50 limits above which crop yield is not expected increase, or if not how does one level compare to the other?

Emileigh Lucas: Hi @Chris Thornton. This value was based on research in the region comparing PSR to water soluble P: Sims, J.T., Maguire, R.O., Leytem, A.B., Gartley, K.L., Pautler, M.C., 2002. Evaluation of Mehlich 3 as an agri-environmental soil phosphorus test for the Mid-Atlantic United States of America. *Soil Sci. Soc. Am. J.* 66 (6), 2016. <https://doi.org/10.2136/sssaj2002.2016>

Amy Shober: Chris, the 50 ppm agronomic critical level is based on probability of crop response to P. If I recall correctly, Emileigh calculated the 0.15 as a P saturation ratio which also accounts for Fe and Al in the soil and is more of an environmental measure.

Amy Shober: Hannah, we had not considered the interaction between N&P with BNF. We are not sure how to account for that but will look into it in the future

Amy Shober: Fiorellino, N., Kratochvil, R. and Coale, F. (2017), Long-Term Agronomic Drawdown of Soil Phosphorus in Mid-Atlantic Coastal Plain Soils. *Agronomy Journal*, 109: 455-461.  
<https://doi.org/10.2134/agronj2016.07.0409>

Thomas Appel: Question to T.Q Zhang: What kind of soil P test?

Chris Thornton: To TQ: interesting that most of the P loss to surface water seems to be Particulate P (PP). High losses of P as Particulate, offers more opportunity for reducing losses by reducing erosion, sediment traps ... (compared to soluble P losses)?

T.Q. Zhang: Yes. About 60-70% of TP loss was in PP. High PP loss can offer us a good/easier opportunity to trap the P leaving the field than DRP

Andrew Sharpley: PP can be efficiently trapped in-field via several conservation practices; however, we must remember that these practices will eventually transition to a source of P. This has been documented in field studies by several researchers globally. This can be addressed by vertical and periodic tillage of no-till soils. Others have looked at application of P-binding materials to field buffers and harvesting and removal of vegetation from buffers, where feasible.

T.Q. Zhang: @Thomas Appel: Soil test P was Olsen P

Amy Shober: Torsten, it was also not uncommon 3 decades ago for soils in our region to receive very heavy manure applications. I had heard of applications of 22 metric ton/ha or higher in some cases. We see Mehlich P concentrations up to 1000 mg/kg in some soils, although this is uncommon. But many of our soils test above 100 mg/kg and it is not uncommon to see concentrations in the 200-300 range, which is where the soils in our study started in 2001.

Debby van Rotterdam: Dr. Zhang what was the net soil P-balance at the application rate of 50 kg P/ha?

T.Q. Zhang: @ Debby van Rotterdam: On average the net soil P balance is about 6 kgP/ha per crop rotation, .

Chris Thornton: To TQ: it seems that the "drawdown" field tests had higher start soil P and by end of experiment had the same soil P as fertilised plots. Were the soil P levels higher than agronomic recommendations?

T.Q. Zhang: @ Chris Thornton: No P is recommended if STP (Olsen P) is above 30 ppm for corn and above 15 ppm for soybean.

Rachid Mrabet, INRA Morocco: to TQ: did you find any kind of relationship between P drawdown and legacy for selected farming systems?

T.Q. Zhang: Hi, Rachid: We are looking at the issue. Hope to have data in the near future.

Doug Myers: I'm glad to hear that pH was considered in the Canadian study. Are others doing field trials paying attention to the role of pH in plant availability?

Chris Dawson: Is there any evidence of a difference between legacy P originally input from manures than from mineral P?

T.Q. Zhang: Chris Dawson: Very interesting question -" Is there any evidence of a difference between legacy P originally input from manures than from mineral P?". We should have data shortly from field plots.

Tales Tiecher: Question for Paulo Pavinato: In Brazil, most soils are cultivated in no-till system combined with surface application of P. At the same time we see excess P in the first centimetres of soil, generating large transfer of P to water bodies, in the same cornfields it is possible to detect P levels much lower than the plant needs a few centimetre below soil surface, generating P deficiency for the plant under water stress conditions. In addition, in the subsurface it is also common to see very acidic conditions and plants suffering from Al toxicity. A strategic/occasional tillage aiming to distribute the element in depth seems to be the way out in many of these areas, correcting the P availability and at the same operation, incorporating liming for Al<sup>3+</sup>. But there is still great resistance to this technique, and a great fear of losing the contents of soil organic matter. What is your opinion about this?

Saurav Das: If anyone interested, >100 years of agricultural experiment; >700 years of manure treatment, >70 years of different N-rates; we recorded P at a depth of 150 cm; though P was not our initial objective; we are now

looking into it, the correlation and causation. A paper from that >100 years study with soil data, which discusses mostly on yield data but also has the soil data: <https://access.onlinelibrary.wiley.com/doi/full/10.1002/agj2.20713>

James Elser: Hello all: I wanted to call everyone's attention to the new US NSF-funded Science & Tech Center on P sustainability, STEPS. It is just getting off the ground and will be executing interdisciplinary work on many of the P sustainability challenges we face, including those from legacy P. Check out <https://steps-center.org/> Also I wanted to let everyone know to hold the first week of November 2022 for the next international Sustainable Phosphorus Summit to be held in Raleigh, NC, under the organization of the STEPS center. More info forthcoming.

Stefaan De Neve: Hi Victoria: How to make a reliable P balance when the different balance components differ by several orders of magnitude, with large uncertainties on the individual components?

Victoria Barcala: @stefan de Neve, thanks for the question. The P going out from the ditch was measured with an autoanalyzer every 15 minutes, this could give us the best available data of the P output. There is indeed a large difference between the stored P and the P leaving the catchment

Chris Thornton: To Victoria. How do the soil P levels across your farm compare to agronomic recommended soil P levels: high, low?

Victoria Barcala: @chris, thanks for the question, most of it is high P

Gunnar Norén: A reflection: Conclusion from many presentation may be\* We have had a heavily overfertilization of P, the last 10-25 years \* Overfertilization with P does not give increased crop yield. Balanced P-application with the crop is enough, and reduce P-leakage

Victoria Barcala: @Gunnar Noren, we saw that the annual rainfall and man-managed groundwater levels have a large impact on the P leaving the catchment in the surface water. A good water supply has also a positive impact on crop growth

Victoria Barcala: here you can find more about this study <https://doi.org/10.1088/1748-9326/abcd4>

Brad Bass, ECCC: Juliane, is the Rainfall Runoff module an empirical equation or does it include any soil dynamics that allow for water and nutrient infiltration to various depths.

Mehdi Nkebiwe: Juliane, are there some limitations arising from using a STP-decline function that is based on a pot trial?

Chris Thornton: Juliane: for the two zero-P fertiliser scenarios, do you expect to maintain crop yield?

Juliane Hirte: @Chris: Yes, for 0% P and 100% NK scenario, but not for the 0% NPK scenario.

Juliane Hirte: We see in our 30-year LTEs that slight yield reductions (5%) start below 50% P application.

Juliane Hirte: @Mehdi: Yes, it is very likely that the soil in the pots was faster P depleted than would be expected in the field (high yields in pot experiment, little soil volume to feed on ...).

Juliane Hirte: @Brad: Sorry that I can't answer this question. You could contact Volker Prasuhn, who has co-developed the model.

Chris Dawson: Sarah, was there no influence from water treatment works in the rivers you studied?

Chris Thornton: Thanks Juliane. The challenge is that for the farmer, the real life economic scenario is N application. Loss of yield because of reduction of N and of P may not be economically sustainable for the farmer?

Brad Bass, ECCC: We have just completed some of the work that Sarah is talking about for the Lake Erie Basin. Please contact me if you would like to discuss this work or see the work - [brad.bass@ec.gc.ca](mailto:brad.bass@ec.gc.ca) We show how much land must be serviced by BMPs to reach the agreed-upon targets for Lake Erie and the costs and benefits of these BMPs.

Sandra Bihn: Do edge of field studies work for soil phosphorus runoff? Could someone provide research on using no P and yields are still good? Can someone provide the Belgium information on P lower than crop requirements

Stefaan De Neve: In Belgium the P limits are lower than crop requirement for most soils. Unfortunately I have this only in Dutch. P fertilization depends on P status. Most soils are high in P, and in these soils P fertilizer limits are



(considerably) lower than P uptake: <https://www.vlm.be/nl/themas/waterkwaliteit/Mestbank/bemesting/aanwenden-van-mest/bemestingsnormen/brochures-normen-en-richtwaarden/Paginas/default.aspx>

Barbara Cade-Menun: Yes, edge of field studies work for soil P runoff, but it depends on the size of the field

Sarah Stackpoole: We did consider the influence of waste water treatment plant effluent. We excluded 30 watersheds of the 173 with P balance, because Waste Water Treatment Facility Effluent accounted for more than 50% of the total river P load.

Stefaan De Neve: For drained fields you can consider installing Pi traps (e.g. iron coated sand)

Chris Thornton: How to answer the farmer who says: if I Don't Apply P, then if the weather is good this year then I will lose crop yield (even if I recognised that in many years the weather will not allow this high crop yield)?

Vimala Nair: Could someone provide research on using no P and yields are still good?

Stefania Appelhans: @Vimala Nair, I shared you a paper on this <https://doi.org/10.1111/ejss.12946>

Debby van Rotterdam: legislative limits to P-application depend on available soil P content of the topsoil in The Netherlands. Because our legacy P is rather high the application is limited to a zero or negative balance

Maarten van Doorn: As a general question, what are your opinions on the soil P tests used in routine agronomic soil testing? Are those sufficient to derive measures to best make of legacy P?

T.Q. Zhang: Hi, Vimala: You can look at the data included in my talk today.

Jian Liu: @Sandra Bihn, we had an edge-of-field study, with reduced P fertilizer input that did not impact crop yield. Impacts of Soil Phosphorus Drawdown on Snowmelt and Rainfall Runoff Water Quality <https://doi.org/10.2134/jeq2018.12.0437>

Vincenzo Conca: General question: what about plant availability of iron or aluminium phosphate?

Juliane Hirte: @Chris: Yes, that is for sure a more complicated aspect of P management in practice. We are currently working on refining fertilisation recommendations and include more co-variables into account (also average MAT and MAP).

Karoline D'Haene: In different regions in Europe the legally maximum allowed P for soils with high P concentration is below P offtake. [https://www.actahort.org/books/1327/1327\\_107.htm](https://www.actahort.org/books/1327/1327_107.htm)

T.Q. Zhang: Hi, Vimala here is the paper on no yield reduction with zero P addition <https://www.frontiersin.org/articles/10.3389/feart.2020.00115/full> (see [ESPP eNews n°56](#))

Panos Panagos: Poland is one of the few Eastern European countries with high concentration in Phosphorus in the agricultural soils. Why? higher fertilizer inputs?

Stefaan De Neve: Hi Vimala, paper on no effect on crop yield for crops including those with high P requirements: Vandermore et al. 2021 <https://www.sciencedirect.com/science/article/abs/pii/S0167880921003649>

Monica Garnier: Not to increase complexity, but according to my opinion also the effects of climate change (e.g. increase of rainfall storminess) should be taken into account

Anna Jama-Rodzeńska: Currently, 40% of the soil in Poland is acidic or very acidic, and its uptake is highly dependent on soil pH and temperature. One in four soil samples tested in Poland by county agricultural chemical stations in 2016-2019 had very low or low levels of available phosphorus. Such content is unacceptable,

Chris Thornton: Should the definition of "Legacy P" be limited to only P above soil agronomic recommended level (minimum to maintain crop yield) or is it simply the difference between "natural" levels and today?

Amy Shoher: Chris, this is the exact question we posed to our US P workgroup ([SERA-17](#)). There was really no consensus. I think this is why Luke Gatiboni suggested that we always define what we mean when we use the term.

Paulo Pavinato: dear Chris and all: if we consider legacy P as only above soil test P limit. what should be considered the big amount of P accumulated in non-available forms in the soil, especially in tropical conditions?

Greta Najcler: @Leonadus can you provide a link to that paper you just mentioned?

Leonardus Vergutz: <https://www.sprpn.org/post/furthering-4r-nutrient-stewardship>

Agnieszka Rutkowska: In Poland 40% of soils monitored by agrochemical stations are characterized by regulated pH and high and very high content of available P and cumulation of available phosphorus in that soils systematically increase.

Sandra Bihn: How is manure vs commercial fertilizer being evaluated - commercial P reduction is economic etc - but what about manure P?

Greta Najcler: @ James Elser - great comment about how to manage expectations!

Yu Gu: general further question following Paulo: how much this "non- available P" will be still available to crops in the further? and when doing fertilizer recommendation, how do we consider the contribution from the "non-available P" in the future?

Stefaan De Neve: The big challenge is not to re-use the easily (plant) available legacy P in soil, but the legacy P that is gradually transformed into less available forms (like residual P). This legacy residual P is probably the largest pool in soil, so how to re-use it? Use PSB, mycorrhizal inoculations, ...?

Debby van Rotterdam: The analytical error is a very good point. We found that you need at least (!) 5 years of data to be able to see a difference in available soil P but it took 10 years to see significant difference in available P reserves. This depends of course on removal rates, initial status and binding capacity. It can be easily calculated if you expect to be able to see a change based on the standard analytical error

Jennifer Davies: General question to all panellists - How much of our legacy P research is being followed up or applied to crop/biogeochemical/hydrological computer-based modelling? How will this influence our understanding of how we manage legacy P?

Daniel Goll: There is a couple studies, but they rely on poorly constrained soil P models: e.g. Barbieri, P., Macdonald, G. K., Raymond, A. B. De, & Nesme, T. (2021). Food system resilience to phosphorus shortages on a telecoupled planet. *Nature Sustain.* <https://doi.org/10.1038/s41893-021-00816-1> Le Noë, J., Roux, N., Billen, G., Gingrich, S., Erb, K. H., Krausmann, F., Thieu, V., Silvestre, M., & Garnier, J. (2020). The phosphorus legacy offers opportunities for agro-ecological transition (France 1850-2075). *Environmental Research Letters*, 15(6). n press <https://doi.org/10.1088/1748-9326/ab82cc>

Ed Weinberg: General Q for the panel. How does one scale up to thousands of ha's or acres that need to address Legacy P losses when it appears from the presentations that it is a proactive but very slow process to remedy and thus needs a lot of "patient" capital?

T.Q. Zhang: Hi, Sandra Bihn: You may look at this paper re. manure P evaluation vs. commercial fertilizer P <https://www.sciencedirect.com/science/article/pii/S0016706116302051>

Syed Shahid Hussain Shah: Can we manage p application as per mining rate from soil to soil?

Mehdi Nkebiwe: Regarding modelling of Legacy P: Yu, W., Li, H., Nkebiwe, P. M., Li, G., Müller, T., Zhang, J., & Shen, J. (2021). Estimation of the P fertilizer demand of China using the LePA model. *Frontiers in Environmental Science*, 492. <https://doi.org/10.3389/fenvs.2021.759984>

Mohamed Eida: General question to all panellists: better utilization of P legacy requires efficient management practices that will base on soil P content analysis. How this matter could be addressed from resources and analysis quality perspectives?

Kari Ylivainio: Here are some results from meta analyses conducted in Finland by Valkama et al. <https://doi.org/10.1016/j.agee.2008.12.004> and <https://link.springer.com/article/10.1007%2Fs10705-011-9434-4> <https://doi.org/10.1007/s10705-011-9434-4>

Sandra Bihn: This discussion of legacy has not included commercial P vs manure P and legacy impacts

Gunnar Norén: Example: farmers use manure for the N-content, but the P-content is overfertilization, on soils with high P-content

Nandita Basu: Modelling how legacy P modelling helps informs water quality: Van Meter et al. <https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2020WR029316?ai=1gvoi&mi=3ricys&af=R>

Carl Bolster: If anyone is interested on modelling uncertainty and predictions of STP drawdown using APLE model

Carl Bolster: APLE model for soil test P <https://access.onlinelibrary.wiley.com/doi/10.1002/jeq2.20328>

Jóska Gerendás: General comment to the panellists: In most talks no reference is made to different P fertilisers and different modes of application (--> 4R principles). Farmers already use fertiliser placement in maize for decades, and such measures increase fertiliser efficiency and could compensate for P applications below P removal.

Vincenzo Conca: It could be even interesting to discuss about solid fertilization from waste activated sludge deriving from wastewater treatment. What about this P amount? About 20% of fertilizing P is contained in wastewater sludge

Monica Garnier: another problem could be increase of erosion because of climate change and consequently loss of soil bound P

Pam Way: How does the panel feel about landscape practices such as constructed wetlands or stormwater wet ponds to address P in downstream basin stormwater runoff? Today's data suggest there is a time lag between science solutions and practical application. Is downstream or basin practices effective to address the legacy P in runoff to surface waters?

Syed Shahid Hussain Shah: can we standardize mining rate based on different soil type, initial soil p level and N and K application rates, if yes can be the discussion tool for P application?

Amy Shoher: Syed, we saw different mining rates in the same soils depending on the starting soil test P. Soils with higher initial soil test P showed more rapid depletion.

Stefania Appelhans: About improving soil tests, we studied the contribution of organic P fractions for soybean and maize P fertilization recommendations: <https://doi.org/10.1111/sum.12581> and <https://doi.org/10.1007/s42729-020-00387-8>

Anders Nättorp: climate Change as a redistribution of dry zones would be nice. We are seeing already today how weather systems stall, leading to weather extremes. Dealing with 1 month of drought and events of torrential rain in the same season seems to be the likely scenario. Any comment on how to deal with that?

Chris Thornton: Climate change is likely to increase soil P losses whilst increasing crop P needs, see [www.phosphorusplatform.eu/Scope137](http://www.phosphorusplatform.eu/Scope137)

Antonio Delgado: These extreme events will result in less efficient use of by crops, and likely higher P losses due to erosion

Monica Garnier: I 100% agree with you Antonio

Dean Collamer: Identification of best management practices and microbials that mine legacy P from less labile forms seems to be a great opportunity for research to better utilize legacy P in our excessively high P soils. e.g. N management. that stimulates P uptake (Roth, Beegle et al. 2011 <https://doi.org/10.1081/CSS-120020451> and 2006 <https://doi.org/10.2134/agronj2005.0220> ). Also, the following paper shows that mycorrhizal fungi and bacteria in combination can facilitate P uptake in maize: Battini, et al. 2017 <https://doi.org/10.1038/s41598-017-04959-0> Also, the following paper shows that numerous soil bacteria can facilitate improved P solubilization/plant uptake/growth of Legacy P. Ibáñez et al. 2021. <https://doi.org/10.3390/microorganisms9081619>

Luke Gatiboni: Yes, that is true. The extreme events related to climate changes are a big concern, for instance, losses of P with soil erosion with huge rainfall events

Jóska Gerendás: Several presenters during today's sessions, as well as authors of scientific papers, state that omitting or substantially reducing fertiliser application does not reduce yields, because effects were not statistically significant. From a farmer's perspective, however, 0.5 t/ha yield difference is substantial, whereas many scientific field studies exhibit minimal significant difference of 1 t/ha or more. Statistical tests normally employed only control the type I error (e.g. alpha = 5%) and cannot prove that a yield reduction is absent. They only confirm that the effect could not be statistically verified. The only valid conclusion that can be drawn from such trial data is that the experimental question (e.g. does it matter to the farmer) cannot be addressed.



Richard Meinert: 0.5 ton yield increase may not be significant to a scientist but to a farmer growing 3000 acres of corn an additional half ton per acre is like adding 75 acres of cropland. Definitely significant to the farmer!

Liisa Pietola: Thank you very much for ESPP, presenters and panellists! Indeed, this is very complex issue for farmers. Let's continue to make most use of our soils for food.

Matt Davis: Thank you and very interesting to hear such a range of speakers. Lots for me to consider with my work in England.

James Elser: Also here is link to the Phosphorus book mentioned. <https://www.amazon.com/Phosphorus-Past-Future-Jim-Elser/dp/0199916918>

Ludwig Hermann: Don't forget to save the dates and plan your trip to Vienna, 20-22 June 2022, to attend ESPC4, the largest P event in years and the next real opportunity to meet face-to-face. See you in Vienna.  
<https://phosphorusplatform.eu/espc4>