P-FUTURES: Towards urban food & water security through collaborative design and impact

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Abstract

Phosphorus is essential to food production, but current management practices fail to ensure equitable access to farmers globally and often results in polluted waterways. There is a lack of local and global governance mechanisms to ensure phosphorus is sustainably managed. The P-FUTURES research initiative aims to address this gap by working with stakeholders to explore visions and pathways of social transformation toward food and water security. In the seed phase of the project, academic, civil, industry, and municipal stakeholders interacted as partners in Blantyre (Malawi), Hanoi (Vietnam), Sydney (Australia), and Phoenix (USA) to collaboratively develop a full proposal and build capacity for transformational change. The article offers guidance on the opportunities and challenges of co-developing a research approach and proposal in a transdisciplinary, international setting.

The Phosphorus Challenge

Human consumption of phosphorus for food production and industrial uses has increased over fivefold since the 1960's [1], making human activities the driving force of phosphorus flows on the planet [2-6]. Sustainable phosphorus management has been recently emphasized as an essential component to meet UN global food security and water quality objectives [7]. Without access to phosphorus, farmers and nations will not be able to produce sufficient food, yet there are no effective governance mechanisms in place to ensure long-term access to the resource or to stimulate sustainable phosphorus

practices [8,9]. Remaining reserves are non-renewable, unevenly distributed, and becoming increasingly scarce and expensive; nearly one billion of the world's poorest farmers are unable to access fertilizer markets [9]. At the same time, losses of phosphorus along the food chain, from runoff and soil erosion from fields, all the way to human and animal excreta and urban food waste, contribute to widespread water pollution [10]. Phosphorus losses to waterways lead to eutrophication [11,12], which in turn can cause toxic algal and cyanobacterial blooms (affecting drinking water supply) and hypoxic zones [13-16].

Cities can be catalysts for larger scale change through their strong political and economic influence and are crucial centers for decision-making and innovation (as seen with global change [17], and specifically climate change [18]). As such, urban areas could be key agents in responding to the global phosphorus challenge because cities are 'phosphorus hotspots', i.e. cities concentrate people, and by doing so concentrate both the demand for food and the generation of phosphorus-rich organic waste [19-21]. For example, cities are being reimagined as closed loop systems where phosphorus in waste streams become resource opportunities for urban and peri-urban agriculture [22-24]. Urban environments therefore represent both the scarcity and pollution sides of the phosphorus challenge and potential solutions.

Local interventions to address scarcity and pollution aspects of the phosphorus challenge have often had unintended consequences. For example, fertilizer subsidies in India, to increase access to farmers, unintentionally created a black-market for fertilizers in Nepal—distorting local markets [25,26]. In the USA, Lake Erie initially saw decreases in harmful algal blooms with the application of a suite of changes in local farming practices and increased treatment of urban wastewater. However, unintended interactions between national energy policies, the selection of "best management practices" such as no-till agriculture, and climate change effects have resulted in the re-emergence of the algal blooms [27]. We use these examples to demonstrate that addressing individual causes of local scarcity or pollution separately may not be sufficient to address phosphorus sustainability challenges. It is not enough to trust that uncoordinated, incremental knowledge and actions will be sufficient to solve these challenges.

Food and water security will need to entail transformative outcomes in phosphorus sustainability, including explicit consideration of global and local resource governance, human well-being and livelihoods, and account for the persistent and growing challenges of inequity, urbanization, and climate change [28,29].

Transdisciplinary Gap to Move Towards Phosphorus Social Transformations

Scientists have made great strides in understanding the biophysical and technical dimensions of the phosphorus challenge (e.g., [30-32]), but these strides have not resulted in the large-scale transformations needed to ensure global (or even local) food security and clean water. There is an increasing awareness that this inaction is related to gaps in knowledge around the social dimensions of the phosphorus challenge and how this knowledge is integrated into decision-making [20,33]. In particular, different

geographical regions and actors are vulnerable to phosphorus scarcity and pollution in different ways [9], and therefore governance strategies must be locally adapted.

Substance flow analyses has been the dominant tool to understand the movement and storage of phosphorus and to help decision makers improve phosphorus management [19-20]. However such studies have rarely resulted in significant changes, in part because they lack explicit inclusion of the unique context-specific environmental, governance, and institutional drivers of phosphorus access and use [9,20]. For example, Kalmykova et al. [34] and Gumbo [35] note that the cultural acceptance of waste reuse could be a barrier to increasing phosphorus recycling, however was not within the scope of their quantitative studies. The cross-scalar nature of the phosphorus challenge from global to local [9] and past to future is also a key barrier to transformation [23]. Infrastructure lock-ins and governance legacies constrain the types of solutions that are available to cities [36-38]. Similarly, MacDonald et al. [39] demonstrate how global trade and national farming and energy policies affect local farming phosphorus flows in the USA and are a socio-political barrier to change. In fact, phosphorus management is linked to both national and urban sustainability and resilience priorities (e.g., food, water, energy, poverty alleviation, and ecosystem integrity). However, these linkages are often not made explicit [20,40-42].

In order to address these knowledge gaps and to create “on the ground” change, there is a need to integrate local stakeholder knowledges specifically through co-production processes [43-45]. Moving beyond engineering technical solutions toward co-developing social-ecological-technological transformations that affect how we use and govern this resource are necessary [9,20].

P-FUTURES Seed Phase Approach

P-FUTURES is a cross-city initiative designed to address phosphorus security challenges and opportunities, funded by the ISSC as a contribution to the Future Earth Transformations to Sustainability programme. P-FUTURES aims to co-create the foundations for transformative change on a trajectory toward food security and water resource integrity. The seed phase (6 months) was designed to create relationships among stakeholders and researchers across cities and design a research approach to social transformations that would be viable for a 3 year project. This phase focused on four cities: Hanoi (Vietnam), Blantyre (Malawi), Sydney (Australia), and Phoenix (USA). The existence of sufficient available phosphorus information and existing research contacts, keen to participate, influenced city selection. We selected these cities to span a wide range of socio-economic and biophysical conditions in order to explore a more comprehensive range of governance, institutional, and social arrangements, as well as technological strategies than can be used in creating sustainable phosphorus pathways.

In contrast to uncoordinated, incremental knowledge and actions, deliberate social visions and implementation pathways for sustainable transformations are needed. This requires reframing research-practice approaches for how and who addresses these challenges [46], as well as defining clear intended outcomes (knowledge, situation, and mutual-learning)

from the onset of the transdisciplinary research approach [45]. In line with Midgley [47] and other soft systems theorists and practitioners, the P-FUTURES team aims for an ethical commitment to creating change through a participatory and reflexive systemic inquiry. As such the seed phase research approach focused on building capacity towards deliberate transformative social changes that: 1) enhance equity, well-being, and livelihood, 2) avoid environmental degradation, and 3) avoid unintended consequences [46,48]. We draw from transdisciplinary research in sustainability science [43,49], adaptive capacity and learning [50-51], future desirable pathways [52-54], and transition management [55-56]. The co-production framework [43-45] was to: 1) share and understand who, what, and how relevant actors, system features, and existing priorities interact with phosphorus, and to identify relationships and common goals, 2) understand (and to an extent experience) each city's specific vulnerability to global, regional, and local aspects of the phosphorus challenge, 3) develop participatory visions and pathways for sustainable food and water systems, and 4) assess the participants' envisioned implementation strategies. The seed phase was used to carry-out experiential learning and workshop activities to build this capacity among stakeholders and researchers in order to refine and deepen the co-production approach put forth in the full proposal.

< insert figure 1 >

Experiential learning included stakeholder visits to urban and peri-urban farms and gardens, landfills and composting facilities, wastewater treatment plants, chemical fertilizer plants, food distribution centers, in addition to diverse socio-economic neighborhoods, and managed and unmanaged natural areas. Full-day interactive workshops engaged over 95 stakeholders (including researchers) across the four cities. We conducted stakeholder mapping to ensure an appropriate diversity of sectors and interests were reflected (Box 1; for detailed stakeholder list see <http://p-futurescities.net>). Core workshop activities included:

1) *Mapping the current situation and existing goals*: Each stakeholder identified their current sector/institution priorities and drivers, and collaboratively integrated these through facilitated systems mapping activities to explore interrelationships, conflicts, trade-offs, and synergies (Figure 2).

2) *Vulnerability assessments*: Using the systems maps of the local, current situation developed in (1), participants co-explored how global phosphorus vulnerabilities [9,33,57] affect and propagate through their city systems through 'what if' probing questions [51] (e.g., What would the effect of a 500% increase in phosphorus fertilizer prices be on the city?).

3) *Visions and pathways*: International examples of sustainable phosphorus management strategies stimulated cross-city comparison and fertilization of ideas to initialize the visioning process. Participants identified sector specific and integrated future goals and explored relationships, trade-offs, and synergies through the systems maps [44,53-54].

4) *Assess implementation strategies*: After a discussion on social transformational

change, participants appraised their strategies and goals then revised them to ensure that they encompassed: principles of equity, justice, and sustainability; significant changes with big implications; real lasting change; and multiple scales and sectors [51]. Followed by a plenary synthesis, the participants identified next steps to collaboratively develop the full proposal.

< insert figure 2 >

Challenges and Opportunities of a Collaborative Approach

The overarching goal of the seed phase of the P-FUTURES initiative was to build capacity for transformational change. It was challenging to balance different disciplinary approaches to transformation, link differing stakeholder priorities and needs, as well as minimize trade-offs between the need to be multi-scalar and site-specific with immediate relevance. For each of these challenges we describe how it was experienced and addressed in the seed phase and then identify opportunities to improve co-production in the full proposal.

Early in the process, cross-city research team discussions about their desired outcomes for the project revealed the need to build capacity to think across knowledge domains and bridge divergent perspectives on what qualified as a transformative outcome. For example, some stakeholder and research partners were predominantly interested in seeking out infrastructure and technological solutions and pilot demonstration projects. Part of these disciplinary suggestions stemmed from a desire to quickly address immediate, local needs related to food security and water quality before considering the long-term implications of these strategies. Throughout the process we faced the need to carefully communicate constraints (and opportunities) in the type and scope of implementation initiatives that the project could support. For example, being careful about setting project expectations given the initial scope, funding, and time constraints of the seed grant. Not surprisingly, project goals and funding was an especially challenging conversation, in that continued funding was both uncertain and short-term, whereas social transformations are a long-term endeavor. After an initial struggle in our first workshop, in subsequent workshops we included explicit discussions on the scope of implementation initiatives as well as asked participants to appraise how transformative their strategies and goals were.

In order to create a salient and relevant proposal, we aimed to link existing priorities and goals to each other, and to holistically address the phosphorus challenge. Stakeholders (including researchers) first worked individually within their sphere of knowledge and elicited their own local priorities and challenges. They then combined their local understanding with new knowledge about global phosphorus challenges to integrate new networks and knowledge relevant to their specific issues. Many of these linkages were new to stakeholders, increasing their understanding of both the challenges and opportunities their city will face in the future. The systems approach to this newly created knowledge also allowed stakeholders to identify missing relationships that need to be included in the next phase of the project. For example, in Blantyre new relationships

between water quality and energy production were uncovered during systems mapping of urban priorities that had not been previously considered. This informed the development of the full proposal by identifying previously overlooked stakeholders.

There was a tension between the need to accommodate co-production and site-specific stakeholder needs and the desire to design research comparable across cities. There was an emphasis on building capacity for cross-city learning, in that the participatory settings included the involvement of international partners, presentation of phosphorus sustainability issues and solutions from other partner cities, and post-workshop distribution of summaries and updates through the project website. However, overall workshop design prioritized co-production processes and local needs over cross-city learning. One important reason for focusing workshop and engagement design around local context was to accommodate for each city's vastly different levels of experience with sustainability, formal planning, and natural resource management. For example in contrast to Blantyre, Phoenix already had experience with scenario approaches in municipal planning. The project has yet to allow international partners to deeply learn from each other but the next phase of the project has been designed to foster more cross-city learning. For example, researchers from all partner cities will attend stakeholder workshops abroad, annual in person meetings with the full research team will allow for more discussion, and a stakeholder advisory board with rotating membership will provide a space for international stakeholders to communicate directly.

Conclusions

Food and water security, urbanization, and phosphorus sustainability are pressing, interlinked issues that must be explored. The seed grant phase of P-FUTURES focused on eliciting preliminary knowledge, scoping the larger project and most importantly, collaboratively building the foundations of a knowledge action network: trust and motivation to develop a deep shared understanding of appropriate transdisciplinary approaches. Developing shared expectations with participants was an especially crucial process for transformational research-practice and resulted in the exploration of key governance and social levers that address immediate solutions and long-term sustainability pathways. Moving forward P-FUTURES will continue to commit to the inclusive involvement of stakeholders, frame the engagement process as a collaboration among full partners, and co-develop the capacity to envision and realize transformational changes.

Acknowledgements

We would like to thank the 95 partners across the four countries who participated in P-FUTURES (see: <http://www.p-futurescities.net/the-p-futures-project/>) including the research partners at the Centre for Water, Sanitation, Health & Appropriate Technology Development (University of Malawi – The Polytechnic), Institute for Environmental Science & Engineering (National University of Civil Engineering, Vietnam), Julie Ann Wrigley Global Institute for Sustainability (Arizona State University, USA), and the Institute for Sustainable Futures (University of Technology Sydney, Australia). We thank the International Social Science Council, Future Earth Transformations to Sustainability

programme (Project ID. T2S_PP_136), the US National Science Foundation Central Arizona Project Long-Term Ecological Research (Grant No. 1026865) for their financial support, and US National Science Foundation Urban Sustainability Research Coordination Network (Grant No. 1140070).

List of Figures:

Figure 1. P-FUTURES collaborative project: the phosphorus challenges, P-FUTURES approach, and planned outcomes. Yellow arrows indicate the workflow of the seed phase of the project. Green arrows indicate the continuation of the P-FUTURES project and intended impacts.

Figure 2. Blantyre workshop: Stakeholders engage with each other in collaborative mapping of current sectorial priorities and their linkages in order to identify vulnerabilities to global and local phosphorus challenges as well as potential interventions.

Box 1. Stakeholder identification and diversity mapping.

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Sector	Relevance
City planning	government perspective of city and regional priorities and goals; implementation of future options
Food production, distribution, and consumption	upstream source of P (e.g., urban farmers, food retailers) and potential options for recycling and efficiency (e.g., reducing waste)
Fertilizer production, distribution, and advising	upstream sources of P for food and landscaping
Solid waste management (organic)	downstream flows of P and capacity for recycling
Wastewater and sewage sanitation services	downstream flows of P and capacity for recycling
Water management	recycling through water reuse
Land-use decision-making	land use changes affect our ability to recycle P
Marginalized groups	stakeholders that are influenced by decision-making but may have limited capacity to implement changes (e.g., those living on the city fringes in underserved areas)
Public health and consumer advocacy	access to healthy foods, clean water and air; environmental and social justice
Environmental protection	terrestrial and aquatic ecosystem health threatened by nutrient pollution
Non-food vegetation	management of timber and municipal landscaping
Non-food P industry	industries that use P as an input in high-tech processing (e.g., detergents, flame retardants, paints, adhesives, pet food, and other industries)

Types of Stakeholder Groups:

Government (e.g., representatives for city, state, and regional governance)

Non-profits (e.g., community and advocacy organizations)

Industry (e.g., industry associations)

Individual actors (e.g., farmers, community members)

Marginalized stakeholders (e.g., community leaders and advocacy organizations for marginalized stakeholders—including consumer groups)

Researchers (i.e., social, natural, engineering, and humanities scholars)

Figure 1

Figure 2