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A one health approach to plant health

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Abstract

One Health has been defined as an approach to the pursuit of public health and well-being that recognizes the interconnections between people, animals, plants, and their shared environment. In this opinion piece, based on a webinar of the same name, we argue that a One Health perspective can help optimize net benefits from plant protection, realizing food security and nutrition gains while minimizing unintentional negative impacts of plant health practices on people, animals and ecosystems. We focus on two primary trade-offs that lie at the interface of plant health with animal, ecosystem, and human health: protecting plant health through use of agrochemicals versus minimizing risks to human health and antimicrobial and insecticide resistance; and ensuring food security by prioritizing the health of crops to maximize agricultural production versus protecting environmental systems critical for human health. We discuss challenges and opportunities for advancement associated with each of these, taking into account how the priorities and constraints of stakeholders may vary by gender, and argue that building the capacity of regulatory bodies in low- and middle-income countries to conduct cost–benefit analysis has the potential to improve decision-making in the context of these and other multi-dimensional trade-offs.

Keywords: One health, Plant health, Human health, Agriculture-environment trade-offs

Background

One Health has been defined as an integrated, unifying approach that aims to sustainably balance and optimize the health of people, animals and ecosystems. It recognizes the health of humans, domestic and wild animals, plants, and the wider environment (including ecosystems) are closely linked and inter-dependent (WHO 2021). However, the concept of One Health is often discussed in the context of zoonosis control, with plant health and environmental concerns typically receiving less attention (Destoumieux-Garzon et al. 2018; Gibbs 2014).

In this opinion piece, based on a webinar of the same name organized by the CGIAR,[1] we argue that a One Health perspective, implemented using the tools of cost–benefit analysis, can help optimize net benefits from plant protection, realizing food security gains while minimizing unintentional n impacts of plant health practices on people, animals and ecosystems. The webinar included presentations on sustainable intensification; benefits to plant health, and risks to human health, of using manure and wastewater to fertilize food crops; Tanzania's experience with pesticide regulation; management of plant-associated food safety hazards where regulatory capacity is weak; and the role of gender in One Health. It was attended by over 200 participants from Asia, Africa,

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Europe, and the Americas,[2] with expertise in crop protection, human nutrition, biotechnology, breeding, medical sciences, farming systems, gender, and agronomy. The largest proportion of the group from whom data are available were drawn from academia (36%), followed by the non-profit sector (23%), government (20%), and the private sector while 8% stated "other" sector.[3] We draw on this international and multidisciplinary expertise, shared through online polls and messages.

Several authors have previously addressed the interactions between plant, human, and animal health. An early review by Scholthof (2003) focuses on linkages between agriculture, plant pathology, and human health, including food availability and food safety with plants as vectors. More recent work by Al-Sadi (2017) similarly describes how plant pathogens can reduce food availability and safety through contamination with toxic compounds. Rizzo et al. (2021) provide four case studies in which plant health is directly tied to food security and safety. Fletcher et al. (2009) point out that linkages that biological commonalities in pathogens of plants, animals, and humans imply an opportunity for scientific advancement, while a team led by Boa (2015) focuses on the advantages of joint service delivery, cross-sectoral coordination, and cross-sectoral learning between plant, human and animal health.

We build on this body of work by focusing two major trade-offs at the interface of plant health with animal, ecosystem, and human health: (1) protecting plant health through use of agrochemicals versus minimizing risks of (a) human exposure to pesticide residues and pathogens, and (b) development of antimicrobial and insecticide resistance; and (2) ensuring food security by prioritizing the health of crops to maximize agricultural production versus protecting environmental systems critical for human health. We discuss challenges and opportunities for advancement associated with each of these, taking into account how the priorities and constraints of stakeholders may vary by gender. In line with the CGIAR's focus on food systems in low- and middle-income countries (LMICs), examples are drawn from these settings. We argue that cost–benefit analysis is a key tool for balancing trade-offs across One Health domains but is underutilized by regulatory bodies in LMICs due to resource and capacity constraints, and present examples of how a One Health perspective can lead to innovation and synergies in the delivery of plant health and other services.

[2] The countries represented, based on data from 135 participants who either entered this information through a pre-enrollment form or mentioned their location in the webinar chat, included: Bangladesh, Benin, Bhutan, Burundi, Cote d' Ivoire, Egypt, Ethiopia, France, Ghana, India, Indonesia, Italy, Japan, Kenya, Malaysia, Mali, Morocco, Mozambique, Nepal, Netherlands, Nigeria, Norway, Pakistan, Peru, Philippines, Singapore. South Africa, Suriname, Switzerland, Thailand, Tunisia, Turkey, Uganda, United Kingdom, United States of America, Uruguay.

[3] Sectoral information is based on a subset of 87 participants who entered this information in a webinar registration form.

Effects of plant health measures on human health

Measures to keep plants healthy can impact human health both positively and negatively. Pesticides used to control plant pests can affect human health by disrupting hormone and immune system function, increasing cancer risk, and impaired brain development (Gilden et al. 2010). Use of insecticides can lead to resistance among vectors of human diseases such as mosquitoes, making them more difficult to control (Yadouleton et al. 2009). Pathogens and antimicrobial resistance genes present in animal manure used as fertilizer, as well as antimicrobials used in crop production, can be transmitted through the food chain, leading to antimicrobial-resistant infections in humans (Jiang et al. 2015; Checcucci et al. 2020).

For many plant health practices, human health, and ecosystem health, and farmers' incentives are aligned. For example, composting and anaerobic digestion of manure can reduce pathogen prevalence and the risk of antimicrobial resistance while increasing the effectiveness of manure as a fertilizer, though additional labor requirements may inhibit adoption (Millner et al. 2014; Ndambi et al. 2019). Biogas produced through anaerobic digestion displaces the use of wood and fossil fuels for cooking, saving farm families time and money and reducing smoke inhalation, especially among women (Dohoo et al. 2012).

Strong plant health can prevent contamination of crops with fungal species that produce dangerous mycotoxins (Strosnider et al. 2006). Informing farmers about these health risks while improving access to technologies to manage them has proven effective, as have market incentives for safer food (Hoffmann and Jones 2021; Magnan et al. 2021). Motivated by the biological vulnerability of children and women's primary responsibility for child health in many societies, ongoing research investigates the role of gender in mediating adoption of mycotoxin control measures (Bauchet et al. 2021).

Heavy metals, which may be present in soils or irrigation water due to upstream industrial activities, livestock production (through use in veterinary medicine), use of certain pesticides, or waste disposal (ATSDR 2012; NASEM 2017), can be absorbed by food crops, contributing to ill-health and intellectual disability (Gibb et al. 2019). Amendment of soils with organic matter, recommended for its beneficial impact on plant health, can reduce take-up of heavy metals by plants (Sharma and Nagpal 2018; Park et al. 2011).

Other practices, such as the use of low-cost but highly toxic pesticides, or imprudent antimicrobial use, imply trade-offs between farmers' incomes and the public good. In such cases, policy options include restricting access to inputs that pose One Health risks, rewarding value chain actors for responsible practices, and designing and enforcing appropriate environmental and food safety regulations. Reflecting the global shift in regulatory practice toward proactive risk management and away from punitive enforcement (Blanc 2018), rules must be feasible for farmers to implement. The role of the state should include capacity building along the value chain and ensuring the safety and quality of available agrochemicals.

Webinar participants were asked to respond to the following question: Where in food value chains is it most effective to address food safety threats to human health from plant health measures? Response options were: (1) Agrochemical supply chains: restrict availability of the most toxic chemicals; (2) On-farm: educate farmers, make safe tech affordable, monitor practices; (3) Influence consumer choice through labelling at retail; and (4) At the household level through consumer education. Among these options, the majority of the 103 participants who responded selected on-farm approaches as most effective (55%), with 24% indicating restrictions on the availability of inputs. Fewer (12%) believed consumer education to be key, and just 9% would rely on consumer choice through labelling at retail. These responses reveal an expectation that regulatory action, as opposed to market mechanisms, are the most promising way to deal with One Health challenges related to plant health.

Achieving food security while minimizing environmental harms

Through its environmental dimension, One Health also frames the complex interaction between human well-being and plant health at a higher level. Increasing crop yields through healthy plants is critical to achieving food security for a growing global population. However, agricultural production also poses threats to environmental processes that underpin human health. Agriculture contributes 34% of greenhouse gas emissions (Crippa et al. 2021), consumes 84% of fresh water (Shiklomanov and Rodda 2003), and is the single biggest source of eutrophication causing nitrogen and phosphorus pollution in aquatic systems (Galloway et al. 2008; Carpenter and Bennett 2011). Further, agriculture leads to soil degradation and erosion (Jie, et al. 2002; Montgomery 2007), and drives biodiversity loss through encroachment on natural areas (Norris 2008), disrupting ecosystems, and thereby increasing the risk of new emerging zoonotic pathogens (Gibb et al. 2020).

This underscores the importance of sustainable agricultural intensification for One Health, *i.e.* increasing production from the same area of land at lower environmental costs (Garnett et al. 2013; Godfray et al. 2010). Sustainable agricultural intensification can be achieved through two approaches; (1) improved efficiency of inputs through soil and water conservation and rationalized use of fertilizers and pesticides; and (2) system re-design, for example, using agroecological or organic principles (Pretty et al. 2018), or breaking from trends of increasing specialization, industrialization and commercialization and moving instead toward integration of crops and livestock (Ramankutty et al. 2018). Research has revealed trade-offs between food production and associated plant health measures, and environmental impacts under both approaches. Increased efficiency of conventional systems could increase food production by 30% per land area (Mueller et al. 2012), reducing pressure to convert additional land into agriculture—but at the cost of higher greenhouse gas emissions and pollution, greater water use, and negative impacts on biodiversity. Organic systems imply reverse trade-offs, with 19–25% lower food production per land area compared to conventional systems, but less environmental damage within cultivated areas (Seufert and Ramankutty 2017). Environmental trade-offs also dominate narratives around livestock production systems, which play key livelihood functions in low- and middle-income countries (Paul et al. 2020).

Interventions to encourage plant health practices that better balance ecological concerns and food production will need to consider the constraints, needs, and motivations of farmers, including those mediated by gender. Increasing the ranks of female extension workers, and holding trainings at times when women can attend, for example, show promise for increasing female farmers' access to agronomic training (Quisumbing and Pandolfelli 2010). There is a great diversity of gender roles and constraints across localities and ethnic groups and along agricultural value chains requiring different strategies to empower female stakeholders (FAO 2010; Olawoye 2018). Webinar participants made the point that farmers and other stakeholders of limited means, and women in particular, may not have the luxury of prioritizing environmental sustainability. This points to the need for external financing, perhaps through international green development or climate funds, to promote ecologically sustainable agricultural practices.

Discussions during the webinar underlined the need to develop approaches that mitigate the trade-offs among human, ecosystem, and animal health goals, and research to inform choices among imperfect

Table 1 Poll options, share of responses, and total number of votes per pair

	Option 1 (proportion of votes)	Option 2 (proportion of votes)	Number of votes
1	Food security is my priority (33%)	A healthy planet is my priority (67%)	39
2	We need to increase food production by 2050 to feed a growing population (67%)	We grow enough food already to feed 10 billion people (33%)	12
3	Technological improvements will lead to a sustainable balance (30%)	Food sovereignty and agroecological agriculture are key to finding the balance (70%)	57

alternatives. Participants were asked to indicate which option within each pair of statements shown in Table 1 they identified with most strongly.

As shown in the table, participation in this poll was low and overall and varied across questions, perhaps indicating uncertainty between the options presented. Of the 39 participants who chose one of the first pair of statements, two thirds prioritized environmental concerns above food security. Of the twelve who chose one of the second, two thirds believed that increased food production would be needed to feed a growing population as opposed to relying solely on redistribution. However, there was skepticism that technological improvements alone would lead to a sustainable balance between these goals, with 70% of 57 participants indicating that food sovereignty and agroecological agriculture are needed to achieve a balance.

Operationalizing a one health approach

The One Health perspective has two principal advantages in tackling the complex challenges described above. First, it encourages the consideration of costs and benefits across multiple domains. Second, it can facilitate innovation in service delivery by bringing together experts from different sectors. This may include the transfer of service delivery models from one sector to another, or the identification of synergies across plant health and other sectors.

Related to the first of these, cost–benefit analysis (CBA) is a critical tool for the operationalization of a One Health approach. CBA is routinely used by governments of high-income countries to quantify and compare the costs and benefits of public investments and regulatory changes across domains including human health, environmental quality, and income (OECD 2018). Application of CBA to animal health is relatively rare, due at least in part to measurement challenges (Harrison 1996). While CBA is commonly used in the context of plant health to consider the impacts of pesticide use on human health or the environment, plant health is not typically considered as an outcome in its own right. Inspired by the Global Burden of Disease program for human health, the Global Burden of Crop Loss initiative and Global Burden of Animal Diseases (GBADs) Programme aim to develop standardized systems for the measurement of the economic costs associated with plant and animal disease, respectively (Finegold et al. 2019; Huntington et al. 2021). These efforts can facilitate the inclusion of animal and plant health burdens in decisions that involve trade-offs across these domains. As trade-offs are expected to depend critically on intensity of exposure to environmental hazards, food security status, and income levels, all of which vary widely across countries, there is a need for context-specific analysis and thus greater capacity for CBA in LMICs.

On the second point, collaboration among experts in diverse fields related to One Health has the potential to lead to innovations in plant health service delivery and to leverage synergies across sectors. Plant health clinics established in Bangladesh, Bolivia, Nicaragua, and Uganda by CABI's Global Plant Clinic are one example. Inspired by models of human health delivery, these clinics are held at central locations such as markets and staffed by extension workers who offer advice on plant health problems and also respond to farmers' questions regarding animal health (Boa et al. 2015). This model aims to increase coverage and quality of plant health services, and to expand farmers' access to these services.

Conclusion

The effects of plant health practices on human health are important but often excluded from intersectoral coordination under the banner of One Health. Incorporating plant health into One Health discussions implies a stronger emphasis on ecological health through the trade-off between food security and planetary boundaries. As with other aspects of One Health, its value for plant health is to create more inclusive approaches to evaluating plant protection interventions that address agricultural needs, but also realize co-benefits with ecosystem, animal, and human health. Efforts underway to improve and harmonize the measurement of animal and plant health burdens are expected to facilitate the inclusion of these domains in quantitative analyses of the trade-offs identified in this paper. Such analysis requires significant resources and skill, and results are expected to vary widely across contexts. Investment in the capacity of

regulatory bodies in LMICs to conduct cost–benefit analysis of One Health problems should be prioritized.

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Author contributions
VH convened the webinar on which this article is based and led writing of the manuscript; all authors contributed material to the webinar; BP, TF and AM contributed sections to the manuscript, NR, AM, JO, RD, NH, PB, RD, ND, PB, and JH provided comments on the draft manuscript. All authors approved the final version. All authors read and approved the final manuscript.

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