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GUEST EDITORIAL

Understanding the relationship between environment, agriculture and health: An interdisciplinary challenge

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INTRODUCTION

In an editorial last year, Prof. Kathryn Monk explained the importance to environmental research of an interdisciplinary approach. She has asked me to share with readers some further, personal thoughts on this topic. I am an ecologist by training, but I spent much of my career managing agricultural research programmes in tropical regions. For the last ten years, I have held a position in a school of public health. This varied disciplinary experience has given me the opportunity to explore and understand interactions between environment, agriculture and human health.

It is helpful to think of environment, agriculture, and health as points in a triangle, each having specific interactions with an adjacent sector, but also being influenced by more complex, three-way interactions. For environmental scientists, the interactions with agriculture are probably the most familiar. Extensive planting of crops like rice and oil palm has dramatic effects on biological diversity, water systems and their function, and soils. The importance of healthy environments to agriculture is repeatedly demonstrated. Thirty years ago, I had the opportunity to review the Indonesian national programme on integrated pest management in rice. Use of pesticides on rice was, paradoxically, causing severe outbreaks of pests like brown planthopper. The environmental processes behind this were actually quite complex. Soon after flooding, aquatic arthropods colonizing rice paddies provided a food source for generalist predators that moved in and built levels capable of suppressing subsequent pest invasion. Pesticides killed off this general predator community, while the pests, which lay their eggs inside plants, were less affected and their populations exploded in this predator-free environment (Settle et al, 1996), Integrated Pest Management (IPM) on rice, pioneered in countries like Indonesia, was for many years a leading example of the value of integrating environmental and agricultural research.

Environmental scientists will be less familiar, perhaps, with the interactions between agriculture and health, so here is a short introduction. Agricultural systems have two impacts on health, which for historical reasons have been treated as separate disciplines in the health sector. They produce food that contributes to nutrition, which is usually, but not always, a health benefit, and they produce distinct health risks, including diseases associated with food and food production, and toxins associated with agriculture, such as the pesticide just mentioned.

AGRICULTURE AND NUTRITION

Agriculture, and the food systems that it supports, has clear benefits. Improving the production of rice and other staples in Asia, associated with the Green Revolution of the last century, has prevented famine, and helped countries provide food security to citizens. But diets are changing rapidly worldwide, particular in urban communities that now hold over a half of the human population. Here, processed food comprising flour from cereals, fats, sugar, and salt, are increasing components of diets, leading to chronic diseases such as diabetes and heart disease, and creating a global emergency for food systems and health (Webb et al, 2020). Poorer households, where food is scarce and processed foods are popular because they are cheap, are particularly affected by this growing "triple burden of malnutrition" – undernutrition combined with obesity and micronutrient deficiency. Micronutrients are poorly provided by these largely cereal-based diets, being found more in vegetables, fruits, and animal-sourced foods. Recent studies show this problem to be particularly severe in East Asian countries, including Indonesia (Mayer et al, 2019; Blankenship et al, 2020)

The agriculture and nutrition challenge today is to shift our agriculture and food systems towards more healthy diets, including more fruits and vegetables. But achieving this is challenging. Agricultural development, which may increase incomes and access to staple foods like rice, may have fewer positive effects as well. A recent study in Indonesia compared the level of micronutrient rich foods in diets of farmers practicing different kinds of agriculture. Diets of households in forested areas characterized by swidden agriculture and agroforestry included a larger number of nutritionally important food groups than households in areas dominated by timber and palm oil plantations (Ikowitz et al, 2016). Changing from swidden to plantation farming also strongly affects time allocation in households, particularly for women who have the greatest responsibility for family nutrition (Rowland et al, 2020). The benefits to diets of agricultural development are therefore controversial (Nurhasan et al, 2020).

AGRICULTURE AND INFECTIOUS DISEASE

The other relationship between agriculture and health rests with diseases and toxins associated with agriculture and food systems. I shall not say much about toxins, which can involve both agrochemicals like pesticides, and toxins produced by crops and by microbes that inhabit them. Despite the success of IPM programmes such as that on rice in Indonesia, pesticide use on food crops continues to rise. However, some of the benefits of IPM programmes in Indonesia and other countries appear to be long-lasting (van den Berg et al, 2020).

Let me focus instead on diseases and agriculture, as this brings us quickly back to the critical importance of environmental research. A recent study used clinical records of infectious diseases from across Southeast Asia to look for associations between the frequency of infectious diseases and the environments in which people were living (Shah et al, 2020). It revealed that people who live or work in agriculture are 1.7 times more likely to be infected with a pathogen than those in non-farming professions.

A particular source of disease risk from agriculture comes from animals. This is because animals that we eat, both wild and domestic, are a historical source of many of the diseases that now affect humans. An estimated 60% of pathogens that cause human diseases originate from wild or domestic animals, and 75% of emerging human pathogens are of animal origin (Jones et al, 2008). Agriculture plays a particular role in spreading these zoonotic diseases because it contributes to the degradation and exploitation of natural environments, bringing humans in contact with other species. The recent Covid-19 pandemic is just the latest in a recent series of such zoonotic disease outbreaks, which have included include avian and swine flu, Ebola virus, Nipah virus, and many others. In many cases, livestock production creates an important conduit between diseases in wildlife and humans. For instance, Nipah virus in Southeast Asia, a disease of bats, entered humans via pig production in peri-urban areas where bats roosted in trees over pig pens, and so the pigs ingested bat feces containing the virus, which was then passed on to humans (Wongnak et al, 2020).

Despite their high-profile, these pandemic diseases from wild animals in natural environments are by no means the most important infectious diseases associated with agriculture. These are a different group of well-known pathogens, largely bacterial, associated with unsafe food, such as species of *Salmonella, Staphylococcus, Campylobacter,* and others. Until recently, food-borne diseases were not seen as key health burdens in low- and middle-income countries (LMICs), but a landmark study in 2015 revealed that the global burden of food-borne diseases is comparable to that generated by malaria, HIV/AIDs or tuberculosis (Havelaar et al, 2022), and the great majority of this burden falls in LMICs, where it is rapidly increasing. While generally not risks to life, these diseases cause considerable illness and economic loss to productivity. Further, they are now associated with the transmission of resistance to antibiotics because of unregulated use of drugs to control them in the human and livestock sector (Antimicrobial Resistance Collaborators 2019). Food safety measures are particularly difficult to implement in tropical regions, with their widespread wet markets, which often create ideal conditions for these food safety problems. Further, these diseases are not just associated with animal-sourced foods, but with fruit and vegetables as well, where handling in markets may transfer bacterial from other sources.

The environmental dimensions of this interaction between agriculture and disease are often complex and fascinating. For instance, many agriculturally associated diseases are vector borne, and their insect or snail vectors depend on the water systems which we create for agriculture. In Africa, for instance, the *Anopheles* mosquito species, which are the principal vectors of malaria, are particularly associated with shallow, temporary water environments. This makes rice cultivation a major source of infection. As efforts in Africa to eliminate malaria are progressed, rice-growing areas are emerging as hot spots of infection, which may require radical changes in the way rice is grown there (Chan et al, 2022). Fortunately, in Asia, the species that transmit malaria do not breed in rice paddies, but in wooded areas. Hence this environmental different in vector biology creates a very different disease risk profile for rural populations.

A recent study in northern Borneo illustrates this complex environment-agriculture-disease relationship. Here, the majority of malarial infections are zoonotic, caused by the parasite *Plasmodium knowlesi* which infects both humans and local species of macaque (Fornace et al, 2019). This study compared data on the distribution of individuals that were seropositive for this parasite, comparing this to environmental and population parameters, measured from drone images of habitats surrounding dwellings. Environmental and agricultural variables, such as fragmentation of landcover due to plantations and farming, predicted exposure to this disease at different spatial scales. Other studies showed that forest fragmentation changed distribution and activity of macaques, a possible cause of changes in infection.

INTEGRATING ENVIRONMENT, AGRICULTURE AND HEALTH

Let me finish on how this interdisciplinary research on environment, agriculture and health may be usefully applied to solving major societal problems. It is often the case that resolving conflicts between these sectors involve trade-offs. For instance, regulating safety in animal-sourced foods may reduce risks from food-borne diseases, but it may also make these foods more expensive, reducing their availability and nutritional benefits to children, particularly in poor communities. Economic modelling is proving a useful tool to examine these conflicts and to identify the balance of trade-offs that maximizes well being, at a household or even a national level.

An important example of this is palm oil production, an agricultural activity that has had tremendous economic benefits in Asia. At the same time, as a highly saturated fat, palm oil consumption has been associated with negative effects on cardiovascular health, while large-scale oil palm production has been linked to deforestation and other environmental impacts. How do we compare these environmental, agriculture and health outcomes and develop from this the most effective national strategy for this activity? Would a national effort to reduce palm oil consumption generate health benefits, in terms of longer, disease-free lives and a healthier workforce, that outweigh possible economic dis-benefits from reduced production, affecting farmers and food chain actors? Would reduced production lead to environmental co-benefits that, together with health benefits, create a net positive, long term effect for a producing country?

A few years ago, colleagues in our research group undertook a modelling study on oil palm production, focused on Thailand (Jensen et al, 2019). This interdisciplinary team created a national level model, calculating in economic terms the costs and benefits of oil palm production in these different sectors. They then explored the impact of a possible policy to reduce palm oil consumption by taxing this product. This modelling experiment showed long-term national economic benefits from improved health, but a need to support economic losses to some growers. They measured environmental effects only in terms of greenhouse gas production, where reduction in production was of little benefit, as plantations would be replaced by field crops less effective at capturing and storing carbon. This modelling was complex, and country-specific, and therefore generated few conclusions of broad significance. But it demonstrated the opportunity provided by interdisciplinary research to contribute to solving truly complex society problems.

Over the years, in our research programme, we have found that interdisciplinary research has been very rewarding in supporting informed policy making. At the scientific level, it requires that scientists from different disciplines be open-minded, and sensitive to the different perspectives and "languages" used by other disciplines, seeking ways to involve all of these from the start of a research collaboration. Often, the structures of university departments and government research institutions makes such collaboration difficult, and younger scientists may perceive little reward to their career progression by stepping outside their specialism to work with other disciplines, however exciting and rewarding this may be. But this pattern of rigid isolation of research disciplines is changing, and it must if scientists are going to provide society with sustainable solutions to these complex problems.

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