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Mitigating Health Risks in Sustainable Agricultural Intensification

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Human health is a fundamental feature of sustainable agricultural intensification.[1] Agricultural intensification that increases the burden of human disease, however environmentally benign, is not sustainable. Conversely, sustainable agricultural methods provide specific opportunities for improving human health.[2] The intensification of food systems in low- and middle-income countries (LMIC), as they transition from subsistence to market-oriented production, is typically associated with human health risks.[3, 4] Some health risks are associated with the initial stages of intensification, for example, concentration of livestock production and animal waste in peri-urban areas. Inputs associated with this intensification, including fertilizers, pesticides, and antibiotics, can have negative effects on farmers' health, clean water, and resistance in pathogens and vectors. In rapidly intensifying agricultural systems, regulatory processes that limit the use of harmful products and their residues in water and food may not be in place. Therefore, LMIC face a particular challenge to "de-risk" agricultural intensification, through technical and policy-related interventions that reduce health risks in transitioning agricultural systems.

The effects of agricultural intensification on human health are typically mediated by three kinds of mechanisms:

1. Environmental changes associated with **development of agricultural landscapes**, as when breeding sites for disease vectors are created as a side effect of irrigation and other production systems;
2. Transfer to humans of pathogens and toxins during **agricultural production processes and via food value chains** — as most recently with COVID-19, and previously with a long list of zoonotic infections such as cysticercosis.

Key Messages

- Agriculture must take its share of responsibility for the health problems it creates.
- In most cases, the required intervention in agriculture is a modification of methods so that the same agricultural purpose can be achieved without the harmful health side effects.
- Cross-sectoral collaboration is needed, involving public health as well as agricultural research institutions, to support basic research and the development and implementation of interventions.
- Such problems cannot be solved by either sector (agriculture or health) alone!

3. **Interference between parallel agricultural and health interventions**, such as increasing antimicrobial resistance (AMR) in human infections through use of antimicrobials in livestock and fish production.

With all these causal mechanisms, the negative health effects are unintended consequences of activities that are agriculturally useful, and may be regarded as essential. In order to avoid such externalities, we need first to find ways to achieve the same agricultural purposes without the unintended health costs, and then build these methods into the process of sustainable intensification. Over the past five years, the A4NH program has built a One Health collaboration, between CGIAR Centers and public health research institutions, to conduct research on these issues, and some significant opportunities have been identified. Three of these are illustrated in the sections below. The overall objective is to identify ways to "de-risk" agriculture from a public health perspective that requires close multi-sectoral collaborations.

Developing agricultural landscapes: Growing rice without growing malaria

The interconnection of rice and malaria in Africa is important for public health. Malaria causes more than half of the global burden of vector-borne disease, and more than 85 percent of all malaria deaths occur in Africa.[5] Unfortunately, Africa is also one of the few places where the main malaria vectors are rice-specialists, breeding abundantly near rice and in the rice fields.[6] In villages next to irrigated rice fields, the numbers of mosquitoes are typically between 5 and 20 times greater than in nearby non-rice villages; the intensity of malaria transmission is also substantially higher.[7, 8]

It is possible to cultivate irrigated rice without breeding mosquitoes, and still get good rice yields. Typically this involves modified water management, but there is ample evidence that almost any change in growing methods, including levelling, sowing, rice variety, weeding and fertilizer, has major effects on mosquito numbers.[9, 10] To stop being part of the malaria problem, and start being part of the solution, rice researchers in Africa should routinely monitor these numbers as one of the indicators that must be considered in testing and making recommendations to farmers. A4NH is developing methods for this.

The established methods of water management to avoid mosquito-breeding are similar to the "alternate wetting and drying" (AWD) technique being developed by CGIAR to address another sustainability issue: greenhouse gas emissions.[11] Ongoing field studies in Africa, where rice intensification is accelerating, are now testing irrigation regimes that could reduce both mosquito and methane production.

Reducing unintended consequences of agricultural production: Zoonotic disease risks

Zoonotic diseases associated with agricultural intensification impact human health in two ways. First, pathogens in animals may "escape" and rapidly adapt to transmit within the human population — for example Ebola, swine influenza, and COVID-19. Understanding these host jump events and risks, and the role of agricultural incursion into new land areas, is essential. Second, endemic zoonoses such as echinococcosis, cysticercosis, brucellosis, Q-fever, and a range of bacteria place an enormous health burden on communities in LMIC. These diseases may reside in animal hosts, especially livestock, and infect humans either through handling and domestic contact or animal-commodity value-chains. The intensification of livestock production, essential to maintain food security, and changing human demographics, lead to increased contact rates between animals and their products and dense human populations. Where wildlife frequent interface habitats, livestock can also act as intermediate and amplifying hosts for wildlife-borne zoonoses.

As small-scale farmers adapt to more market-orientated production, while remaining relatively small scale in terms of production methods, the risk of transmission of zoonotic diseases, through products produced on farms, extends to a much broader consumer group in distant areas including towns and cities. Under A4NH, research on socio-ecological drivers of these diseases was initiated and partnerships with policy makers established to support the development of risk-based surveillance and control interventions.

Climate, land use, and socioeconomic changes are expected to increase the risk of zoonotic diseases. The opportunity is to be ahead of the curve — understanding these interfaces, developing and initiating surveillance systems to monitor them, and providing policy-adapted data to intervene.

Interference between interventions: Reducing human AMR arising from agriculture

Almost 700,000 people die annually as a result of an antimicrobial resistant infection, and 90 percent of these deaths occur in Africa, Asia, and South America.[12] This clear geographic distinction is also reflected in the levels of AMR: countries in Asia, Africa, and South America have higher levels than those in Europe and North America.[13] AMR is found in people, animals, food, and the environment. Poor animal husbandry and infection control, inadequate sanitation, inappropriate food handling, and socioeconomics facilitate selection and spread of AMR. Seventy-three percent of the global use of antimicrobials is in livestock production, projected to increase by 67 percent by 2030, largely due to intensification of livestock and fish production in LMIC.[14]

As small-scale farmers adapt to a more market-orientated production by intensification of livestock and fish systems, they frequently increase use of antimicrobials to compensate for poor animal husbandry and to promote growth. Current research is quantifying antimicrobial use in changing livestock, fish, and crop production systems in Africa and Asia, using multidisciplinary methods to understand the agricultural contribution to AMR in livestock and humans in LMIC. The CGIAR AMR Hub was created in 2019 to integrate this work, identify AMR transmission pathways between agriculture and human health systems, identify and test interventions to reduce AMR risks, and understand the social and economic consequences of potential interventions as a basis for selecting those that will most effectively support sustainable agricultural intensification while reducing human health risks.

HIGH-BURDEN EXAMPLE	RICE AND MALARIA IN AFRICA	ENDEMIC ZOONOSES SUCH AS CYSTICERCOSIS	EMERGING VIRUSES SUCH AS COVID-19	ANTIMICROBIAL RESISTANCE
Burden Indicators	• Malaria kills >300,000 African children per year. • Fraction due to rice uncertain but large in rice-growing villages.	• Zoonoses cause human and animal ill-health, death. • Cysticercosis results in 3M DALYs lost globally, the highest burden foodborne parasitic diseases. • Zoonotic diseases endemic in agricultural systems. Transmission amplified by livestock keeping.	• CDC estimates H1N1 killed 151,700–575,400 worldwide; COVID-19 has already exceeded this; annual burden likely to be much greater. • Emerging infectious diseases are associated with severe socioeconomic impacts. IMF projects COVID-19 will reduce global economy by 3% in 2020.	• 700,000 die annually, 90% in Africa, Asia, and South America. • Up to 10M deaths expected by 2050. • Contribution from animal use unclear, especially in LMIC.
Transmission niche is created by…	Agricultural landscapes: when rice fields replace natural wetlands, diverse invertebrate community replaced by monoculture of malaria vectors.	• Farmers exposed through proximity to livestock and their products. • General population exposed as animal-sourced foods move though livestock commodity value chains.	• Niche exists but is unoccupied before cross-over event. • Must consider separately determinants of a. crossover event into human-human transmission; b. R_0 of human-human transmission.	• Same antimicrobials used in animals and humans. • Animal-to-human transmission via direct contact, consuming contaminated animal products or the environment.
Developmental Processes	In many African countries, the Ministry of Health plans malaria elimination while the Ministry of Agriculture plans to expand irrigated rice. The latter will likely interfere with the former.	Is a zoonotic disease a veterinary or public health problem? Despite over a decade of focus on One Health approaches, this question remains an institutional barrier.	Crossover: • encroachment, habitat destruction, exploitation of wildlife/bushmeat • wet markets R_0 and spread: Many development factors including: • Agricultural intensification • International travel • Migrant labour, labor camps	• Initial stages of livestock intensification often involve increased use of antibiotics. • One Health global action plan by OIE, FAO, WHO. • 35% of LMIC have national action plans to combat AMR. • 6–10% of LMIC monitor antimicrobial use (AMU) and AMR in animals.
Who creates the risk?	Rice farmers	Livestock producers and livestock product processors	Livestock farmers, people involved in marketing wildlife and wildlife products	• All users of antimicrobials: livestock producers and humans • Some uses promote resistance more than others? Probably, but poorly understood.
Who suffers the risk?	General population nearby	General population, farmers, meat-eaters	General population	General population
Health Interventions: Why not adequate?	Good control recently achieved with insecticide-treated nets, but resistance a major problem; insecticides not a permanent solution.	Treating infected people is necessary, but does not deal with the natural reservoir of pathogens in the animal hosts.	• Emergence of a disease is usually difficult to predict, and interventions are often applied late. • "Generals always prepare to fight the last war" – we planned for influenza, we got COVID-19.	Antimicrobials are essential for treatment of infectious diseases in both sectors.
Agricultural Interventions: How agriculture can de-risk and become part of the solution	• Routinely monitor mosquito breeding in all research on rice-growing methods. Consider this outcome indicator along with others (yield, quality, etc). • Develop growing methods that minimize production of both methane and mosquitoes.	• Interventions targeted at livestock necessary to reduce risks of transmission, and thus to avoid adverse human health outcomes. • Doubly cost effective: many zoonotic diseases also impose animal health constraints.	Crossover: • Enhance surveillance in high-risk areas and production systems to limit spillover events. • Inclusive conservation of natural resources where livelihood options are diversified to reduce R_0 and spread. • Identify specific high-risk agricultural activities and address them.	• Cross-sectoral reduction of AMU. • Improved husbandry and herd health practices incl. hygiene and disease prevention. • Rapid detection of pathogens and AMR. • Reducing antimicrobial residues and AMR levels in farm effluents and manure.
Intersectoral Aspects	Current agricultural concepts of "sustainability" prioritize ecological harms and give less attention to human health externalities.	Potential for collaboration between animal, human, and environmental health – One Health, including for surveillance.	Collaborations with health, socio-economists, and environment actors to understand.	One Health approach to mitigate AMR, including AMU regulations, and national monitoring of AMU and AMR in animals, humans, and food.

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