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Authors: Trimmer, John T., Bauza, Valerie, Byrne, Diana M., Lardizabal, Amanda, and Guest, Jeremy S.

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Harmonizing Goals for Agricultural Intensification and Human Health Protection in Sub-Saharan Africa

John T. Trimmer[1], Valerie Bauza[1], Diana M. Byrne[1], Amanda Lardizabal[1], and Jeremy S. Guest[1]

Abstract

Increased agricultural production will be necessary to feed rapidly growing populations in sub-Saharan Africa, where many households currently practice low-input, subsistence farming. Efforts to expand food production will likely include agricultural intensification to enhance productivity of existing cropland, and holistic frameworks are needed to quantitatively evaluate trade-offs and synergies between intensification and other dimensions of development. Beyond well-documented interactions with environmental and economic issues, intensification's complex relationship with human health should take a position of primary importance in any framework designed to advance food security. While intensification can lead to improvements in nutritional status, neglecting sources of potential adverse health impacts, including water source contamination and direct contact with agricultural inputs or environmental pathogens, may undermine prospective gains. Harmonizing goals will require interdisciplinary teams applying frameworks that integrate tools such as quantitative risk assessment, environmental life cycle assessment, and economic models to comprehensively evaluate potentially dissimilar strategies across common metrics while accounting for interdependencies and uncertainties. With local implementation partners, these teams will be well-equipped to develop holistic interventions that effectively promote food security and protect human health while considering local constraints and opportunities across multiple dimensions of development.

Keywords

intensification, human, health, Africa, agriculture

Placing Agricultural Intensification Within a Broader Framework

To feed the growing global population, current agricultural production must double by 2050 (Godfray et al., 2010). Increased production will be particularly crucial in sub-Saharan Africa (SSA), where populations are projected to grow from 1.0 billion in 2017 to 1.9 to 2.3 billion in 2050 (United Nations, 2015), and where approximately 218 million people are currently undernourished (Food and Agriculture Organization of the United Nations, 2015) with increased risk of morbidity and mortality (Bain et al., 2013; de Onis & Branca, 2016). For example, among Ghanaian children younger than 5 years, 23% were stunted and 57% were afflicted with anemia in 2011 (United States Agency for International Development, 2014). The poorest households in SSA typically rely on smallholder farmers, themselves hovering precariously on the threshold of food insecurity, who practice subsistence agriculture characterized by low chemical inputs and high labor requirements (Frelat et al., 2016; Goldsmith, 2017; van Ittersum et al., 2016; Tscharntke et al., 2012). Considering agriculture already represents the largest land use on the planet (Foley et al., 2011), one plausible path to increasing food production involves agricultural intensification (Palm et al., 2017; Spera, 2017), which enhances productivity of existing

[1]Department of Civil and Environmental Engineering, University of Illinois at Urbana-Champaign, IL, USA

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Corresponding Author:
Jeremy S. Guest, Department of Civil and Environmental Engineering, University of Illinois at Urbana-Champaign, 205 N. Mathews Ave., 3221 Newmark Civil Engineering Laboratory, Urbana, IL 61801, USA.
Email: jsguest@illinois.edu

cropland through increased cropping intensity, irrigation, fertilizer and pesticide use, and monoculture (Foley et al., 2011; Matson, Parton, Power, & Swift, 1997; van Ittersum et al., 2016).

Achieving the greatest benefits through agricultural intensification requires considering its interactions with other dimensions of development (Garnett et al., 2013). Perhaps the most well-established connections concern its negative environmental impacts, including greenhouse gas emissions, water scarcity due to irrigation demands and climate change, soil erosion, pesticide resistance, and highly altered nitrogen and phosphorus cycling (Alliance for a Green Revolution, 2014; Foley et al., 2011; Matson et al., 1997; Kassie, Teklewold, Jaleta, Marenya, & Erenstein, 2015; Steffen et al., 2015; Tilman, Cassman, Matson, Naylor, & Polasky, 2002; West et al., 2014), suggesting that any agricultural transition should focus on resource efficiency and conservation along with improved yields (Mueller et al., 2012; van Ittersum et al., 2016). From an economic standpoint, offering households greater opportunities to diversify and safeguard their livelihoods through improved market access, off-farm employment, and rural infrastructure may be at least as important as agricultural intensification in reducing rural poverty (Frelat et al., 2016; Godfray et al., 2010; Rosegrant & Cline, 2003; van Ittersum et al., 2016). Beyond these considerations, the relationship between agricultural intensification and human health should take a position of primary importance in any framework designed to advance food security. While substantial improvements in nutrition, health status, and economic well-being could be achieved through intensification, neglecting sources of potential adverse health impacts could create cycles that undermine prospective health gains.

Elucidating Connections Between Human Health and Agricultural Intensification

While agricultural intensification has the potential to contribute to increased food security and improved health outcomes, it can also open various risk pathways that may compromise human health in other ways. For example, one aspect of intensification involves farmers using greater quantities and application rates of pesticides, but many widely-used pesticides are known to have negative health effects, both acute (e.g., enzyme inhibition causing vomiting, diarrhea, or respiratory failure) and chronic (e.g., endocrine disruption, neuropsychiatric impairment, heart and liver damage, and multiple cancers; Swiss Federal Institute of Aquatic Science and Technology [EAWAG], 2016). Moreover, the most hazardous pesticides, banned in many high-income countries, continue to be stockpiled and circulated in SSA, where workers who may have limited access to protective equipment also may not be informed of proper handling procedures or health impacts (EAWAG, 2016; Jepson et al., 2014; Sheahan, Barrett, & Goldvale, 2017). Pesticide exposure can occur through numerous pathways, including through consuming foods retaining pesticide residues and drinking water contaminated by agricultural runoff (Akoto, Andoh, Darko, Eshun, & Osei-Fosu, 2013; Akoto, Gavor, Appah, & Apau, 2015; Bempah, Donkor, Yeboah, Dubey, & Osei-Fosu, 2011; Fosu-Mensah, Okoffo, Darko, & Gordon, 2016). For farmers and their families in SSA, the highest risks may come from direct contact or inhalation during pesticide application, mixing, and in-home storage, due to improper handling and insufficient protective equipment (EAWAG, 2016; Jepson et al., 2014).

Increased fertilizer application can lead to another set of health risks, although their severity likely depends on local soil conditions and nutrient retention (Neill et al., 2017; Palm et al., 2017). Along with increased eutrophication potential (Smith, Tilman, & Nekola, 1999), surface water or groundwater sources contaminated with agricultural runoff or leachate can exhibit elevated nitrate and nitrite concentrations (Matson et al., 1997; Tilman, 1999), which are connected with methemoglobinemia (blue baby syndrome; Fewtrell, 2004; Sadler et al., 2016). Possible connections with birth defects and various cancers have also been reported (Brender et al., 2013; Sadler et al., 2016; Ward et al., 2005), although these links remain uncertain and have not been incorporated into international drinking water guidelines (World Health Organization, 2011). Furthermore, if animal manure or human waste are used as supplementary nutrient sources, the risk of pathogenic exposure through direct contact or drinking water contamination may be significant (Gerba & Smith, 2005; Tyrrel & Quinton, 2003).

Pathogenic exposure and infection, while not always directly related to agriculture, can undermine the benefits of increased food availability by affecting human nutrient absorption. Enteric infections, including diarrheal diseases, soil-transmitted helminths, and environmental enteric dysfunction (EED), can reduce intestinal absorption and divert nutrients away from growth to immune response, contributing to a cycle in which infection causes worsened nutritional status and leading to greater susceptibility for further infection (de Onis & Branca, 2016; Guerrant, Oriá, Moore, Oriá, & Lima, 2008; Korpe & Petri, 2012). Acute exposure to infected feces can cause diarrheal and soil-transmitted helminth infections, while chronic fecal pathogen exposure is hypothesized to be the primary cause of EED (Korpe & Petri, 2012; Trehan, Kelly, Shaikh, & Manary, 2016). Exposure to environmental chemicals, including pesticides, may also contribute to EED (Mapesa, Maxwell, & Ryan, 2016). Enteric infections that reduce nutrient absorption and impair immune function may play a substantial role in malnutrition, as gold standard nutrition interventions are estimated to reduce child stunting by only one third (Bhutta et al., 2008). Therefore, reducing enteric infections through water, sanitation, and hygiene (WASH) interventions may enable greater realization of the nutritional benefits of increased food security.

Harmonizing Goals and Moving Toward Holistic Interventions

To achieve lasting and consequential gains in nutritional security, efforts toward agricultural intensification should account for interactions with health and other-related dimensions of development (e.g., water and sanitation, education, energy; Sanchez, Denning, & Nziguheba, 2009; Wallington & Cai, 2017). In this effort, planners must identify and understand diverse, locally relevant, and often uncertain variables and decisions, such as those related to hydrology, climate, local soil quality, chemical storage and application practices, the types of fertilizers and pesticides available, knowledge and applicability of organic farming practices, and water sources (Godfray et al., 2010; Michelson, 2017; Mueller et al., 2012). Harmonizing goals for improved human health and increased agricultural productivity constitute a core aspect of this endeavor and can encompass a variety of possibilities. Holistic approaches explicitly integrating improved food security, nutrition, and WASH could generate synergistic benefits by breaking the cycle surrounding enteric infections. The results of current trials (Arnold et al., 2013; Humphrey et al., 2015) testing nutrition and WASH interventions' individual and combined effects may provide strong evidence for future integration across these dimensions of development. In addition, strategies already being explored to address the environmental concerns of intensification could provide simultaneous human health protection. Techniques including precision agriculture, reduced tillage, contour farming, crop rotation, polyculture, agroforestry, and improved farmer education on crop-specific nutrient requirements and pesticide application have the potential to limit fertilizer and pesticide use, reduce environmental contamination, and improve crop resilience to climate change, thereby lessening associated health risks (Godfray et al., 2010; Goldsmith, 2017; Matson et al., 1997; Mueller et al., 2012; Waldron et al., 2017).

Given the broad range and varied effects of possible strategies, maximizing intended benefits and minimizing unintended consequences require structured frameworks capable of identifying and analyzing trade-offs and synergies across dimensions of development (Wallington & Cai, 2017). For example, pesticide use is correlated with improved agricultural output and income, but it can also cause adverse health outcomes that lead to increased health-care costs and time lost due to illness (Sheahan et al., 2017). As another illustration, intensification may reduce crop diversity on smallholder farms, potentially diminishing dietary diversity and its nutritional benefits (Jones, Shrinivas, & Bezner-Kerr, 2014; Pellegrini & Tasciotti, 2014), although access to new and better markets may counteract these dietary losses (Sibhatu, Krishna, & Qaim, 2015) and enhance food security and rural development (Endres & Endres, 2017). Quantitative risk assessment (QRA) frameworks (Haas, Rose, & Gerba, 2014), applicable to chemical and microbial contaminants and various exposure pathways, may be particularly appropriate in ensuring that human health is protected. QRA provides a proactive approach capable of estimating the effects of potential interventions and suggesting improvements before any health hazards occur. Furthermore, QRA can be integrated with other tools, such as environmental life cycle assessment, to simultaneously evaluate outcomes and consider trade-offs across multiple dimensions of development (Kobayashi, Peters, Ashbolt, Shiels, & Khan, 2015; Kobayashi, Peters, & Khan, 2015). Linking QRA and life cycle assessment with economic models that estimate altered labor availability, health-care expenditures, and income from correlations with crop yields, food security, and health status (Sheahan et al., 2017) could lead to comprehensive frameworks able to compare dissimilar interventions across common metrics, accounting for the interdependencies that connect agriculture, environmental sustainability, economics, and health (Brawn, 2017; Cohn, 2017; Waldron et al., 2017; Wallington & Cai, 2017).

Any multifaceted framework or intervention must additionally consider a wide array of social, political, economic, and historical dimensions while accounting for various spatial scales, value systems, local constraints, and variabilities inherent in relevant variables and decisions (Endres & Endres, 2017; Garnett et al., 2013; Godfray et al., 2010; Palm et al., 2017; Sheahan et al., 2017; Tilman et al., 2002; Waldron et al., 2017). Building analytical models that allow for stochastic variables, randomly generated simulations, stakeholder involvement, and multicriteria decision analysis (Mendoza & Martins, 2006) will be particularly useful in addressing the uncertainties surrounding various parameters (e.g., health outcomes) and comprehensively evaluating context-specific strategies with disparate aspects across multiple scenarios. This level of complexity suggests a pressing need for dynamic interdisciplinary research teams capable of thinking holistically to harmonize multiple, qualitatively distinct goals. As evidenced by the connections and risks outlined above, any such team focused on improving agricultural productivity should include environmental and health specialists, as well as experts on complementary topics such as government policy, market access and employment, rural infrastructure, sociology, and gender equity. With local implementation partners (Palm et al., 2017), these diverse teams are well-equipped to develop holistic interventions that promote food security, protect health, and produce positive, appropriate, and enduring change.

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