

Rural Health & Development at the Food-Water Nexus

A proposal to the Environmental Ventures Project program, Woods Institute for the Environment

by

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Summary: Water resources management, smallholder food production, poverty, and infectious disease are inextricably connected in the world's poorest regions. In sub-Saharan Africa (SSA) limited access to water for both productive and domestic uses increases vulnerability to infectious diseases, the leading causes of morbidity and mortality in SSA. Within these complex linkages, identifying intervention points and constructive policy responses requires an understanding of how and the extent to which freshwater supplies and nutrition jointly influence health outcomes. The proposed project, which involves both place-based empirical research and analysis of secondary data, will explore these water-nutrition-health interconnections. It will identify the extent which, and potential causal mechanisms by which, access to domestic and productive water supplies and associated nutritional benefits affect the progression of both HIV and TB among adults living in rural African households.

Proposed project period: 1 July 2011 – 30 June 2013

Background, motivation, and prior work

Water resources management, smallholder food production, poverty, and infectious disease are inextricably connected in the world's poorest regions. In sub-Saharan Africa (SSA) limited water infrastructure investment limits agricultural production and rural income growth, restricting households' access to improved nutrition. Fully one quarter of the SSA population is malnourished. Moreover, 40% of households in SSA lack access to an improved domestic water source; the majority survive on less than 25 liters of water per person per day for all their domestic needs.

Limited access to water for both productive and domestic uses increases vulnerability to infectious diseases such as HIV and tuberculosis (TB), two of the leading causes of morbidity and mortality in SSA.¹ Progression of these illnesses is thought to be more rapid among individuals whose immune systems are compromised by malnutrition. Illness, in turn, leads to reduced dietary intake and nutrient malabsorption, creating a vicious cycle that worsens the impact of both malnutrition and infectious disease. Within these complex linkages, identifying intervention points and constructive policy responses requires an understanding of how and the extent to which freshwater supplies and nutrition jointly influence health outcomes.

There is surprisingly little rigorous empirical work that integrates the three areas of water infrastructure planning, nutrition, and infectious disease in ways that lead to actionable insights. Research is largely limited to exploring relationships between pairs of these domains. In the water sector, for example, freshwater management has historically been bifurcated into agricultural *versus* other (domestic, industrial, commercial) uses. Recent research is just beginning to explore the impacts on poverty, equity, and water system sustainability of infrastructure investments that supply both domestic and small-scale productive uses (*e.g.*, growing crops and raising livestock) at the household level.² Similarly, the interplay between nutrition with both HIV and TB is garnering increased attention; several influential studies have illustrated the role of food security and nutrition in improving disease outcomes.³ To our knowledge, however, there is no peer-reviewed literature that investigates the linkages across water, smallholder food production, nutrition, and infectious diseases such as HIV and TB.

Project objectives

The proposed project, which involves both place-based empirical research and analysis of secondary data, will explore these water-nutrition-health interconnections, and will serve as a stepping stone toward the development of theoretical and experimental paradigms linking water, agriculture, and health. The broad goals of the project are 1) to investigate the interactions between household productive and domestic water use, nutritional outcomes, and infectious disease, and 2) to identify local interventions and policy responses that are likely to improve overall health outcomes. **More specifically, the project will identify the extent which, and potential causal mechanisms by which, access to domestic and productive water supplies and associated nutritional benefits affect the progression of both HIV and TB among adults living in rural African households.**

¹ Lopez AD, Mathers CD, Ezzati M, Jamison DT, Murray CJL. The global burden of disease and risk factors. 2010.

² See, for example, Van Koppen, B., Moriarty, P., and Boelee, E. 2006. *Multiple-use water services to advance the millennium development goals*. Colombo, Sri Lanka: International Water Management Institute.

³ See, for example, Fawzi WW, Msamanga GI, Spiegelman D, et al. A randomized trial of multivitamin supplements and HIV disease progression and mortality. *New England Journal of Medicine* 2004; 351:23-32.

Study site, research design, and methods

Three provinces—Rift Valley, Central, and Eastern—of Kenya, east Africa, have been selected for the project. This is an area where the project PI (Davis) has recently carried out fieldwork on rural water supply services and maintains strong professional contacts. This area is also emblematic of the challenges linking water resources management, nutrition, and infectious disease in sub-Saharan Africa. Households here are heavily reliant upon agriculture for their livelihoods, with crops and livestock accounting for 44% and 16% of household incomes, respectively. Farmers typically face a five-month dry season each year with limited crop production and farm income.

The burden of both HIV and TB are high in Kenya. An estimated 10.4-11.0% of women between 25 and 34 years old live with HIV, and HIV treatment coverage is less than 40% of those who qualify for treatment by WHO guidelines.⁴ Kenya's TB epidemic is among the world's worst, with an annual incidence rate of over 300 cases per 100,000 population and a mortality burden second only to HIV among adults.⁵ Moreover, the two diseases commonly travel together: TB prevalence among incident HIV cases is upwards of 40%. Co-infection is exceptionally morbid, and the link with nutritional status appears to be strongly correlated.

Less than half of rural households in this region have access to an improved water supply, and *per-capita* water availability in Kenya is only about 1/10th that of neighboring countries. Rural communities in this region also exhibit a range of conditions vis-à-vis type and scale of agricultural production and installed water infrastructure, thus enabling comparative analysis of the linkages between freshwater management, food production, nutrition, and health.

Figure 1: Research design

	Access to improved domestic water supply services	No access to improved domestic water supply services
Access to productive water supply infrastructure	Group 1	Group 3
No access to productive water supply infrastructure	Group 2	Group 4

The research design for the proposed project incorporates both observational and quasi-experimental elements. We will select four sets of villages in order to populate the factorial matrix shown in Figure 1. Villages will be classified with respect to the presence or absence of improved domestic water supply services,⁶ as well as with respect to the presence/absence of infrastructure that enables smallholder production of crops and livestock year round. Efforts will be made to hold other village-level characteristics potentially related to health outcomes relatively constant, *e.g.*, proximity to an all-weather road and health clinics.

Data collection will focus on women of reproductive age and children under the age of five years. HIV prevalence and incidence are highest among young women, and HIV positive women are less

⁴ Kenya National Bureau of Statistics (KNBS) and ICF Macro. 2010. Kenya Demographic and Health Survey 2008-09. Calverton, Maryland: KNBS and ICF Macro. In.

⁵ World Health Organization | Global tuberculosis control 2010. (Accessed March 28, 2011, at http://www.who.int/tb/publications/global_report/en/.)

⁶ The definition of "improved" water supply services used by the World Health Organisation/UNICEF Joint Monitoring Programme will be adopted for village classification. See <http://www.wssinfo.org/definitions-methods/introduction/> for more information.

likely than men to access treatment. Women are also typically responsible for managing food, water, and health care at the household level. Young children are at high risk of mortality from HIV; 50% of HIV-infected children who do not receive treatment die before reaching their second birthday.⁷ Moreover, changes in nutritional status are relatively more important (from a developmental perspective) and more readily manifested in anthropometric data (*e.g.*, weight for age) among children *versus* adults.

Random samples of households will be drawn from villages in each of the four water infrastructure categories, with the aim of recruiting 100 households per group. Following informed consent procedures, in-depth interviews with each participant will be carried out using personal digital assistants (PDAs). We will collect information from each household regarding its agricultural production; home consumption; income from all sources; water supply and sanitation services; self-reported health symptoms and behaviors; and socioeconomic and demographic characteristics. Assuming adequate resources (discussed below), we will obtain samples of drinking water from each household's water source and in-home storage container and test them for fecal indicator bacteria (a measure of health risk for waterborne illness). We will also collect anthropometric measures (*e.g.*, height, weight, middle-upper arm circumference) of the adult female respondent and under-five children, to estimate the extent of wasting and stunting for these household members.

Respondents with self-reported diagnosis or symptoms consistent with HIV or TB will answer additional questions based on WHO and CDC clinical staging criteria.⁸ We will rely on self-reports and on clinical staging criteria such as thrush, persistent fever, weight loss, diarrhea (HIV wasting syndrome), peripheral neuropathy, and shingles to estimate HIV disease stage. We will also collect information on treatment adherence and tolerance, as those could depend critically on water and nutritional status. We will estimate prevalent and incident TB, using self-reports and a symptom-based questionnaire. Here too we will collect information on treatment adherence and success.

We will return to the same households approximately one year following our baseline study so as to evaluate temporal changes in production, consumption, and health. Such changes will not be the result of project activities (*i.e.*, we will not implement an intervention during the intervening period); however, under Kenya's current rural water investment program it is expected that at least some of the villages will experience changes in their productive and/or domestic water supply infrastructure. We can thus make use of comparisons between groups, and also within a subset of villages in each group, to draw causal inferences about the effects of different combinations of water access on nutrition and infectious disease.

Analysis of collected data will be carried out using statistical modeling approaches that accommodate complex causal relationships. Fuzzy set qualitative comparative analysis, for example, allows the identification of multiple "recipes" of causal factors that, when combined, give rise to a particular outcome of interest.⁹ This approach is relevant for cases in which multiple causal pathways to an outcome may exist, thus rendering inappropriate traditional regression

⁷ Weiser SD, Fernandes KA, Brandson EK, et al. The association between food insecurity and mortality among HIV-infected individuals on HAART. *JAIDS Journal of Acquired Immune Deficiency Syndromes* 2009; 52:342

⁸ See http://www.aidsetc.org/aidsetc?page=cm-105_disease for more information on this classification system.

⁹ Ragin, C. C. 2008. "Qualitative Comparative Analysis Using Fuzzy Sets (fsQCA)." *Configurational Comparative Analysis*. B. Rihoux and C. Ragin. Thousand Oaks, CA and London: Sage Publications.

analysis (which seeks to quantify average effects of explanatory variables within a single causal relationship). Structural equation modeling is an alternative analytical approach that the team is considering because it allows for explicit modeling of both measurement error (*e.g.*, in subjective opinions and self-reported health behaviors) and mediated relationships (*e.g.*, access to improved water supplying mediating the relationship between on-plot agricultural production and child development). Our data analysis plan will be finalized in conjunction with the development of our data collection instruments and sample frame over the course of the project.

We will augment our analyses with data from the nationally representative Demographic and Health Survey (DHS). Two recent waves of the Kenya DHS (2003 and 2008-9) collected rich health information, including HIV and TB symptoms and risk behaviors, as well as HIV blood tests. These health data will be combined with information about agricultural production, household consumption, and access to water supply infrastructure, so as to test and refine the models of water-nutrition-health relationships developed during analysis of our primary data.¹⁰

Significance and expected follow-on work

We view the proposed project as a unique opportunity to quantify water-production-nutrition-health linkages, and to identify promising interventions that can make the most of the scarce resources available for water resources development, food security, and HIV and TB in sub-Saharan Africa. This type of multidisciplinary investigation is simply not being pursued, resulting in poorly coordinated research investments and decision-making across the water/food/health domains.¹¹

We will organize an advisory board for the project comprised of senior personnel in Kenya's Ministry of Water and Irrigation, Water Services Trust Fund, and Ministry of Health, along with representatives from leading development and health organizations active in Kenya (*e.g.*, the World Bank, CDC-Kenya, Kenya Medical Research Institute, and the Gates and McKnight Foundations). We have budgeted for two meetings of this advisory board so as to incorporate its input into our research design, as well as to have an immediate audience with senior decision-makers when findings from the work emerge.

We will also work with these partners to develop a follow-on proposal for a large-scale project that will test one or more interventions identified by our project as having the potential to improve human welfare on a relatively large scale in a cost-effective manner. We have identified a number of potential funding opportunities for this subsequent work, including the NSF's Dynamics of Coupled Natural and Human Systems program; the Bill & Melinda Gates Foundation's Global Development Division; and 3ie's impact evaluation program.

Although policy advising will not occur until intervention strategies are tested more rigorously, we will work with a number of NGOs in the region, such as IDE, World Vision, and CARE, to orient ongoing humanitarian programs around water-agriculture-nutrition-health linkages.

¹⁰ The latest Kenya DHS collected information from 9,057 geo-referenced households, including 7,001 HIV tests.

¹¹ For example, the Gates Foundation's programs on global health and agricultural development have virtually no intersection despite the potentially strong connections between health interventions and improved nutrition.

Project participants

Three faculty investigators from three different schools (Engineering, Medicine, and Earth Sciences) have come together to develop the proposed project. Their disciplinary expertise extends beyond their school affiliations.

Jenna Davis is the Principal Investigator on the project. She brings expertise in water resources management, water and sanitation services planning, and household survey development to the project. She will have responsibility for developing the sample frame of villages and households in Kenya; developing measures of water supply and sanitation service quality; organizing the household survey modules and programming the data collection instruments for use on PDAs; and collecting spatial data using GIS devices. Davis has extensive field-level experience in sub-Saharan Africa with research focused on water, sanitation, and hygiene. She is excited to expand her work into exploring new intersections with food production, nutrition, and infectious disease.

Eran Bendavid is an infectious diseases physician and faculty affiliate at the Center for Health Policy and Stanford Global Health. He has contributed widely to issues HIV care and population health in sub-Saharan Africa. Bendavid will have responsibility for developing the measures and scales for estimating burden of HIV and TB in the household survey, as well as measurements of population health metrics. He will also take the lead in the analysis of the Demographic and Health Survey data that will test and validate the team's modeling of collected primary data. Exploring the interface between human health and environmental determinants is an area of great interest and intuitive development for Bendavid's research program.

Roz Naylor is the Director of the Program on Food Security and the Environment (FSE) at Woods and FSI and a Professor of EESS. Naylor is an economist by training and has a long history of field studies on agriculture, food security, and food policy throughout the world. Recently she has been a PI on a project in West Africa measuring the impact of productive water use (solar-powered drip irrigation systems) on incomes and nutrition among poor households using a matched-set comparison survey similar to the one proposed here. Naylor will be responsible for developing survey modules on cropping systems and nutrition at the household level, and will contribute substantially to modeling of collected data. Integrating her expertise into the realms of water infrastructure planning and infectious disease would represent a new and exciting step for FSE and her career in agricultural development.

None of the PIs have worked together previously, and all are enthusiastic about the possibility of collaborating on this project. Bendavid and Davis are junior faculty; Bendavid is in the first year of his appointment at Stanford. All three PIs are committed to participating in all phases of the project, including the in-country fieldwork. The project team will hold fortnightly meetings to ensure that all participating faculty and students are operating as an integrated unit. If, as we anticipate, a large number of students are interested in becoming involved with the project, we will also create a "special topics" seminar class to provide a formal structure for their participation.