Report of a Workshop on
Agricultural Development and Disease Risk in a Changing African Landscape
Saturday 30 June 2018, Accra City Hotel, Accra, Ghana

Workshop introduction

Rousseau Djouaka (IITA, Benin) outlined the objectives of the workshop: to explore potential infectious disease risks associated with future changes in agricultural landscapes in West and Central Africa, and to identify priority needs and topics for interdisciplinary research.

Jo Lines (LSHTM, UK) presented a review of interactions between agriculture and infectious diseases. Human populations live today in man-made landscapes, shaped profoundly by agricultural development. Clear relationships between agricultural development and infectious diseases include a range of zoonotic pathogens, leishmaniasis associated with irrigated crops in Tunisia, trypanosomiasis associated with palms in South America and mosquito borne diseases associated with rice and rubber production systems in different regions. The presentation focused on the relationships between rice production and malaria. Early research showed that communities in rice growing areas may or may not have higher malaria burdens than those in non-rice areas – low burdens have been attributed to improved incomes and associated improvements in malaria prevention in rice schemes – the "paddy paradox". However, more recent studies have shown clearer associations of rice growing with malaria, and it was suggested that this has emerged as prevention of malaria has improved everywhere, revealing the particular contribution that rice-related mosquito production makes to malaria burden. Intermittent irrigation is a strategy that has been shown to reduce mosquito numbers in rice fields, but introducing such health-related activities into agricultural systems will require considerable collaboration between the two sectors.

Two panel discussions followed. First, health experts identified future trends in health priorities and interventions in West Africa and commented on possible links to agricultural change. Then, agricultural experts identified future trends in agriculture in the region, and suggested where these might have implications for health.

Health Panel

Irene Agyepong (Ghana College of Physicians and Surgeons, Ghana) observed that in the coming decades, West Africa would be dealing with a substantial, if declining, burden of infectious diseases like malaria and HIV AIDS, and a growing burden of non-communicable diseases, like hypertension and diabetes. Malnutrition, both under and over-nutrition would be a continuing challenge, with links to agricultural systems, as would be new and emerging diseases.

Peter Enyong (University of Buea, Cameroon) considered how health had been, and would be, affected by changes in agricultural landscapes. Some agricultural change will reduce disease risks by creating environment unfavourable for vectors and disease, for instance the reduction of tsetse with agricultural development. But agricultural development also brings people together, e.g. around dams, creating denser populations and improving conditions for disease. Agrochemical use, which is presently unregulated, poses a potential health

threat. Most neglected tropical diseases (NTDs), which are a priority for international health interventions, have links to agricultural systems.

Joseph Okebe (MRC-LSHTM Unit, Gambia) focused on work in the Gambia and particularly malaria. Malaria is declining and elimination is now seen as an achievable target. Higher, seasonal levels of malaria, in the east of the country, appear linked to agricultural landscapes, particularly wetlands, rice growing and livestock production around the river.

In discussion, it became clear that the interaction of agriculture and health was often quite indirect and linked to other interventions. An example was the creation of dams for hydroelectric power and irrigation. This could change water flow and seasonal flooding below the dam, affecting farming and fishing and, indirectly, the quality of diets and health. Changes in the water system would also affect levels of diseases like malaria, onchocerciasis, schistosomiasis and other NTDs.

Some novel idea arose from the discussion, including that of creating maps of diseases associated with agricultural landscapes and crops, as has been done for zoonotic diseases and livestock systems. Improved surveillance for disease threats in agricultural systems was identified, particularly for poorly studied risks like physical injury and chemical pesticides. It was noted that, while health and agricultural systems collected spatio-temporal data, integrating data from these two sectors faced technical difficulties, frustrating efforts to understand agriculture-disease relations. Improving data integration, as well as new integrated surveillance and longitudinal studies should be the way forward.

Agriculture Panel

Robert Asiedu (IITA, Nigeria) gave an overview or recent and future food crop development in West Africa. Roots and tuber production has been expanding in recent decades and will continue to do so. For these and other crops like maize, the challenge will be increasing yield per ha, as expanding area of crop cultivation will reach its limit. Area under cultivation will also be influenced by climate change, although breeding for drought tolerant varieties, e.g. of maize, could allow continued range extension. The region will probably see growing conflict between farmers and herders as cattle production moves south out of the Sahel. Overall, there will be a shift towards more intensive mono-cultural production for tree and field crops, which may accelerate soil degradation and agrochemical use. A wide range of new pests and diseases may also constrain increasing crop production.

Kazuki Saito (AfricaRice, Cote D'Ivoire) spoke about likely trends in rice production in West Africa. Rice has shown a 50% increase in consumption in Africa in the past decade, but 40% of rice consumed is imported. Several donor-assisted and local programmes for rice self-sufficiency in West Africa are underway which need to increase yield of paddy rice, still half the global yield levels. Targets can only be achieved by increasing both yield per ha and area planted to lowland rice, by about 6m ha. Inputs and double cropping will increase, but the focus should be on a sustainable rice platform, which involves diversification of local production. Alternate wet and dry rice production might address malaria risks and the climate change problem of methane production in rice paddies, but farmers presently have few incentives to take this up.

Natalia Estrada Carmona (Bioversity International, France) described her centre's approach to drawing on ecosystem services in agricultural landscapes to improve production and reduce inputs. Smallholder agriculture will continue in Africa for some time. By mapping how landscapes are used, rural communities can explore what they will gain and lose through changes in agriculture. She gave several examples of current landscape programmes that could also incorporate a health dimension, including how farming communities access local food resources in forests, how the management of dams can improve diversified production (fish, cattle, crops), and the development of farming systems that address seasonal hunger periods.

A number of ideas came up in discussion. Improving agriculture, food security and nutrition is, for the health sector, a major contributor to disease prevention. Changing diets and a growing demand for animal-sourced foods will alter agricultural systems, with a likely increase in West Africa particularly in chickens, pigs and small ruminants, key hosts to zoonotic diseases. Urban-rural migration will also be important for agriculture and disease. Once more, the idea of identifying and monitoring agricultural interventions that had a high potential to affect health outcomes was identified.

Case Studies

In the next part of the workshop, existing research on agriculture-disease interactions were explored through a series of case study presentations, chaired by Bassirou Bonfoh (CSRS, Cote D'Ivoire). He introduced case studies with an overview of agriculture and health interactions. He shared a conceptual framework which illustrated how climate change influenced agricultural production, which in turn influences food and diets, as well as diseases, leading to a population health outcome. He observed that research across this space was focused on agriculture and nutrition, or agriculture and health, but needed to consider all three interactions, and identified agricultural parameters that could be developed as health indicators. Further, we should pay attention to how farmers health affects agricultural productivity, and thereby feeds back on access to resources for maintaining health. To address these research challenges, we need a systems approach.

Philip Amoah (IWMI, Ghana) summarized years of IWMI research on wastewater use in urban and peri-urban agriculture in Ghana. Most of the sewage treatment systems in Ghana are not working, and faecal contamination of wastewater used for irrigation of vegetables and other crops is high, creating disease hazards for urban consumers. Pathogen and parasite levels on food in markets is about twice the recommended levels, and most is attributable to contamination in the field, not in markets. This creates a considerable hazard, and more work is needed on risk and the consequences for human health.

Bernard Bett (ILRI, Kenya) presented three case studies on how changes in agricultural landscapes in East Africa has changed infectious disease risk. An irrigation scheme in the Tana River area in Kenya has raised vector borne disease prevalence and lowered levels of cattle-dependent zoonotic diseases. Fencing land for livestock production in southern Kenya, in areas once used by pastoralists, leads to a change in levels of Brucella, linked to changes in contact with wildlife. In Zambia, the spread of farming in areas previously devoted largely to grazing has led to a decrease in trypanosomiasis. These cross sectional studies reveal variable outcomes of land use change, and point to a need for more longitudinal studies to understand disease processes.

Abel Biguezoton (CIRDES, Burkina Faso) presented research on risks of emergent and re-emergent zoonotic diseases in West Africa. Sampling of human and livestock populations revealed cases of tick-borne rickettsial infections in both livestock and humans, and borreliosis in livestock. A separate study on human trypanosomiasis revealed a shift in northern limit of this disease southward over the last 50 years, possibly due to climatic changes. Vectors of human trypanosomiasis persist in urban areas, some animal trypanosomiasis vectors have disappeared, and conditions for zoonotic transmission between animals and humans persist. The five priority zoonotic diseases in Burkina Faso now are anthrax, rabies, avian influenza, brucellosis and dengue.

Julien Zahouli (CSRS, Cote D'Ivoire) described research on mosquito communities in rice growing areas in Cote D'Ivoire where plasmodial incidence was about 60%. Two sites were studied, one rural and one peri-urban. *Anopheles* species dominated both sites, and *A. gambiae* was by far the most abundant species, although rural sites showed more mosquito diversity. At the rural site, most biting and resting was recorded in houses, while at the peri-urban site biting was as high outdoors and resting in houses was less frequent. From the data, transmission rates at the two sites were estimated.

Charles Wondji (LSTM/IITA, Cameroon) presented recent research on the role of agricultural insecticides in development of resistance in mosquitoes. Decline in malaria in Africa is largely attributable to bed net use but resistance to pyrethroids used in bed nets has been increasing across the continent. There is strong evidence that mosquito resistance to pyrethroids is higher in areas and seasons of high agricultural use, with cotton, rice and market vegetables being the crops with highest insecticide use. Resistance is growing in urban areas in West Africa, and It is not clear how much of this is contributed by urban and peri-urban agriculture. New pesticides are being introduced for vector control (actellic, neonicotinoids) but these are also already being used by farmers, while an entirely new set of products has been developed for malaria targets. All this make research to develop strategies to protect the efficacy of insecticides for vector control most urgent.

Development of research priorities and projects

Workshop participants then worked together to address the following questions: What are the diseases that will require an integration of health and agricultural interventions? What kind of research will be needed to develop these solutions? Finally, how can this be done – i.e. what kind of projects and where? Participants identified four areas where they wanted to focus: rice and infectious diseases; zoonotic diseases, agrochemical use, and urban agriculture. The conclusions of each group were reported back and discussed by all participants. These are summarized below.

1. **Rice and infectious diseases**

The group noted that malaria was not the only disease associated with rice production, and proposed that an inventory should be made of all known vectors and diseases associated with rice-cropping (e.g. *Culex tritaeniorhynchus* a vector of Japanese encephalitis). Studies could be made on vectors to identify virus DNA. Cross-sectional serological studies could be made of human populations in rice-growing vs non-growing communities, distinguishing recent cases and previous exposure. Serology could also be done on animals in rice production systems to identify zoonotic risks. Particular attention should be paid to the relationship between diseases, vectors and particular types of irrigation (e.g. what kinds of irrigation support snail vectors of schistosomiasis or mosquito vectors of lymphatic filariasis?).

For malaria, there is a need to resolve the “paddy paradox”. Studies are needed on vectoral capacity in rice systems. Instead of cross-sectional comparisons between rice-growing and non-growing villages, longitudinal studies should be designed to explore the effect of addition of rice production to disease burden, collecting information on all potential factors that might affect burden, including human and mosquito behaviour. It was noted that different levels of transmission confound what we are seeing, and that this may require carefully matched pairs of rice vs non-rice villages.

Research on social and economic perspectives of farmers regarding rice and their perception of mosquitoes, malaria and health. Approaches to growing rice that produces fewer mosquitoes should be assessed, including studies on the range of current production methods and their effects on mosquito abundance and species composition. These include production of different rice varieties, transplanting vs broadcast seeding, dry season rotation (e.g. with vegetables, cereals), drainage and water systems, and labour demands over the system. In this way, malaria risk could be mapped across the different landscapes of rice production.

Research is also needed to understand how farmers might adopt new technologies, particularly if the benefits of doing so are not obvious or immediate – e.g. time spent not farming due to malaria infections may have a demonstrable economic impact that could influence farmer behaviour. Community engagement and participation will be important in such studies.

2. Zoonotic diseases

From a practical perspective, the zoonotic diseases which will require an integration of health and agricultural interventions can be classified into four different types, each with their own set of knowledge gaps and research questions.

For *diseases of intensification*, including transition from pastoral to agro-pastoral systems, such as AMR, HPAI, drug/pesticide residues, Brucella, cysticercosis, research in needed to improve surveillance systems, including new diagnostic tools, mapping approaches and joint surveillance programmes across veterinary and medical systems. Research is also needed on sensitization, the effects of policy and legislation and biological and genetic research on host immune responses.

For *diseases associated with habitat modification* through agriculture, such as Ebola, Nipah and trypanosomiasis, research is needed on the effect of change on vector and reservoir host ecology, so as to reveal disease drivers. Modelling may have a particular role in such research. Research on host immunity dynamics will also be important, as well as on improved surveillance to detect changes in disease.

For *diseases which are vaccine preventable*, such as anthrax, rabies, and bovine TB, research on improving vaccine uptake, through sensitization and extension is needed, and the value of taking a cross-sectoral, one-health approach should be assessed by benefit-cost analysis. Research will be needed to develop new vaccines and improve on existing ones, and once more, research is needed to establish effective surveillance programmes (including DIVA tests) to facilitate and assess vaccination campaigns.

For *diseases emerging as non-malarial fevers*, there is an immediate need for better diagnostic tools and surveillance, and how best to sensitize health systems and communities to these new threats. Research to establish the burden of these diseases on communities will be important in raising awareness and stimulating action.

Across these types of zoonotic diseases, initiating these research activities will require establishment of collaborations between agricultural, environmental and public health research, bringing together their institutions, national and international and their research donors. An immediate opportunity is to build bridges for research collaboration between regional projects which are on-going, and disseminating research results from programmes through One Health platforms. This sharing of research can, in turn, be used to identify research gaps and to target high risk areas where new research projects should be directed.

3. Agrochemicals, agriculture and health

This group identified two different research priorities under this heading: understanding and reducing health risks from agrochemical exposure, and minimizing agriculture's contribution to pesticide resistance in disease vectors. For *health risks from agrochemicals*, there is very little data available, and clear need to understand what chemicals are being used for what purposes (including continuing use of obsolete and banned projects); how it is being used by farmers and the consequences for exposure; and what health consequences arise, both acute and chronic, from such use. This is a substantial task and some initial insight and focus might be achieved by studying populations involved in similar and agricultural production, but differing in their use of particular products. Studies will be needed to understand presence and movement of chemical contaminants in food supply chains and in local environments, including water supply and waste systems.

Evidence of agrochemical impacts on health can inform policy making, but it was noted that in many countries, the policy platform for regulating agrochemicals, in which this evidence could be used, does not even exist. Research on constructing such platforms may, therefore, also be given priority.

For *agrochemical contributions to vector resistance* the focus should be in resistance in malaria vectors, but it was noted that agrochemicals may contribute to know resistance in vectors involved in transmission of lymphatic filariasis, schistosomiasis and onchocerciasis. There is a strong argument not only for reducing exposure of disease vectors to agrochemicals but reducing agrochemical use on agricultural pests as well, as this would make a major contributor to reducing risks of vector resistance, and lead to effective stewardship of useful pesticide products in both sectors. Hence, an integrated public health and agricultural approach is recommended.

A first step for this research would be to identify cropping and livestock systems with particular potential for generating resistance in malaria vectors. Clearly, systems with a record of intensive pesticide use, like cotton, rice and vegetables, would be most significant. But there would also be a value to mapping resistance levels in vectors and agricultural pests and diseases associated with particular production systems. Identifying not only resistance but resistance mechanisms may help to link agrochemicals use and vector resistance. For instance, for malaria mosquitoes in rice systems, larvae are more likely to be exposed to agrochemicals, while adults may be more exposed to insecticide used in bednets and household residual spraying. Therefore, analysis of mosquito resistance, to determine whether it involves mechanisms in larval and/or adult stages could help to identify the relative contribution of agrochemicals.

Immediate opportunities for research exist with the introduction of new insecticides for vector control. Some of these are existing compounds registered for agricultural use (e.g. actellic and neonicotinoids), while others are entirely new, developed through public-private partnerships for vector control. Stewardship of these projects to maintain their value in vector control will be a priority, and their implementation will provide an opportunity for studies on resistance development in the field, linked to selection studies in the lab to identify mechanisms and develop tools.

4. Urban agricultural systems and disease

Research in urban agricultural systems cuts across many of the areas above, as these systems may create conditions for zoonotic diseases and encourage irrigated cropping and greater pesticide use. But as rapidly growing farming systems, with distinctive differences from rural systems, they deserve increased attention. Three priority research areas were identified. *Production of vegetables from urban wastewater* poses risks of microbial and chemical (pesticide/heavy metals) contamination of vegetables consumed by urban populations. On the other hand, wastewater and manure from urban livestock keeping provide critical water and nutrients to urban vegetable farming, creating income and employment benefits in water management and agricultural supply chains.

Irrigation in urban agriculture can contribute to the problems identified above, and also provide breeding sites for vectors, e.g. anopheline vectors of a range of urban diseases. Use of pesticides in irrigated urban/peri-urban may also encourage development of resistance in vectors of malaria and other diseases. *Peri-urban production of poultry, pigs and dairy* produces nutritious foods and manure used in urban agriculture, but waste and effluent from these systems can carry and spread microbial diseases and AMR.

All of this points to a need to better understand urban food systems, and their relative positive and negative (especially disease-related) aspects. This investigation should start with characterization of different types of urban/peri-urban agricultural systems and the food supply chains they support, involving both formal and informal markets. Once these systems are characterized, safety and health issues can be investigated and risk analysis undertaken. This could include, for instance, water quality assessment form different agricultural sources and its association with local community health, nutrient cycling, land and water footprints of these urban production systems, and analysis of links between urban agriculture and disease vector abundance and resistance to insecticides used in agriculture.

Research projects on urban agriculture and disease could involve descriptive studies, including characterization of planned and unplanned urban land and water use for agriculture and how its supports livelihoods. Studies on spatial associations of urban agriculture and health risks, including integration of existing agricultural, health and geospatial data, could reveal important associations (e.g. genome sequencing of sewage systems to identify diseases entering and leaving them from particular catchments). Novel urban food system interventions would make ideal systems for evaluating disease and health risks. All of this research could benefit from links with urban development initiatives, such as the C40 group for innovative city development, as well as with community groups.

Close of Workshop

Bernard Bett closed the workshop on behalf of the organizers, and commented on the strong, common research agenda that had emerged and the opportunities to collaborate between groups and institutions on a number of themes identified and discussed. He also stressed the need and opportunity for building capacity in this research area, to enable researchers to work across agricultural, veterinary and public health disciplines and to bring evidence to policy.

Workshop on Agricultural Development and Disease Risk
in a Changing African Landscape
Saturday 30 June 2018, Accra City Hotel, Accra, Ghana

Organized by the CGIAR Agriculture and Nutrition for Health Program (A4NH), in conjunction with the 3rd annual Agriculture, Nutrition and Health Academy Week, Accra, Ghana

The workshop will bring agricultural and public health researchers together to explore potential infectious disease risks associated with future changes in agricultural landscapes. It will have a particular focus on West and Central Africa, highlighting relationships there between development of irrigated cropland and vector borne diseases, livestock development and zoonotic diseases and land use change and emerging diseases. The aim of this meeting is to identify priority needs and topics for interdisciplinary research. The A4NH programme will then help potential collaborators to develop research proposals in this area.

Workshop Programme

Saturday 30th June – Programme/Agenda	
Time	***Activity***
08:30 – 09:00	**Registration** (Tea and coffee)
	SESSION 1 – REVIEW OF INTERACTIONS
09:00 – 09:10	**Introduction and Objectives** – Dr Rousseau Djouaka (IITA, Benin)
09:10 – 09:30	**Survey of interactions between agriculture and disease** – Prof Jo Lines (LSHTM, UK)
09:30 – 10:45	**Panel: the Public Health Perspective on Agriculture in West Africa** Moderator: Prof Jeff Waage (LSHTM, UK) --- Panellists: Prof Irene Agyepong (University of Ghana, Ghana) Prof Evelyn Ansah (University of Health and Allied Sciences, Ghana) Prof Peter Enyong (University of Buea, Cameroon) Dr Joseph Okebe (MRC LSHTM, The Gambia)
10:45 – 11:00	**Tea/ Coffee Break**
11:00 – 11:45	**Panel: Trends in Agriculture – Implication for Landscapes and Disease?** Moderator: Dr John McDermott (CGIAR A4NH, USA) --- Panellists: Dr Robert Asiedu (IITA, Nigeria) Dr Kazuki Saito (Africa Rice, Côte d'Ivoire) Dr Aminou Arouna (Africa Rice, Côte d'Ivoire) Dr Natalia Estrada Carmona (Biodiversity International, France)
	SESSION 2 – CASE STUDIES ON AGRICULTURE-DISEASE INTERACTIONS
12:00 – 13:00	**Introduction** – Dr Bassirou Bonfoh (CSRS, Côte d'Ivoire) --- **Health Implications of wastewater reuse in urban and peri urban vegetable production in Ghana** – Dr Philip Amoah (IWMI, Ghana) ---

	Impacts of land use change on the distributions of selected zoonotic diseases: evidence from selected case studies in East and Southern Africa – Dr Bernard Bett (ILRI, Kenya) --- **Risk of emergent and re-emergent vector-borne diseases in West Africa: cases of rickettsiosis, borreliosis and human trypanosomiasis** – Dr Abel Biguezoton (CIRDES, Burkina Faso)
13:00 – 14:00	**Lunch break**
	SESSION 2 – CASE STUDIES (CONTINUED)
14:00 – 14:30	**Malaria vector ecology and plasmodium transmission in irrigated rice growing areas, Côte d'Ivoire** – Dr Julien Zahouli (CSRS, Côte d'Ivoire) --- **Role of agriculture in selection of resistance to insecticides in malaria vectors** – Prof Charles Wondji (LSTM/IITA, Cameroon)
	SESSION 3 – BREAKOUT DISCUSSIONS TO IDENTIFY PRIORITIES/PROJECTS
14:30 – 15:30	**Breakout discussion groups**
15:30 – 16:00	**Tea/ Coffee Break**
	SESSION 3 – BREAKOUT DISCUSSION (CONTINUED)
16:00 – 17:00	Feedback from breakout groups, discussion and wrap up Moderator: Prof Jeff Waage (LSHTM, UK)
17:00	Close of Workshop – Dr Bernard Bett (ILRI, Kenya)