ISSN: 2474-3658

Tambo et al. J Infect Dis Epidemiol 2018, 4:056
DOI: 10.23937/2474-3658/1510056
Volume 4 | Issue 3
Open Access

Journal of
Infectious Diseases and Epidemiology

REVIEW ARTICLE

Digital Surveillance and Communication Strategies to Infectious Diseases of Poverty Control and Elimination in Africa

Ernest Tambo[1,2,3*], Shang Xia[4,5], Xin-Yu Feng[4,5] and Zhou Xiao-Nong[3,4,5]

[1]Africa Disease Intelligence and Surveillance, Communication and Response (Africa DISCoR) Foundation, Yaoundé, Cameroon

[2]Higher Institute of Health Sciences, Université des Montagnes, Bangangté, Cameroon

[3]WHO Collaborating Centre for Tropical Disease Research, Key Laboratory of Parasite and Vector Biology, Ministry of Health, Shanghai 200025, PR China

[4]National Center for International Research on Tropical Diseases, Ministry of Science & Technology, Shanghai 200025, PR China

[5]National Institute of Parasitic Diseases, Chinese Center for Disease Control and Prevention, Shanghai 200025, PR China

***Corresponding authors:** *Ernest Tambo, WHO Collaborating Centre for Tropical Disease Research, Key Laboratory of Parasite and Vector Biology, Ministry of Health, Shanghai 200025, PR China*

Abstract

Investing in digital technologies to support health-based research, modelling and planning, preparedness and timely effective response, and long-term management benefits has been recognized in improving epidemiological analysis, disease prevention, control to elimination, health education and promotion. This paper provides valuable insights and approaches for public health in collection, analysis, interpretation, use and dissemination of health surveillance data, resource allocation, for guiding decision-making policy on infectious diseases priorities, control and elimination interventions and actions in achieving Africa Union, 2063 Agenda and global health initiatives. We highlight innovative directions and useful digital public health technology applications in understanding and data mapping models for health and environment decisions, support in improving health service access and uptake in Africa. Also exploring geographic epidemiology, climate impact; vectors and pesticide control, pollution, waste management and wildlife effective digital surveillance indicators, preparedness, monitoring and response on current applied infectious diseases approaches and interventions in improving early warning alert and effective management to local, national and regional needs in health-care planning and service delivery in community health systems. While leveraging on public private partnerships (PPP) health systems and policy re-engineering in improving the quality health service delivery and outcomes, healthy life, social inclusiveness and social cohesion for shared productivity and sustainable development.

Keywords

Digital, Public health, Surveillance, Preparedness, Prevention, Response, Infectious diseases, Poverty, Africa

Abbreviations

DHP: Digital Public Health; GPS: Geographic Positioning Systems; GIS: Geographic Information System; RS: Remotes Sensing; R&D: Research and Development; HIV: Human Immunodeficiency Virus; MDGs: Millennium Development Goals; EVD: Ebola Virus Disease; H7N9: Influenza Variant; TB: Tuberculosis; CO_2: Carbon dioxide; STIs: Sexually Transmitted Infections; PPP: Public Private Partnership; AU: Africa Union; 3S" technology: GPS, GIS, and RS; AIDS: Acquired Immuno-Deficiency Syndrome; MERS: Middle East Respiratory Syndrome

Introduction

Africa is not only well known for its natural wonders, but also for the conflicts events, poverty and hunger, especially the contemporary double public burden of the infectious diseases and rising non-communicable diseases [1]. These diseases continue to be the source of increasing co-morbidity and co-mortality each year, complicated with limited access clean drinking water and sanitation, and weak provision of basic health services to most African vulnerable populations [2-4]. For

Citation: Tambo E, Xia S, Xin-Yu F, Xiao-Nong Z (2018) Digital Surveillance and Communication Strategies to Infectious Diseases of Poverty Control and Elimination in Africa. J Infect Dis Epidemiol 4:056. doi.org/10.23937/2474-3658/1510056

Accepted: August 21, 2018: **Published:** August 23, 2018

a long time, impact of the double burden on the continent has led unfortunately to imbalance with healthcare and socioeconomic inequalities as part of their everyday lives. The 2014 Ebola outbreak in West Africa has dramatically raised awareness of the global burden of infectious disease and raised questions about the preparedness of public health systems [5-7]. Although non-communicable diseases are the leading cause of morbidity and mortality in most developed nations, infectious disease remains a major public health concern in Africa [8]. Yet, most African countries are still unclear and reductant on the implications and opportunities of digital technologies applications operationalization in defining and examining the global distribution of infectious disease, in both time and location, unravelling the spatio-temporal patterns, persistent trend and burden of infectious diseases and in overhauling the national health systems delivery and utilization on the field and point of care [9]. Generally, it is becoming increasingly clear that the digital technology can improve disease reporting by supplementing formal surveillance with publicly generated digital disease surveillance of most predominant diseases in every continent, such as HIV/AIDS, tuberculosis, malaria and emerging outbreaks, which have made terrible consequences of premature mortality of children and young adults, and consequently man-made poverty [10,11].

However, in fact, most of the diseases in Africa are such that can be prevented by measures starting with personal hygiene and proper education, especially for infectious disease [12,13]. It has been proven that Africans could be able to prevent a great deal of these deaths by tackling the issue of epidemic that to stop the transmissions of such diseases by public health interventions. In this respect, public health plays a central role in disease control and prevention to protect the population from the hazard of disease [14].

The digital earth technology advancement and applications with its core technology-"3S" technology (GPS, GIS, and RS) have become increasingly used as new means for disease control and prevention, surveillance, awareness rising, and decision support systems [15-17]. However, most studies focused on their effectiveness, and feasibility between traditional methods of risk factors data collection, spatial and temporal mapping and disease surveillance with limited integration with health information systems, despite the challenges with interpretation and evaluation of implications. Their usefulness is highly advantageous with respect to scalability and productivity, cost and portability, and offers many opportunities in geographical epidemiological studies in any setting provided with minimal/comprehensive infrastructure and socioeconomic conditions, compliance [18], disease surveillance [19], health information systems, point-of-care support services and care [20], health promotion, disease prevention, and emergency health response in sharing benefits of the unfolding digital technology revolution [21,22].

This paper provides valuable insights and approaches for digital public health implementation in collection, analysis, interpretation, use and dissemination of health surveillance data, resource allocation, for guiding decision making policy on infectious diseases public health priorities, contextual evidence-based interventions and actions in achieving new horizons of Africa Union (AU) 2063 Agenda and global health programs.

Review

Public health burden of infectious diseases in Africa

In Africa, the primary burden of diseases remains attributable to preventable diseases ranging from infectious diseases such as malaria, HIV/AIDS, viral haemorrhagic fevers, tuberculosis and cholera to the rising non-communicable diseases [2]. Although the burden of morbidity and mortality from infectious diseases has been decreasing in recent years; however, the disease is still severely reducing the quality of life and productivity of society and eroding economic growth [23]. According to The World Health Organization (WHO) report, in the African Region, infectious disease still cause the majority (69%) of death, and 46% of all deaths were children aged under 15 years, what' more, the disease burden per person in Sub-Saharan Africa increased between 1990 and 2001, mostly because of HIV/AIDS, tuberculosis and malaria [24]. Meanwhile, Africa is undergoing an epidemiological transition with rapid increasing chronic and non-communicable disease such as cardiovascular disease, diabetes, respiratory disease and cancers. Studies have shown the relative risk of tuberculosis infection in different types of diabetes patients, the linkage of HIV treatment with type II diabetes, and the co-infection state of HIV and tuberculosis [25-27]. These associations between different kinds of diseases could potentially have a major public health impact in sub-Saharan Africa. Projected trends in 2030 are not optimistic because some communicable diseases will remain the leading cause of death and shadowed by others [28].

Operational population-based knowledge and information on infectious disease, transmission dynamics and burden is critical in informed health policy decision making, health investment resources allocation, capacity development, evidence-based programs and interventions. For example the potential of GPS/GIS/RS studies in visualizing, analyzing and spatial modeling methods of data related to vector borne diseases (VBD) approaches have shown associations with a specific geographic landscape and epidemiologic risk factors including malaria, human African trypanosomiasis, leishmaniasis, lymphatic Filariasis, Loa loa filariasis, onchocerciasis, Rift Valley fever, dengue, yellow fever, borreliosis, rickettsioses, Buruli ulcer and Q fever, and improve our understanding of how environmental and

Table 1: Major infectious diseases in Africa in alphabetical order.

Disease name	Disease genre	Disease burden (estimated cases/death)*
Amebiasis	Parasitic disease	70,000 deaths
Cholera	Bacterial disease	3-5 million/100,000-120,000 deaths
Dengue	Viral disease	390 million/indetermination
Ebola	Viral disease	15,000 deaths
Giardiasis	Parasitic disease	Indetermination
Guinea-Worm	Parasitic disease	Indetermination
Hepatitis	Viral disease	Hepatitis A: 1.4 million cases Hepatitis B: 240 million cases/780,000 deaths Hepatitis C: 130-150 million cases/350,000 to 500,000 deaths Hepatitis E: 20 million cases/56,600 deaths
HIV/AIDS	Viral disease	35 million cases/1.5 million deaths
Hookworm	Parasitic disease	Indetermination
Leishmaniasis	Parasitic disease	1.3 million cases/20,000 to 30,000 deaths
Lymphatic Filariasis	Parasitic disease	120 million cases
Malaria	Parasitic disease	198 million cases/584,000 deaths (2013)
Onchocerciasis	Parasitic disease	Indetermination
Polio	Viral disease	416 cases (2013)
Schistosomiasis	Parasitic disease	20,000 to 200,000 deaths
Syphilis	Viral disease	Indetermination
Trypanosomiasis	Parasitic disease	6314 cases (2013)
Tuberculosis	Bacterial disease	9 million cases/1.5 million (2013)
Typhoid	Bacterial disease	22 million cases/216,500 deaths (2011)
Yellow Fever	Viral disease	200,000 cases/30,000 deaths

*The data are cited from WHO website accessed May 23rd, 2017.

climatic factors affect the vectors and transmission of VBDs [29,30]. Hence, promising opportunities for surveillance, monitoring and evaluation of a range of national infectious diseases risk and threats, programs and interventions impact.

Infectious diseases burden in Africa represents a series of complex interplay between pathogenic, clinical and epidemiological diversity and interwoven with maternal, perinatal, nutritional challenges, non-communicable/communicable disease burden, and other injures, where communicable disease accounts for an essential component of the total burden [31]. There is a long list of serious diseases (Table 1) spread in a variety of ways causing serious concern for social and human development in the region. These diseases included: AIDS, malaria, pneumonia, tuberculosis, diarrhea, polio, measles and Ebola etc., which have killed large numbers of people due to environmental impact, lack of potable drinking water and hygiene as well as inadequate services delivery and utilization bottlenecks in control to elimination programs, and in achieving the universal coverage and Millennium Development Goals (MDGs) [9,32,33]. For example, malaria in Africa still affects more than 200 million people annually, causing 0.6 million deaths, and it is estimated that 90% of these deaths were in the WHO African Region according to the latest report from WHO/AFRO [34]. The mosquito-borne disease is widely considered to be the deadliest disease with an exorbitantly high prevalence rate in sun-Saharan Africa where pregnant women, non-immune travelers, refugees, children and displaced persons are risk populations, especially young children [35,36].

Other infectious diseases include Human immunodeficiency virus (HIV) /AIDS, Tuberculosis or TB, dengue, African Trypanosomiasis, cholera, diarrhea, river Blindness/Onchocerciasis, Ebola and soil-transmitted helminthiasis [37,38]. These diseases are either caused by virus that attacking the immune system, bacteria invading the organs, or the parasitic worm entering the human body and living up for many years. In addition, the common diseases prevail in Africa also include measles, tetanus, and whooping cough, and some other new emerging disease such as Ebola virus disease in West Africa. These serve as powerful reminders of the global risk from new and emerging infectious diseases continues to grow and our vulnerability to emerging and re-emerging pathogens have not changed in many fundamental ways including evolution and resistance development [39].

Moreover, a contemporary greater concern of non-communicable diseases rising in Africa has been documented from hypertension to cardiovascular diseases, diabetes and cancers. This is yet another worrisome threat to poor African countries that are short-handed in dealing the traditional infectious disease in addition to drugs shortages that plague every now and then in most African countries. The challenge enlarged with technical and non-technical barriers, lack of huge amount of resources and weak national health laws and legal system has discouraged not only the public but also government and related stakeholders. Infectious diseases of poverty control and elimination to eradication in Africa requires robust and contextual based implementation of health systems and policy re-engineering supported by including public private partnerships (PPP), government and stakeholders in reducing the toll of infectious diseases morbidity and mortality. Thus, the need to intensify community awareness campaigns, participation and empowerment, capacity development, health education and effective information communication towards projects and programs ownership and community-based interventions are paramount in improving coverage, services and care for healthy and quality life and welfare, improved health service delivery and quality outcomes, social inclusion and cohesion, better productivity and sustainable economic development (Table 1).

Digital public health paradigm in infectious diseases surveillance, prevention and elimination

The convergence of digital technology with health, referred to as digital health (or GPS or GIS/RS connected health, mHealth, eHealth, etc.) focuses on improving health system outcomes by making reliable, effective and actionable information and communication available to all relevant stakeholders [40,41]. Furthermore adequate planning and comprehensive approaches in DPH human resources development and capacity building to support the growing needs and demand in much needed electronic health records and health management, care interventions, regulations and Health policy reforms in Africa. The effective implementation of DPH in African public health systems requires the establishment of a robust DPH framework, adapted strategies and tools to local realities and context. Whether that is for efficient patient monitoring in hospitals, better chronic disease management, proactive preventive care or optimizing performance in healthcare delivery and utilization, it is still to be proven. The enabling community-based digital skills require robust system architectures for hospitals and connected sports/fitness solutions [41]. For example, wearable sensor design technology for independent living and smart home systems for the elderly, algorithms for extracting actionable information from data including data fusion and trending, regulatory guidance and market strategy, competitive analysis, innovative technology analysis and matching chronic diseases care delivery as a business model development ready in transforming health and social care [40,42].

Moreover the need for strong advocacy in government and its stakeholders/partners political commitment and financial investment in DPH R&D, infrastructures and facilities in Africa are imperative [43]. Significantly, lessons learnt in its effective deployment and applications in malaria, TB, Ebola and cancers could serve as experimental examples in relevant markets such as regulated medical device development, innovative consumer products and wireless communications, bringing all the expertise under one roof to develop the perfect digital health solutions [44,45]. Hence, the new paradigm of digital health systems in health services delivery and interventions, tracking and efficient record archiving can be accomplished through wireless medical devices, smart connectivity, iPhone and Android applications (consumer health and medical), telemetry solutions for wireless implants, smart interventional tools. Post-exposure and operative monitoring technology for pollutants and adverse effects can be done respectively through connected medical devices as eel as solutions for medication management and medication adherence monitoring [46-48].

The development and use of digital earth technology with its core technology-"3S" technology (GPS, GIS, and RS) have become increasingly common provide more favorable means and technical support for disease survey, spatial surveillance and risk monitoring and evaluation [48,49]. Digital application in disease control and prevention proposed the need to combine the two previously distinct fields of statistical research and spatial technologies, which had rarely been associated before the famous case of cholera in London in 1845 [50]. Over the following decades, scientists have made tremendous strides in health, science and communications technology since the days of John Snow. The realm of current opportunities to collect, store and ultimately use data at each level of the health system is increasing exponentially, digital earth technology has become integral to public health item credited with reducing the time to recognition of a threat or outbreak and facilitating public health responses to outbreaks and emerging diseases [30]. As well as the need to integrate laboratory surveillance was emphasized, in terms of personnel, reagents and supplies, as well as the confirmation process for reported disease epidemic threats [39]. The evaluation digital health implementation research in Africa with laboratory-based participation in the subsequent years of IDSR implementation in Ghana, The Gambia, Tanzania, Uganda and South Africa identified continued weaknesses in terms of trained laboratory personnel, especially at district and sub-district levels, processing of laboratory and technical results, capacity and ability to link laboratory results with the weekly surveillance reporting system and monitoring, which on its part reflected a steady increase timely reporting and decision making policy [29,42].

Strengthening digital public health strategies and tools applications

The “3S” (GPS, GIS, and RS) technologies can be used widely in disease surveillance, monitoring, prediction and strategy-making [29]. A comprehensive literature review has identified an extensive assortment of health-related potential benefits to both public health patients and professionals such as no-cost access to data, intuitive and easy-to-use tools, support and training. Also in mapping and forecasting population risk assessment of short-term exposure and risk analysis, general environmental risk factors association between traffic exposure levels and the occurrence of diseases, geographic variability in the prevalence, geographic cluster analysis and impact analysis of health survey databases, risk-score models simulations and estimations, seasonal pattern analysis, surveillance data of infectious diseases (malaria, HIV, influenza, polio, EVD, MERS and TB) evaluation [17,22,29]. Interestingly, real-time emergency surveillance and tracking system to detect bioterrorist events and emerging infections, multinational impact assessment of influenza pandemics; potential for "3S" patio-temporal mapping and predicting of global distribution of infectious diseases, and spatial modeling of landscape sensitivity to climate change and wildlife management worldwide including Africa. GIS applications have potentials upon GIS by public health professionals such as no-cost access to data, intuitive and easy-to-use tools, support and training, more research and applied methodologies and cross-sectoral approaches [17,22,32,41]. Public health problems in Africa have been associated to local geography, environmental and climatic conditions those favour especially VDBs, zoonoses and emerging outbreaks which can be effectively analyzed using mapping and modeling techniques. The prime goal of environmental and health management is to reduce existing risks and prevent the introduction of new uncontrolled risks. Since alterations to human health are often associated with or caused by sudden or gradual changes in the environment, a prerequisite for health risk management is the identification of environmental hazards and their effects, coupled with suitable monitoring programs to provide the data necessary for priority setting and decision making. One of the best ways to monitoring and managing environmental risk factors and threats through the utilization of the power functionalities available of fast emerging digital technologies in better management of environment and in turn better health management [51-57]. The spatial-temporal distribution patterns of most of the diseases are complicated, geographical information System (GIS) emerged as the core of the spatial technology which can integrate wide range of dataset available from different sources to different GIS modules for geo-statistical analysis in detail, including spatial data sources, mapping and geo-processing tools, distance calculation, digital elevation model in different endemic/epidemic settings [29,40,51]. These GIS tools have contributed immensely in understanding the epidemiological processes of malaria and examples drawn have shown that GIS is now widely used for research and development as well as decision making policy in infectious diseases control and prevention. GIS has facilitated the analysis of access to health facilities and disease risk in different populations combined with the management and analysis of health and health-care data [52,53]. Studies on the human immunodeficiency virus (HIV) using information on individuals collected during a prevalence study to characterize smaller geographical areas in Tanzania and several villages in Mozambique with enhanced accessibility of services maternal-child emergency referral system in Ethiopia. This formed an aggregated analysis of geographical and social patterns relevant to HIV transmission in the study areas in health-care planning [54,55].

Global positioning systems (GPS) tracking enables highly accurate and reproducible measurement of distance. Dwolatzky, et al. used a handheld computing device programmed with customized software and linked to a GPS receiver to trace patients to assist TB control programmes in areas without useful street maps [54,55]. The study took place in two communities in Greater Johannesburg, South Africa which improved that it is feasible to use a simple PDA/GPS device to locate the homes of patients. GPS technology is more accurate than aerial photos in identifying homes and more efficient than addresses provided by participants and could be used to map and reduce part of the burden on HIV, TB and Hepatitis control programs [55,58].

Remote sensing (RS) is the acquisition of information about an object or phenomenon on Earth by making satellite measurements. It has distinct advantages because it can collect the information repeatedly and automatically. The availability and application of remote sensing (RS) techniques are becoming increasingly important to improve our understanding of human health. In modern usage, RS generally refers to the use of aerial sensor technologies to detect the earth surface, the atmosphere and oceans by means of propagated signals such as electromagnetic radiation emitted from air craft or satellites. Based on RS images, a lot of information on detected objects can be obtained including information on vegetation, land use/land cover, and water bodies. These geographical factors are closely related with the occurrence of many environment-related diseases and can affect even predict their distributions accordingly [56]. Therefore various extracted factors from RS can serve as a bridge for linking RS techniques with disease studies. Dambach took a high-resolution satellite view from the satellite during 2008 to generate a land cover classification in the malaria endemic lowland of North-Western Burkina Faso on the purpose of finding the most favorable sites for Anopheles production according to known correlations of Anopheles larvae presence and surface water-related land cover [59]. By doing this, potential high and low risks for malaria at the village level can be differentiated from satellite data. This is a potentially useful approach which could lead to more focused disease control programmes such as malaria control measures (impregnated bed nets, indoor spraying and larval control measures) specifically target to a small-scale level [59]. A large number of researchers have taken advantage of GIS, RS and GPS in their studies. It is possible that to locate the homes of patients, conduct community-based treatment, clear away the reservoir, which prove to be helpful in management of disease outbreak along with innovative health-care planning, program and management practices.

Fostering digital health implementation in infectious diseases operational research and remote service delivery

Digital health operational research applications in infectious diseases control to elimination and eradication is a growing field, and there is not yet a national or even world center for an ecosystem to develop those applications in health systems and amongst stakeholders from scientists, policy makers, entrepreneurs, academics, pharmaceutical firms and industry) to the broader vulnerable community. Investing in DPH operational research in infectious diseases elimination and eradication is crucial to address gaps in knowledge and healthcare systems challenges and to bring digital health ecosystem to the field and bedside [60]. In the past, digital health application makers might have been able to develop technology they claimed could help users lose weight, sleep better, or improve their muscle tone, and sell it via the App Store or Google Play [61]. But recent changes in the FDA rules have expanded some agencies and organizations portfolio to begin evaluating applications that claim to assist people with health issues; but also address issues related to patient resources, security, privacy, consent, data sharing, information/work flows, buy in digital health and wearable technologies. Noteworthy, digital health isn't just about the integration of digital technology and devices; there is a whole market for apps that help with lifestyle adaptations such as exercise, weight loss, overall fitness, and other health issues as well as physicians, with a more open attitude toward adopting digital technology for their medical practices, with clear suggestions for insurers, healthcare companies, physicians and other stakeholders to explore and develop such technologies to help patients relationship with health professional, planning and forecasting, resources allocation, services and care delivery in most infectious diseases of poverty in Africa (e.g.: malaria, TB, schistosomiasis, polio, filariasis [57]. The adoption and integration of digital technology with existing disease care processes has not yet fulfilled its potential to transform care and value for patients in contrast to aviation, meteorology, geography, intelligence, banking and commercial retail sectors today use these technologies to improve efficiency and performance, quality services and expanded outcomes/benefits. Africa government, their healthcare system and related sectors must either do the same or lose he digitalization opportunity to the stakeholders in the healthcare industry including infectious diseases evidence-based policy and programs priorities, service delivery hospitals, private clinics or home care management, health insurers and the pharmaceutical industry to innovate and revamp the interactions between consumers (patients), providers and payers [61]. This could help caregivers to work more as a team in promoting efficient use of information communication, self-management using health applications in healthcare, wellness, or medical app on their mobile device. This in turn increases patient-clinician interaction and can replace more than 10% of in-office patient visits, to physicians. The impact of e-visits with caregivers online and home or self-use of diagnostic testing of basic conditions into the hands of patients require further investigations [62].

For example in Southern Africa (South Africa, Mozambique, Botswana and DR Congo), the application of mobile digital technology in rural health programmes has been conceptualized and put into practice through improved communication infrastructure in effective malaria and tuberculosis treatment involving patients and healthcare professionals in intensive programmes of medication and close monitoring for patient compliance and outcomes. It was therefore vital that reliable laboratory diagnostic services and care are available during the duration of the treatment. Hence, the problem of transporting clinical samples from the rural clinic to the nearest laboratory and communicating the results back timeously and efficiently as rural areas are most in need of mobile communications technology [50,54,55,58,60,62]. Successes led to extension to laboratory testing for HIV and sexually transmitted infections (STIs) to the whole of Transkei and other parts of South Africa as well as consolidating and improving tuberculosis sputum specimen collection and resulting distribution systems, improving the quality control and assurance of laboratory services and improving the supervision and support of laboratories with significant impact on HIV transmission behavioural changes and ABC compliance [63].

Vectors and disease mapping in providing clues on the incidence and prevalence has long been a part of public health, and disease mapping is useful for health service provision and targeting interventions if avoidable risk factors are known [60,64]. Geographical studies of disease and environmental exposures may in some cases be sufficient by themselves to justify action, for example if the exposure-disease association is specific, the latency is short and the exposure is spatially defined. Typically, disease mapping has two common uses: smoothing away noise to draw maps and assessing specific hypotheses concerning incidence. The earliest example of the disease mapping is the map of the addresses of cholera victims related to the locations of water supplies in 1854 by Snow [50]. The putative pollution sources were assessed on the bases of the street addresses of recorded victims and their proximity to water supply pumps. The representation and analysis of maps of disease incidence data is established as a basic tool in the analysis of regional public health, and the subject of area of disease mapping has developed considerably in recent years [65]. The study of the geographical distribution of the disease can have a variety of uses. The main areas of application can be conveniently broken down into the following classes: disease mapping, disease clustering, and the ecological analysis. In the first class, usually the object of analysis is to provide estimate the true relatively risk of a disease of interest across a geographical study area (map) and the subject is simply to clean the map of disease of the extra noise to uncover the underlying structure. Application for such methods lays in health services resource allocation and disease atlas constructions. For example, Julius mapped and described the spatial patterns of the malaria and diarrhea mortalities in an urbanizing area in to compare the spatial patterns of urban malaria and diarrhea mortalities and to assess the distribution of risk for urban malaria and diarrhea mortalities. For example the school's Malaria Institute in Macha, in national malaria elimination in Zambia use common factors for integrating different environmental correlates of malaria risk, expanded the use of traditional field and laboratory studies linked to the core's environmental GIS database to understand the relationship between measured outcomes, such as the distribution or abundance of a malaria-carrying mosquito species, and numerous environmental features such as climatological modeling of disease vector (mosquito) population dynamics. Data and maps are available for land cover type, land surface temperatures, calibrated radiance, vegetation, air temperature, and precipitation, land cover, meteorological conditions, soil types, and sociological data and reductions in malaria prevalence to national malaria evidence-informed interventions [40]. Similarly, Zhou Xiaonong compiled and published the Chinese Atlas of Schistosomiasis which include China's population density, soil type, the distribution of schistosomiasis, China's schistosomiasis epidemic area, distribution area of oncomelania, and others NTDs [66,67].

Disease clustering has particular importance in public health surveillance and concerns the analysis of unusual aggregation of disease risk factors where it may be important to be able to access whether a disease map is clustered and where the clusters are located. This may lead to examination of potential environmental risks and hazards. A particular special case arises when a known location is thought to be a potential risk or pollution hazard. The analysis of disease incidences around a putative source of hazard is a special case of cluster detection. Zulu used HIV prevalence from point data obtained from surveillance antenatal clinics by extracting surfaces prevalence estimates, and analyzing spatial dependency (autocorrelation) and clustering of HIV prevalence to enhance understanding of local spatiotemporal variation in HIV prevalence, to reveal possible underlying factors and provide potential spatial targeting of interventions [68].

The ecological analysis involves analyzing aggregate data for groups of individuals to make inferences about relationships at the individual level, which is the great relevance within epidemiology research, as its focus is the analysis of the geographical distribution of the disease in relation to the explanatory covariates, usually at an aggregated spatial level [69]. In non-communicable diseases, issues related to disease mapping and incorporation of covariates in statistical procedures have be found in different risk areas should be noted and visual mapping in two classic studies that examined the relation of cardiovascular incidence in the UK to a variety of variables (including water hardness, climate, location, socioeconomic and genetic factors and air pollution) [70], and the respiratory health of school children and volatile of organic compounds in the outdoor atmosphere [71]. Today, ecological analysis has been applied much more fields and to deal with the relations between disease onset and social, environmental influences, such as Patterson tried to investigate if childhood-onset type I diabetes is a wealth-related disease [72]. Newson have the interest in analysis paracetamol sales and atopic disease in children and adults [73]. The need to note in these cases individual data is related to explanatory variables, critically important to provide information on spatial characteristics of the observed morbidity and mortality and mapping the spatial distribution of cluster level fraction of deaths, researches used of geographical or spatial statistical tools in the analysis of data routinely collected for public health purpose (mortality distribution maps, or with ecological studies of disease relating with explanatory variables to draw the risk maps) can led to greater findings which could show the relative risk to be affected by an event [56].

Modeling applications in DPH data is essential in models derivation, very useful in predicting and understanding current and future the vectors and disease trend, distribution pattern and locations and underlying risk factors [74,75]. Often the models include the aspects of null (hypothesis) spatial distribution of the cases, which capture the nature of normal variation which is expected, and aspects of the alternative spatial distribution [76]. There are different models for different types of disease haven been built in the past decades, for example, the classic Ross-MacDonald mathematical models of malaria transmission which have played a central role in development of research on mosquito-borne pathogen transmission and the development of strategies for mosquito-borne disease prevention and control [49,76]. Although a growing acknowledgement of geographical, ecological and epidemiological complexities in modelling transmission, most models during the past 40 years closely resemble the Ross-Macdonald model. Wells-Riley model is specific for air borne disease transmission; Chung-Min Liao quantified the public health risk associated with inhalation of indoor airborne infection based on the Wells-Riley mathematical model to estimate CO_2

exposure concentrations in-indoor environments and analyze the relationships between indoor carbon dioxide concentration and consequence rate [77].

Challenges to in modeling transmission risks are very interesting, for example since the emergence of acute infectious disease such as H7N9 bird flu, Ebola. The classic model can readily be extended to address other diseases by calculating their infection risks in terms of corresponding factors. Jason applied a modified Wells-Riley model to estimate the risk of tuberculosis transmission on 3 modes of public transit (minibus taxis, buses, and trains) in South Africa. Lewnard developed a transmission model of Ebola virus to assess the effectiveness of expanding EVD treatment centres, increasing case ascertainment, and allocating protective kits for controlling the outbreak in Montserrado [78]. Actually, the model is not only used for develop transmission models but also incorporated in other digital application process. For instance, in order to solve the fundamental problem (the local sample sizes within each region required for desired levels of statistical precision are often unavailable or unattainable) to meet the higher requirements of disease mapping, model-based approaches expressed as mixed effects models offer a mechanism to "borrow strength" across small areas to improve local estimates [77-79]. Hierarchical models for disease mapping are evolving and updating which include generalized linear model, Zero-inflated Poisson models, spatiotemporal models, multivariate CAR (MCAR) models. The field of modeling will continually to generate research interest by offering a robust, flexible, and enormously popular class of models. Interdisciplinary work and international collaboration is still needed for the success in developing a model that can be useful worldwide [79].

Harnessing digital public health implementation science in tackling barriers and boosting new opportunities in Africa

Technical and non-technical barriers remain exist in the operational and translational implementation of this new digital paradigm on infectious diseases of poverty, evidence decision making policy, care delivery and utilization at individual, community and national levels [1,38,40]. These include lack of infrastructure, facilities and expert, issues of patient information security, privacy of data and secure access, patient consent, data-sharing, fragmented workflows, medical devices and diagnostic tools quality control and assurance, proving effectiveness and lack adverse conditions proper documentation, challenges in interpretation of health outcomes, and digital buy-in [39-41]. However, are worried about the privacy and security of digital technology and wonder whether increased reliance on handheld tools will compromise the confidentiality of their medical information and personal medical information privacy. Moving forward with digital technology requires that providers must overcome barriers in terms of neither public nor private insurance reimbursement policy, regulation and implementation research.

There needs for policy changes that recognize and favor the new landscape of access and use coverage of digital health information benefits to urban and remote settings health care and service delivery monitoring tools in poverty infectious diseases control and elimination [29,39]. Several reported reasons explained why varied extent and level of health-care delivery and utilization exist in Africa including sociocultural beliefs, behavioural attitudes to health seeking and uses, challenges in the overall national health systems mainly services delivery in remotes rural communities [12,23,30,45,58]. However, major health systems challenges include large disparities in wealth and inequities, lack of basic needs requirements for healthy life such as clean water, adequate nutrition, reasonable housing conditions, limited access to vaccinations and school dropout and widening differences in healthcare delivery. Gaps in most cases are related to weak political will and investment or financial resource allocation commitment, inadequate human resources as well as the need to overcome economic, organizational, and technology disparities across African countries. For example South Africa accounts for the worst global tuberculosis epidemics fuelled by the spread of HIV infection [54]. The incidence of tuberculosis increased from 300 per 100,000 people in the early 1990s to more than 950 per 100,000 in 2012, poor health infrastructures and facilities, weak and lack of investment in health priorities issues, corruption and lack of M&E on existent programs and interventions, and lack of performed-based investment. In addition most rural and urban communities have limited to no or very limited access to clean and potable drinking water and proper sanitation facilities. Therefore, Africa accounts for more than half of the world's maternal and child deaths. What makes situation worse is the uninterrupted conflicts between different tribes or regions disrupt the daily life and damage facilities, hinder prevention of infectious disease, diseases then take an even greater toll [24,80].

Resolving Africa health challenges can be best illustrated by genuine, effective and evidence contextual approaches and tools to meet and mitigate the needs. These include use of digital technologies strategies in diseases surveillance to clearly define the complexity, nature and extend of the disease status, effective monitoring and surveillance networking programs in order to define the most effective interventions. Disease surveillance programs should also be a top priority and there is also a need for the specialized application of digital technologies to become more affordable and readily available in resource-limited developing countries. Thus, the digital technologies can be viewed as a potential tool for a novel approach of science, to promote the public health in terms of disease monitoring, surveillance as well as control policies with overall health care and public health policies to local populations to fight diseases in Africa. Currently, the digital earth technologies is only applied in an limited area, it has not been applied in various disease, and the different components need to integrated to maintain the quality in usage, enhance the power in data management, and improve precision in risk predictions to bring its functionality and effectiveness [2,13].

Promoting digital health new partnership opportunities in attaining the infectious diseases elimination and eradication in Africa

Sub-Saharan Africa still bears the disproportionate burden of infectious disease and faces a major public-health challenge from both rising non-communicable diseases and emerging outbreaks rapid response and containment [1,27,69]. With infectious diseases continue to afflict Africa and other non-communicable disease such as cancer and new-emerging disease (Ebola, Plague) are rising, the overall disease burden in sub-Saharan is continued to be heavy [5,80].

Attaining the SDGs, Africa Union (AU) Agenda, 2063 and Global health diseases control to eliminations agenda will require strong political commitment and investment in the rapid development of computer technology. As GIS/RS technology is becoming increasingly mature and has become the necessary tools for data processing, analysis and visualization. At the same time, the integrated software such as ArcView, GenaMap, MapInfo, the updated digital tools such as social media platform and smart mobile phone, communications and exchanges as well as Google Earth provide new approaches for disease information for all, awareness and literacy in control and prevention measures. For example, P Gong reported the mobile phones were essential for preventing outbreaks of infectious diseases after the Sichuan earthquake in China when existing public health communication system was severely earthquake damages [67]. Google Earth is a virtual globe, map and geographical information program with the distinctive function in viewing geographical features online, and it is applicable for second development when needed. These technologies have become new methods for the scholars of clinical medicine and public health field, much needed in Africa [81].

Previous implementation research studies have shown time and again that strategic and prioritizing approaches to disease elimination and eradication in sub-Saharan Africa is needed to build on what works there and what is unique to the region [1,3,7,8,15,27,30,79,80]. The digital earth technology is efficient in collecting and presenting data and disease incidences, which help to formulate corrective and preventive approaches immediately for disease prevention and control. However, to achieve this will need new technologies, investment, and resource integration [9,80].

Substantial progress has been made in some African countries in digital technology poised to alter how infectious diseases control and pre-elimination stages, in understanding the quality of the environment and related risk factors to vectors dynamics, disease transmission to patient healthcare, and cost of service delivery in reducing the loss of life and preventable morbidity from early childhood to elderly ages [1,4,7,42,67,78,81]. New partnerships geospatial applications in health are being forged under the general umbrella of "One Health" involving human health, animal health, and environmental health exponents where solutions are sought for how to prevent as well as respond to new threats and in improving health outcomes and medical system efficiency [39,42,67]. More research and knowledge are needed on the strategic transmission dynamics of vectors and host-pathogen interactions mapping and predictions at local, regional and inter-regional level, particularly the measurable progress in risk prevention and mitigation provided by new digital technologies focusing research on the drivers for emergence [82-84]. Simulation and modeling risks factors of diseases and targeted interventions impact could considerably enhance our ability to prevent and respond disease, and that we genuinely work under the "one health surveillance and response" concept that rely on actionable digital interventions, personalized care quality and prediction [85-88]. Hence, generating actionable digital health tools to yield better health and medical outcomes to both population and healthcare providers require strategic planning, preparedness and response [89,90], and evidence actions focusing on infectious and chronic diseases prevention, effective sustained control to elimination programs and interventions [91-94].

Research priorities in digital public health technology implementation in Africa

Digital public health medicine or e-health-medicine: Can Digital medicine or public health applications make or support healthy Africa free of infectious diseases agenda?

The urging digital healthcare technology access and community of practice in advancing "*healthy Africa free of infectious diseases"* requires greater political commitment and investment toward preventative measures and effective caring by placing technology that is accessible to patients and medical providers at home and hospital settings. Mapping can help to solve both policy and research needs. It can also help health care to go through infectious diseases public health services delivery paradigm shift: to focus more on population and community health education and promotion, risk mitigation, preparedness and vigilance, diseases and illness prevention and control. This can be achieved through better management, early identification, and public alerting as to environmental risks (determinants of health) and population vulnerabilities. Epidemiologists should play a greater role in deciding requirements for visualization of public health science and methodologies synergism for evidence-based solutions and contextual adaptation to public-private pubic engagement of actionable healthcare system and cost effective delivery. Big data sharing, GIS/RS mapping and modeling tools could be used to explore novel epidemiology and public health concepts, to analyze population health parameters, access disease information in a timely manner, establish understanding on how to work with spatial data and use these digital techniques to solve epidemiology and public health problems, develop healthcare policy initiatives and priorities, proactive and coordinated medical response measures and monitor risk factors and determinants of infectious diseases threats. Notably, effective monitoring, consolidation and adherence to standards and best practices, is needed to ascertain the effectiveness of intervention strategies for both infectious and rising chronic diseases. But also, in improving healthcare services access and uptake, and responding to health emergencies events in a timely manner based on national digital health information systems support on public health decision-making and consolidated partnerships.

Digital public health technology applications could be very useful in understanding and mapping major models of environmental health decisions, health data maps, mapping of health service providers, population growth, disease cluster identification, geographic access to health-care, and geographic epidemiology, climate impact; vectors and pesticide control, pollution, waste management and wildlife management. Whereas research into innovative “3S” (GPS/GIS/RS) in health and medicine should be striving to resolve knowledge and application gaps such as inconsistent in their applications to and maintenance of regional needs in health-care planning. The need to leverage on digital surveillance and monitoring response on current infectious diseases approaches and interventions in improving early warning alert, documentation of effective surveillance indicators for timely preparedness and response in prevention and control. Its usefulness in major infectious diseases such as malaria, schistosomiasis, filariasis, polio and influenza as well as recent West Africa Ebola outbreak has been demonstrated. Mainly, in tracking and care expansion such as home management in malaria, dual patient-practitioners information communication when appropriate and also provide targeted digital interventions in public health systems for where they make the most sense, while figuring out how and where digital technology may replace or augment traditional visits based on a patient’s medical conditions. In such as implementation health care reimbursement cycle or insurance scheme, it is certainly able to improve the service delivery and outcomes, monitoring diseases in enabling faster Africa public health decision-making along with a viable, sustainable green environmental and economic development paradigm shift.

Competing Interest

The authors declared that they have no competing interests.

Authors’ Contributions

ET, SX, XYF and XNZ conceived the study and provided technical support for data collection and analysis. ET and XNZ collected the data, analyzed and interpreted it, and drafted the manuscript. ET and XNZ performed extensive revisions on the manuscript. All authors read and approved the final manuscript.

Acknowledgements

We extend our sincere thanks to support of all staff at National Institute of Parasitic Diseases, China CDC, based in Shanghai, and Fourth Roundtable on China-Africa Health Cooperation teams for their tirelessly contributions. ET is a recipient of the M S&T Equipment for career development grant Award, China, 2013. The project was supported by China UK Global Health Support Programme (grant no.GHSP-CS- OP3).

References

1. Ernest Tambo, Chidiebere E Ugwu, Yayi Guan, Ding Wei, Xiao-Ning, et al. (2016) China-Africa health development initiatives: Benefits and implications for shaping innovative and evidence-informed national health policies and programs in Sub-Saharan African Countries. Int J MCH AIDS 5: 119-133.
2. Murray CJL, Lopez AD (2013) Measuring the global burden of disease. N Engl J Med 369: 448-457.
3. Zacharia Mtema, Joel Changalucha, Sarah Cleaveland, Martin Elias, Heather M. Ferguson, et al. (2016) Mobile Phones as Surveillance Tools: Implementing and Evaluating a Large-Scale Intersectoral Surveillance System for Rabies in Tanzania. PLoS Med 13: e1002002.
4. Ukwaja KN, Alobu I, Abimbola S, Hopewell PC (2013) Household catastrophic payments for tuberculosis care in Nigeria: Incidence, determinants, and policy implications for universal health coverage. Infect Dis Poverty 2: 21.
5. Nsubuga P (2014) The Ebola outbreak in West Africa: A story of related public health challenges and a pointer to solutions to mitigate the inevitable next outbreak. Pan Afr Med J 19: 48.
6. Ernest Tambo, Shenglan Tang, Lin Ai, Xiao-Nong Zhou (2017) The value of China-Africa health development initiatives in strengthening “One Health” strategy. Global Health Journal 1: 33-48.
7. Wiwanitkit V, Tambo E, Ugwu EC, Ngogang JY, Zhou XN (2015) Are surveillance response systems enough to effectively combat and contain the Ebola outbreak? Infect Dis Poverty 4: 7.
8. Omoleke SA (2013) Chronic non-communicable disease as a new epidemic in Africa: Focus on The Gambia. Pan Afr Med J 14: 87.
9. Mboera LEG, Mfinanga SG, Karimuribo ED, Rumisha SF, Sindato C (2014) The changing landscape of public health in sub-Saharan Africa: Control and prevention of communicable diseases needs rethinking. Onderstepoort J Vet Res 81: E1-E6.

10. Tambo E, Adedeji AA, Huang F, Chen JH, Zhou SS, et al. (2012) Scaling up impact of malaria control programmes: A tale of events in Sub-Saharan Africa and People's Republic of China. Infect Dis Poverty 1: 7.

11. Ansa GA, Walley JD, Siddiqi K, Wei X (2012) Assessing the impact of TB/HIV services integration on TB treatment outcomes and their relevance in TB/HIV monitoring in Ghana. Infect Dis Poverty 1: 13.

12. Idoko OT, Kochhar S, Agbenyega TE, Ogutu B, Ota MO (2013) Impact, challenges, and future projections of vaccine trials in Africa. Am J Trop Med Hyg 88: 414-419.

13. NASPHV (2007) Compendium of measures to prevent disease associated with animals in public settings, 2007: National Association of State Public Health Veterinarians, Inc. (NASPHV). MMWR Recommendations and Reports 56: 1-13.

14. Hennessy CH, Buchner DM, Jordan JM, Leveille SG, Shefer AM, et al. (2001) The Public Health Perspective in Health Promotion and Disability Prevention for Older Adults: The Role of the Centers for Disease Control and Prevention. J Rural Health 17: 364-369.

15. Liu J, Liu X, Gao L, Wei Y, Meng F, et al. (2011) Application of digital earth technology in research of traditional Chinese medicine resources. Zhongguo Zhong Yao Za Zhi 36: 243-246.

16. Siedner MJ, Lankowski A, Tsai AC, Muzoora C, Martin JN, et al. (2013) GPS-measured distance to clinic, but not self-reported transportation factors, are associated with missed HIV clinic visits in rural Uganda. Aids 27: 1503-1508.

17. Dwolatzky B, Trengove E, Struthers H, McIntyre JA, Martinson NA (2006) Linking the global positioning system (GPS) to a personal digital assistant (PDA) to support tuberculosis control in South Africa: A pilot study. Int J Health Geogr 5: 34.

18. Schur N, Vounatsou P, Utzinger J (2012) Determining treatment needs at different spatial scales using geostatistical model-based risk estimates of schistosomiasis. PLoS Negl Trop Dis 6: e1773.

19. Clements ACA, Garba A, Sacko M, Touré S, Dembelé R, et al. (2008) Mapping the Probability of Schistosomiasis and Associated Uncertainty, West Africa. Emerg Infect Dis 14: 1629-1632.

20. Tefferi A, Vardiman JW (2008) Classification and diagnosis of myeloproliferative neoplasms: The 2008 World Health Organization criteria and point-of-care diagnostic algorithms. Leukemia 22: 14-22.

21. Ratmanov P, Mediannikov O, Raoult D (2013) Vectorborne diseases in West Africa: Geographic distribution and geospatial characteristics. Trans R Soc Trop Med Hyg 107: 273-284.

22. Karagiannis-Voules DA, Biedermann P, Ekpo UF, Garba A, Langer E, et al. (2015) Spatial and temporal distribution of soil-transmitted helminth infection in sub-Saharan Africa: A systematic review and geostatistical meta-analysis. Lancet Infect Dis 15: 74-84.

23. Benatar S, Brock G (2011) Global health and global health ethics. Cambridge University Press, United Kingdom.

24. Feasey N, Wansbrough-Jones M, Mabey DC, Solomon AW (2010) Neglected tropical diseases. British Medical Bulletin 93: 179-200.

25. Suthar AB, Lawn SD, del Amo J, Getahun H, Dye C, et al. (2012) Antiretroviral therapy for prevention of tuberculosis in adults with HIV: A systematic review and meta-analysis. PLoS Med 9: e1001270.

26. Beaglehole R, Epping-Jordan J, Patel V, Chopra M, Ebrahim S, et al. (2008) Improving the prevention and management of chronic disease in low-income and middle-income countries: A priority for primary health care. Lancet 372: 940-949.

27. Marquez PV, Farrington JL (2013) The challenge of non-communicable diseases and road traffic injuries in sub-Saharan Africa: An overview.

28. Smil V (2008) Global catastrophes and trends: The next 50 years. Mit Press, United States.

29. Nsoesie EO, Kluberg SA, Mekaru SR, Majumder MS, Khan K, et al. (2015) New digital technologies for the surveillance of infectious diseases at mass gathering events. Clin Microbiol Infect 21: 134-140.

30. Mwabukusi M, Karimuribo ED, Rweyemamu MM, Beda E (2014) Mobile technologies for disease surveillance in humans and animals. Onderstepoort J Vet Res 81: E1-E5.

31. Mathers C, Fat DM, Boerma JT (2008) The global burden of disease: 2004 update. World Health Organization.

32. Mukanga D, Tshimanga M, Wurapa F, Binka F, Serwada D, et al. (2011) The genesis and evolution of the African Field Epidemiology Network. Pan Afr Med J 10: 2.

33. Travis P, Bennett S, Haines A, Pang T, Bhutta Z, et al. (2004) Overcoming health-systems constraints to achieve the Millennium Development Goals. Lancet 364: 900-906.

34. Murray CJ, Ortblad KF, Guinovart C, Lim SS, Wolock TM, et al. (2014) Global, regional, and national incidence and mortality for HIV, tuberculosis, and malaria during 1990-2013: A systematic analysis for the Global Burden of Disease Study 2013. Lancet 384: 1005-1070.

35. Halstead SB (1966) Mosquito-borne haemorrhagic fevers of South and South-East Asia. Bulletin of the World Health Organization 35: 3-15.

36. Gubler DJ (1998) Resurgent vector-borne diseases as a global health problem. Emerg Infect Dis 4: 442-450.

37. Deribe K, Meribo K, Gebre T, Hailu A, Ali A, et al. (2012) The burden of neglected tropical diseases in Ethiopia, and opportunities for integrated control and elimination. Parasit Vectors 5: 240.

38. Walsh JA, Warren KS (1979) Selective primary health care: An interim strategy for disease control in developing countries. N Engl J Med 301: 967-974.

39. Rweyemamu M, Kambarage D, Karimuribo E, Wambura P, Matee M, et al. (2013) Development of a One Health National Capacity in Africa: The Southern African Centre for Infectious Disease Surveillance (SACIDS) One Health Virtual Centre Model. Curr Top Microbiol Immunol 366: 73-91.

40. WHO (2011) mHealth: New horizons for health through mobile technologies. Social Indicators Research 64: 471-493.

41. Kvedar J, Coye MJ, Everett W (2014) Connected health: A review of technologies and strategies to improve patient care with telemedicine and telehealth. Health Affairs 33: 194-199.

42. Karimuribo ED, Sayalel K, Beda E, Short N, Wambura P, et al. (2012) Towards one health disease surveillance: The Southern African centre for infectious disease surveillance approach. Onderstepoort J Vet Res 79: 454.

43. Badr EE (2007) Establishing an observatory on human resources for health in Sudan. A report for the World Health Organization (WHO) and the Federal Ministry of Health (FMOH).

44. Simarro PP, Cecchi G, Paone M, Franco JR, Diarra A, et al. (2010) The Atlas of human African trypanosomiasis: A contribution to global mapping of neglected tropical diseases. Int J Health Geogr 9: 57.

45. Wanyua S, Ndemwa M, Goto K, Tanaka J, K'Opiyo J, et al. (2013) Profile: the Mbita health and demographic surveillance system. Int J Epidemiol 42: 1678-1685.

46. Baatjies R, Meijster T, Lopata A, Sander I, Raulf-Heimsoth M, et al. (2010) Exposure to flour dust in South African supermarket bakeries: Modeling of baseline measurements of an intervention study. Ann Occup Hyg 54: 309-318.

47. Witt CJ, Richards AL, Masuoka PM, Foley DH, Buczak AL, et al. (2011) The AFHSC-Division of GEIS Operations Predictive Surveillance Program: A multidisciplinary approach for the early detection and response to disease outbreaks. BMC Public Health 11: S10.

48. Thomson MC, Elnaiem DA, Ashford RW, Connor SJ (1999) Towards a kala azar risk map for Sudan: Mapping the potential distribution of Phlebotomus orientalis using digital data of environmental variables. Trop Med Int Health 4: 105-113.

49. Conley AK, Fuller DO, Haddad N, Hassan AN, Gad AM, et al. (2014) Modeling the distribution of the West Nile and Rift Valley Fever vector Culex pipiens in arid and semi-arid regions of the Middle East and North Africa. Parasit Vectors 7: 289.

50. Lawson A, Biggeri A, Böhning D, Lesaffre E, Viel J-F, et al. (1999) Disease mapping and risk assessment for public health. John Wiley and Sons, United States.

51. Abellana R, Ascaso C, Aponte J, Saute F, Nhalungo D, et al. (2008) Spatio-seasonal modeling of the incidence rate of malaria in Mozambique. Malar J 7: 228.

52. Bailey PE, Keyes EB, Parker C, Abdullah M, Kebede H, et al. (2011) Using a GIS to model interventions to strengthen the emergency referral system for maternal and newborn health in Ethiopia. Int J Gynaecol Obstet 115: 300-309.

53. Mohamed NS, Nofal LM, Hassan MH, Elkaffas SM (2004) Geographic information systems (GIS) analysis of under-five mortality in Alexandria. J Egypt Public Health Assoc 79: 243-262.

54. Kaboru BB, Ogwang BA, Namegabe EN, Mbasa N, Kabunga DK, et al. (2013) TB/HIV Co-Infection Care in Conflict-Affected Settings: A Mapping of Health Facilities in the Goma Area, Democratic Republic of Congo. Int J Health Policy Manag 1: 207-211.

55. Martin NK, Devine A, Eaton JW, Miners A, Hallett TB, et al. (2014) Modeling the impact of early antiretroviral therapy for adults coinfected with HIV and hepatitis B or C in South Africa. Aids 28: S35-S46.

56. Pigott DM, Golding N, Mylne A, Huang Z, Weiss DJ, et al. (2015) Mapping the zoonotic niche of Marburg virus disease in Africa. Trans R Soc Trop Med Hyg 109: 366-378.

57. Chabot Couture G, Seaman VY, Wenger J, Moonen B, Magill A (2015) Advancing digital methods in the fight against communicable diseases. Int Health 7: 79-81.

58. Krishnamurthy R, Frolov A, Wolkon A, Vanden Eng J, Hightower A (2006) Application of pre-programmed PDA devices equipped with global GPS to conduct paperless household surveys in rural Mozambique. AMIA Annu Symp Proc, 991.

59. Dambach P, Sie A, Lacaux JP, Vignolles C, Machault V, et al. (2009) Using high spatial resolution remote sensing for risk mapping of malaria occurrence in the Nouna district, Burkina Faso. Glob Health Action 2.

60. Tatem AJ, Huang Z, Narib C, Kumar U, Kandula D, et al. (2014) Integrating rapid risk mapping and mobile phone call record data for strategic malaria elimination planning. Malar J 13: 52.

61. Pu R, Kelly M, Anderson Gerald L, Gong Peng (2008) Using CASI Hyperspectral Imagery to Detect Mortality and Vegetation Stress Associated with a New Hardwood Forest Disease. Photogrammetric Engineering & Remote Sensing 74: 65-75.

62. Black AD, Car J, Pagliari C, Anandan C, Cresswell K, et al. (2011) The impact of eHealth on the quality and safety of health care: A systematic overview. PLoS Med 8: 188.

63. Zungu-Dirwayi N, Olive Shisana, Eric Udjo, Thabang Mosala, John Seager (2004) An Audit of HIV/AIDS Policies in Botswana, Lesotho, Mozambique, South Africa, Swaziland and Zimbabwe. HSRC Press.

64. Tchuem Tchuente LA, Dongmo Noumedem C, Ngassam P, Kenfack CM, Gipwe NF, et al. (2013) Mapping of schistosomiasis and soil-transmitted helminthiasis in the regions of Littoral, North-West, South and South-West Cameroon and recommendations for treatment. BMC Infect Dis 13: 602.

65. Simarro PP, Cecchi G, Franco JR, Paone M, Diarra A, et al. (2014) Mapping the capacities of fixed health facilities to cover people at risk of gambiense human African trypanosomiasis. Int J Health Geogr 13: 4.

66. Lai YS, Zhou XN, Utzinger J, Vounatsou P (2013) Bayesian geostatistical modelling of soil-transmitted helminth survey data in the People's Republic of China. Parasit Vectors 6: 359.

67. Gong P, Xu B, Liang S (2006) Remote sensing and geographic information systems in the spatial temporal dynamics modeling of infectious diseases. Science in China Series C: Life Sciences 49: 573-582.

68. Zulu LC, Kalipeni E, Johannes E (2014) Analyzing spatial clustering and the spatiotemporal nature and trends of HIV/AIDS prevalence using GIS: The case of Malawi, 1994-2010. BMC Infectious Disease 14: 285.

69. Pigott DM, Golding N, Mylne A, Huang Z, Henry AJ, et al. (2014) Mapping the zoonotic niche of Ebola virus disease in Africa. Elife 3: e04395.

70. Pocock S, Shaper A, Cook D, Packham R, Lacey R, et al. (1980) British Regional Heart Study: geographic variations in cardiovascular mortality, and the role of water quality. Br Med J 280: 1243-1249.

71. Black WC, Gorrochetegui-Escalante N, Randle NP, Donnelly MJ (2008) The Yin and Yang of linkage disequilibrium: mapping of genes and nucleotides conferring insecticide resistance in insect disease vectors. Adv Exp Med Biol 627: 71-83.

72. Patterson C, Dahlquist G, Soltesz G, Green A, EURODIAB ACE Study Group. Europe and Diabetes (2001) Is childhood-onset type I diabetes a wealth-related disease? An ecological analysis of European incidence rates. Diabetologia 44: 9-16.

73. Allmers H, Skudlik C, John SM (2009) Acetaminophen use: A risk for asthma? Curr Allergy Asthma Rep 9: 164-167.

74. Bente D, Gren J, Strong JE, Feldmann H (2009) Disease modeling for Ebola and Marburg viruses. Dis Model Mech 2: 12-17.

75. Ruiz-Moreno D, Vargas IS, Olson KE, Harrington LC (2012) Modeling dynamic introduction of Chikungunya virus in the United States. PLoS Negl Trop Dis 6: e1918.

76. Parham PE, Pople D, Christiansen-Jucht C, Lindsay S, Hinsley W, et al. (2012) Modeling the role of environmental variables on the population dynamics of the malaria vector Anopheles gambiae sensu stricto. Malaria Journal 11: 271.

77. Liao CM, Chang CF, Liang HM (2005) A probabilistic transmission dynamic model to assess indoor airborne infection risks. Risk Anal 25: 1097-1107.

78. Lewnard JA, Mbah MLN, Alfaro-Murillo JA, Altice FL, Bawo L, et al. (2014) Dynamics and control of Ebola virus transmission in Montserrado, Liberia: A mathematical modelling analysis. Lancet Infect Dis 14: 1189-1195.

79. Andrews JR, Morrow C, Wood R (2013) Modeling the role of public transportation in sustaining tuberculosis transmission in South Africa. Am J Epidemiol 177: 556-561.

80. Michaud CM, Murray CJ, Bloom BR (2001) Burden of disease--implications for future research. JAMA 285: 535-539.

81. Yu L, Gong P (2012) Google Earth as a virtual globe tool for Earth science applications at the global scale: progress and perspectives. International Journal of Remote Sensing 33: 3966-3986.

82. Bergquist R, Whittaker M (2012) Control of neglected tropical diseases in Asia Pacific: Implications for health information priorities. Infect Dis Poverty 1: 3.

83. Nguyen-Viet H, Doria S, Tung DX, Mallee H, Wilcox BA, et al. (2015) Ecohealth research in Southeast Asia: past, present and the way forward. Infect Dis Poverty 4: 5.

84. Tambo E, Xiao-Nong Z (2014) Acquired immunity and asymptomatic reservoir impact on frontline and airport ebola outbreak syndromic surveillance and response. Infect Dis Poverty 3: 41.

85. Zhou XN (2012) Prioritizing research for "One health - One world". Infect Dis Poverty 1: 1.

86. Zhou XN, Bergquist R, Tanner M (2013) Elimination of tropical disease through surveillance and response. Infectious Diseases of Poverty 2: 1.

87. Fung IC, Fu KW, Ying Y, Schaible B, Hao Y, et al. (2013) Chinese social media reaction to the MERS-CoV and avian influenza A(H7N9) outbreaks. Infect Dis Poverty 2: 31.

88. Ackumey MM, Gyapong M, Pappoe M, Maclean CK, Weiss MG (2012) Socio-cultural determinants of timely and delayed treatment of Buruli ulcer: Implications for disease control. Infect Dis Poverty 1: 6.

89. Kliner M, Knight A, Mamvura C, Wright J, Walley J (2013) Using no-cost mobile phone reminders to improve attendance for HIV test results: A pilot study in rural Swaziland. Infect Dis Poverty 2: 12.

90. Salam RA, Haroon S, Ahmed HH, Das JK, Bhutta ZA (2014) Impact of community-based interventions on HIV knowledge, attitudes, and transmission. Infect Dis Poverty 3: 26.

91. Tambo E, Ugwu EC, Ngogang JY (2014) Need of surveillance response systems to combat Ebola outbreaks and other emerging infectious diseases in African countries. Infect Dis Poverty 3: 29.

92. Bhutta ZA, Sommerfeld J, Lassi ZS, Salam RA, Das JK (2014) Global burden, distribution, and interventions for infectious diseases of poverty. Infect Dis Poverty 3: 21.

93. Tambo Ernest, Ghislaine Madjou, Yves Mbous, Oluwasogo A Olalubi, Clarence Yah, et al. (2016) Digital health implications in health systems in Africa. European Journal of Pharmaceutical and Medical Research 3: 91-93.

94. Ernest Tambo, Thomas A Anyorigiya, Alice Matimba, Ahmed A Adedeji, Jeanne Yonkeu Ngogang (2016) Digital pharmacy and pharmacovigilance ecosystem in Africa: Perceptions and opportunities. Eur J of Pharmaceutical and Medical Research 3: 84-90.