COHEN

CITIZEN OBSERVATORIES FOR HEALTH AND ENVIRONMENT

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List of participants

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2 IKT	SENECT/IKT Technology - Geißler & Mäck GbR **(SME)**	Germany
3 UKL-HD	UniversitätsKlinikum Heidelberg	Germany
4 DLR	Deutsches Zentrum für Luft- und Raumfahrt	Germany
5 DIEHL	DIEHL Defence (Logistics Optimisation)	Germany
6 STU	Stockholms Universitet	Sweden
7 EASP	Escuela Andaluza de Salud Pública	Spain
8 UES	Universidad de El Salvador	El Salvador
9 MSPAS	Ministerio de Salud Pública y Asistencia Social	El Salvador
10 USIU	United States International University	Kenya
11 CSIR	Council for Scientific and Industrial Research	South Africa

1. Excellence

Health problems are an increasingly important issue, especially in developing countries. Therefore, we suggest here to use citizens' own digital devices to communicate environmental and human risk factors and risk mitigation strategies in the context of environmental and human health. Within a Citizen Observatory, citizens observe environmental conditions, receive a short-term (immediate) benefit and the Citizen Observatory itself creates a long term positive impact on human health.

With a *simple, everyday usable open source application for mobile devices*, we will enable the communication of risk[1]-incidents and the access to risk minimising resources[2]. In the context of *Citizen Observatories* (CiObs), the citizens can report *resources and risks* with this app. This app shall be used in the context of *health, agriculture and environment* in the pilot regions El Salvador, Kenya and Ghana where one major problem are chronic diseases which show their symptoms only in the long run. We focus on three different pilot regions to be able to derive a *generative concept* that can be applied to other regions facing similar problems and thus benefit from synergy-effects.

The proposed in-situ observatory uses *citizens' own devices* as a s*patial decision support client* for e.g. low-cost precision agriculture and for the optimisation of health service delivery. In the three pilot regions, different decision support is required due to different local conditions. Together with a geographic information system (GIS)[3] merging environmental, agricultural, human health data as well as satellite based information, the *citizens' own devices* are used to *strengthen environmental monitoring capabilities* for e.g. the application of agrochemicals. The *crowd sourcing*[4] *approach* has the potential to support spatial decisions on activities in environmental analytics due to events reported to GISs.
Focusing on the example of El Salvador and the agriculture, *low-cost applications* via digital devices allow e.g. the reduction of agrochemicals due to crop health observations. The in-situ observations and monitoring of the citizens will create an *economic benefit* for tailored application of agrochemicals. Furthermore, the proposed solution creates an *environmental benefit* due to reduction of agrochemicals used and an expected *long-term benefit for the environmental and human health*, i.e. less chronic kidney disease (CKD) in El Salvador. Nevertheless, the primary driver for citizens participating in the observation activities is the *short term benefit* of an efficient use of agrochemicals by preserving the same harvest yield.

The involved novel partnerships between e.g. the agro-technical, environmental and health science-related development and *small and medium enterprises* (SMEs) in the private sector are mandatory to develop regional accepted spatial decision support services that analyse the reported crop health and application data and return tailored recommendations for agrochemicals.
The decision support client, however, creates *running costs for the spatial analysis* of e.g. crop health. The app itself will be *open source* and thus available free of charge. The decision support data, which is required in developing countries or in locations, *where human health is at risk, is freely available*. *For other users, we will make such decision support data available for a fee*, e.g. decision support data for wine growing in Germany. Such decision support data could be information on an optimised way of spraying pesticides, which would be used by the wine grower to save costs and to increase sales.

1 In the context of the present project, *risk* is understood as a quality that reflects both the range of possible outcomes and the distribution of respective probabilities for each of the outcomes. This can be expressed as: risk is equal to hazard (probability of occurrence of a dangerous event) times vulnerability (the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard, (cf. http://www.unisdr.org/we/inform/terminology).

2 In the present project, a *resource* is understood as something that can be used for support or help, an available supply that can be drawn on when needed, (AHD, 2009).

3 A *GIS* is a tool for planning development and environmental control, as well as an instrument for decision support. On the one hand, it consists of a geo-referenced database, while on the other it comprises techniques for data acquisition, actualisation, processing and visualisation of the results. The semantic data are geometrically related to a homogeneous geo-referenced coordinate system, allowing for the controlled interrelation of the information. (Bähr & Vögtle, 1999, p.1).

4 *Crowd sourcing* denotes the broadcasting of problems to the public, and an open call for contributions to solving a problem. Members of the public submit solutions which are then owned by the entity which broadcast the problem, (cf. Howe, 2006).

Consequently, the decision support client for mobile devices is an *open source* tool with communication and crowd sourcing features to create a large number of users by utilising existing mail servers as back-end for the IT infrastructure. The commercialisation via *SMEs* is designed as spatial decision support service. The service costs are covered by the citizens who commercially benefit due to reduced application of pesticides, and optimised farming respectively.
The spatial decision support of events and its communication needs an application of software on an *everyday basis*. Therefore, we selected an enhanced communication tool with decision support features to leverage the benefit of emerging spatial technologies, data and information sharing for crop monitoring and food security and an increased environmental and health impact. To address future cellphone generations, we will develop this app for cheap smartphones.
Nevertheless, within the project the proposed solution must address the *"last mile[5] problem"* in rural areas in El Salvador, Kenya and Ghana, facing two main handicaps in these regions:

1. mostly older cellphones or feature phones are used instead of smartphones, and
2. there is a lack of cell coverage.

Solutions for the last mile problem are essential to reach as many potential users as possible and to have an impact on optimising the health situation.

1.1 Objectives

Overall Objective:

Citizens can observe and report environmental and human risk factors with a simple, everyday usable open source app for the user's own devices.
The communication of risk-incidents and the access to risk minimising resources will be enabled to optimise the health-situation in the context of a CiOb. With the developed method, a *short-term benefit* shall be created, which has a *long-term positive impact on health*.
The citizens' own digital devices serve to communicate risk mitigation strategies to citizens in risk situations. The proposed in-situ observatory uses *citizens' own devices* for performing observations and to communicate risk mitigation strategies to citizens in risk situations in the manner of a *spatial decision support client* for e.g. low-cost precision agriculture and for the optimisation of health service delivery.

Objectives:

- Building up the *sustainable infrastructure of CiObs* by means of implementing *Living Labs (LLs)* in the pilot regions *El Salvador*, *Ghana* and *Kenya*.
- Development of a simple, *everyday usable open source app* for mobile devices that enables the communication of rare risk-incidents and the access to resources for risk mitigation in the *agricultural and the health context* serving as a *spatial decision support client.*
- Development of a suitable (generative) *decision support* and *risk mitigation strategies* for the three different pilot regions.
- Finding solutions to bridge the *last mile problem* to reach as many potential users as possible to enlarge the effect on the health situation.
- Identifying a deliverable *short-term benefit* to improve user engagement.
- *Founding new SMEs* that cover the scope of regional decision support and build a *network of EU and non-EU SMEs* providing and adjusting continuously the services to the user requirements, even after the end of the project.
- Evaluation of the developed method and provide a *proof of concept*.

1.2 Relation to the Work Programme

We will develop an *innovative technology* for supporting health risk mitigation. With the developed method, a

5 The phrase *'last mile'* is used in the telecommunications and technology industries to describe the technologies and processes used to connect the end customer to a communications network. A last mile problem exists, if the end link between consumers and connectivity has proved to be disproportionately expensive to solve, cf. http://www.investopedia.com/terms/l/lastmile.asp).

short-term benefit is created, which has a long-term positive impact on health. In the context of CiObs, access to risk minimising resources and risk-incidents can be reported with an everyday usable open source app for *citizens' own devices* (e.g. mobile devices) by the citizens. This app shall be used in the context of health and environment (agriculture).
Before the software development starts, we will perform a software analysis keeping an eye on *emerging* open source *technologies* that could be implemented and further developed for the planned app. In this way, the development costs of SMEs are lowered by building on existing open source modules.

The proposed in-situ observatory uses citizens' own mobile devices as a spatial decision support client for e.g. low-cost precision agriculture or for the optimisation of health service delivery. Together with a GIS merging environmental, agricultural, human health data as well as satellite based information, the mobile devices are used to *strengthen environmental monitoring capabilities* for e.g. the application of agrochemicals. In conclusion, the citizens observe, report and receive decision support within the CiOb.

In the present project, *data and information sharing* is a very important aspect, as the Open Community Approach (cf. http://at6fui.weebly.com/open-community-approach.html) is pursued. Therefore, we will make the developed application available as open source software and use the open content of e.g. OSM, the Copernicus Land Monitoring Service or GEOSS.

We will ensure the *effective transfer of environmental knowledge for policy, industrial, research and societal use, with a focus on the domain of land cover/land use, both in rural and urban areas* by implementing an everyday usable open source app for citizens' own devices and solutions for bridging the last mile, where the transferred environmental knowledge is tailored to the user´s needs and supporting the generation of risk awareness via risk literacy. The app is a communicator with a familiar, easily comprehensible user interface, to support frequent use. The open source app is first of all a free communicator to facilitate large numbers of users by using existing information technology (IT) infrastructure of mail-servers for message exchange.

By evaluating and optimising the work flow in the LLs, the *system proposed for CiObs is scaled up, demonstrated, deployed, tested in its entirety and validated in real-life conditions*.
Novel partnerships between the private sector, public bodies, NGOs and citizens are assured by implementing LLs. The concept of a LL is based on *strong involvement of citizens and citizens' associations together with the industrial sector* (e.g. SMEs). SMEs which offer regional decision support for CiObs do not exist yet. Therefore, a Master Plus Programme at the *Uni KO-LD* is initiated to combine the competences for this service with a customised education program. Together with the Business Startup Office of the University (http://www.uni-koblenz-landau.de/de/kompetenzzentrum/kooperationsangebote/assoziationspartner-innen/gruendungsbuero), persons will be educated that will be able to found an SME with the required profile. Consequently, the development of SMEs for the compiled project tasks will be supported. The citizens in the CiOb receive a commercial benefit via the application of the spatial decision support provided by the app developed in this project. SMEs will provide the commercial spatial decision support services after the end of the present project.

1.3 Concept and Approach

1.3.1 Overall Concept

The key aspect of *CiObs* is the direct involvement of local citizens, and not only of scientists and other professionals. Harnessing the citizens' collective intelligence, e.g. of distributed information, experience and knowledge embodied within individuals and communities can fill the gaps that many areas of environmental management are still suffering from. Namely, CiObs should enable citizens' participation in environmental monitoring, and contribute to environmental governance by providing relevant data and information that can help improving decision-making processes. Citizens' participation is advanced by providing them with a voice and supporting them with knowledge on their environment and as a consequence of raising their awareness (Liu et al. 2014).
In this context, the concept of *LLs* is a sustainable approach to apply the concept of CiObs. By this means, risk in the health and agricultural sector is minimised and benefits and reach of community-based interventions for diseases through integration with other agricultural, health and development sectors are maximised.
An LL attempts to design successful problem solutions by including local people into the decision-making

processes. Building a *sustainable* infrastructure for the operation of a LL can contribute to problem solving for a variety of scientific questions. The underlying idea of a LL is that the ideas, experiences and knowledge of the people, as well as their daily needs with respect to the support by products, services or applications, should be the starting point of innovation (cf. Cunningham et al. 2011). Stakeholders, like researchers, health care workers, agricultural workers, teachers or members of the industry, offer their services in the field of possible *risk mitigation* to the community members. The community members can select, which risk mitigation strategy is usable for them. Therefore, the risk mitigation strategies are *user driven innovations*. In the course of this, the individual parties of a LL pursue a common goal. *Low-cost* methods ensure that as many people as possible can participate in a successful problem-solution, particularly in developing countries. In the present case, the LL serves, among others, to explore low-cost techniques to reduce health-risks of the local population and to monitor the community-needs concerning the health situation. Consequently, the aim is to optimise public health.

In the present project, our pilot regions are El Salvador, Ghana and Kenya. We focus on three different pilot regions to be able to derive a *generative concept* that can be applied to many of the existing other regions facing a problem with a similar structure and to profit from synergy-effects. All CiObs integrate the local knowledge of citizens and their observations in the risk mitigation approach. In the proposed CiObs there are differences in the participation of citizens in the problem solving approach. These differences and generalisable aspects of the proposed CiObs will be identified in the final phase of the project. In this way, a successful and sustainable transfer of results to other scenarios of CiObs providing spatial decision support for risk mitigation and resource optimisation is maximised.

One identified critical health problem in *El Salvador* is *chronic kidney disease (CKD)*. Nationally, CKD is currently the leading cause of hospital mortality in men with a case fatality rate of 11.0%, (Ministry of Health - El Salvador). Studies in the adult population of the Salvadoran farming communities show that the majority of cases with CKD were heavily influenced by factors such as male gender, older age, agricultural occupation, hypertension, family history of hypertension and contact with some pesticides, (cf. Orantes et al. 2014).
In *Kenya*, human health is affected, among others, by the use of inefficient combustion devices. By inhaling carbon fumes of combustion devises from cooking with firewood, charcoal and use of African traditional candles, diseases such as *bronchitis, lung infections, nasal problems* etc. are triggered.
In *Ghana*, the disease *Buruli ulcer* (BU) causes major health problems. BU is a human infectious disease caused by *Mycobacterium ulcerans*. The clinical picture is characterised by necrosis of the subcutaneous tissue leading to devastating skin defects, permanent disability and death. The mode of transmission is unknown. Currently most people present themselves to public health facilities at advanced stages, when treatment is costly, time-intensive, and often not able to fully rectitude the function of the affected body part (mostly limbs).
Dengue fever, a viral disease transmitted by *Aedes* mosquitoes, has expanded in the past decades to unprecedented levels, due to its association with unplanned urbanisation and poor housing conditions. It nowadays affects large areas in Latin America, Central Africa, India and South-east Asia. About half of the world population live in areas under risk of dengue transmission. Mosquito breeding sites are abundant in areas with unreliable water supply, ongoing urban construction, and deposition of trash. Community participation is crucial for control efforts in times where an effective vaccine or therapy is not available.

The present project has the aim to reduce the risk to human health through a *One Health approach*. The One Health approach recognises, that the health of humans, animals and ecosystems are interconnected. Consequently, if risks that originate at the animal-human-ecosystems interface shall be addressed, a coordinated, collaborative, multidisciplinary and cross-sectoral approach is needed. (http://www.onehealthglobal.net).
All diseases mentioned above have constraints that have an impact on the control and elimination of the diseases. Certain constraints that trigger the diseases or reduce the severity of the diseases have a diverse spatial distribution and impact on risk mitigation in rural areas.
In the three pilot regions Kenya, Ghana and El Salvador, different decision support is required due to different local conditions. One exemplary risk mitigation strategy is the provision of information on a disease tailored to the population. Different kinds of sources, e.g. medical or socio-economic data as well as satellite imagery or other geo-spatial data are analysed and combined to derive such information, which can be e.g. the current risk at the geo-location of the user, preventive measures to protect from an infection, or available resources near the geo-location of the user. This information will be provided to the user in an adaptive way, to improve the comprehension and risk literacy. Therefore, we will analyse the health situation, the information and

communication technology (ICT)-situation, the cultural situation and the socio-economic situation and identify a frequently used information and communication-channel (ICT4D). Furthermore, we shall find solutions to bridge the *last mile problem* to reach as many potential users as possible to improve the health situation.

Human beings make decisions mainly dependent on short-term benefits, (cf. AAAS Project 2061, 1990). Thus, the provided risk mitigation strategies should be based on the principle of *visible short-term benefit* that creates a long-term impact on health. We will investigate, develop and adjust resources for risk mitigation and provide them to the community members.
Digital devices (e.g. smartphones, feature phones, tablets, PCs, etc.) combined with a last mile solution will be integrated into the LL to enable the citizens to report their observations and to enable the provision of tailored information on risk mitigation to the community-members. *Public health agencies* are involved to assess the reported observations. Public health recommendations can be submitted to users to improve *risk-mitigation strategies* with regional available resources. We will determine the deviation between global health goals and community needs and we will develop and implement a solution with the maximum acceptance of the community with including issues like potential language barriers or low literacy. In the course of this, we will negotiate the health goals within the LL. Afterwards, we will evolve and implement methods to reach those health goals with the available resources.
Concluded, we will develop a *spatial decision support system (SDSS)*. A SDSS is a combination of *GIS* and *decision support system (DSS)*[6] (Yang et al. 2007).
In the context of the spatial decision support client, the *crowd sourcing approach* has the potential to support spatial decisions on analytic activities due to reported events to GISs and merge them with medical or socio-economic data as well as satellite imagery or other geo-spatial data. In this way, valuable information for the citizens can be generated.

An *SME-network of EU and non-EU SMEs* is supposed to arise from the requirements and the structure of the LLs. Through the sustainable character of LLs, the project concept shall *persist after the end of the project*. That is, continuous feedback-inquiry of the citizens and provision and adjustment of the services to the user requirements by the SMEs after the end of the project. Additionally, through the Business Startup Office of the *Uni KO-LD* the founding of new SMEs within the present project will be supported. Furthermore, the ICT infrastructure is renewed and extended and new communication channels will be created, which can be used by EU and non-EU SMEs to transfer their information e.g. advertisement to market their products.

1.3.2 Positioning of the Project

In order to develop a prototype which enables communication in a simple, everyday usable way, the following software development will be carried out and the following Technology Readiness Level (TRL) will be reached:

[TRL 3] Development of a graphical user interface design for a client for spatial decision support via rapid prototyping;
[TRL 4] Development of a prototype of a client for spatial decision support, which enables communication in a simple, everyday usable way;
[TRL 5] Implementation of an encoding-mechanism to protect sensible data.
The integration of an open source navigation-tool will be crucial to enable navigation. Realisation of a link to an augmented reality tool (e.g. “Mixare”, TRL 4/5) and to an open source navigation system (e.g. “Navit” to enable navigation.

1.3.3 Research and Innovation Activities

Recently, several *CiObs* emerged in an environmental context. In 2011, the environmental concept of CiObs was

6 A *DSS* can be defined as a computer-based tool used to support complex decision making and problem solving. It provides access to a wealth of information pertaining to a specific problem. The following types of information are available: information content, maps and data. This information may be contained in databases and GIS. DSSs may help to answer questions about the level of risk, the remedial technology options, the costs or whether the regulatory targets can be achieved. DSSs can provide powerful functionalities for analysis, visualisation, simulation and information storage that are essential to complex decision processes. Moreover, information and options can be presented within an ordered structure, visualised from a space-time perspective, elaborated in simulated scenarios and therefore more easily discussed by the interested parties to reach a common rehabilitation objective. (Shim et al. 2002, p. 1 & Marcomini et al. 2009, p. xviii f).

introduced in the project *"Eye on Earth"* (http://www.eyeonearth.org) with the European Environmental Agency (EEA) creating the first 'official' environmental portal that includes a CiOb on air, noise, nature, coral reefs and water quality (Liu et al., 2014). Under the FP7 topic ENV.2012.6.5-1 "Developing community-based environmental monitoring and information systems using innovative and novel earth observation applications" the EU has funded five CiOb-related projects at the end of 2012:

- "Citclops – Citizens' Observatory for coast and ocean optical monitoring", 2012–2015 (http://www.citclops.eu);
- "Omniscientis – Odour monitoring and information system based on citizens and technology innovative sensors", 2012–2014 (http://www.omniscientis.eu);
- "CITI-SENSE – Development of sensor-based Citizens' Observatory Community for improving quality of life in cities", 2012–2016 (http://www.citi-sense.eu);
- "WeSenseIt – Citizen Observatory of Water", 2012–2016 (http://www.wesenseit.com); and
- "COBWEB – Citizen Observatory Web", 2012–2016 (http://cobwebproject.eu).

EU-funded projects which contain core components that were heavily based on the CiOb concept:

- ENVIROFI, 2011–2013 (http://www.envirofi.eu) and
- HENVINET, 2007–2011 (http://www.henvinet.eu.)

The present CiOb-project differs from the other mentioned CiOb-projects in so far, that health risk mitigation is supposed to be implemented in high risk locations, where the health system strongly requires optimisation. Furthermore, different life threatening diseases shall be combated by creating a short-term benefit for the population to encourage the citizens to contribute to the development of and to apply risk mitigation strategies in the context of a CiOb. Together with a GIS merging environmental, agricultural, human health data as well as satellite based information, the mobile devices are used to *strengthen environmental monitoring capabilities* for e.g. the application of agrochemicals. Concluded, the citizens observe, report and receive decision support within the CiOb.

Another innovation is the implementation of a *LL* within the CiOb, as a new approach to innovation and ICT development, emerged during the 1990's. It encompasses the idea of creating an environment that offer users the opportunity to take part actively in the co-creation of innovation and, more specifically, the development of ICT-related products and services (e.g. idea generation, development, implementation and evaluation) (EnoLL, 2014; Følstad, 2008; Geerts, 2011).
IST-Africa is commencing an updated study on existing and emerging LLs in Africa during 2014 – 2015. Several LLs exist and emerge in Africa (cf. http://www.ist-africa.org/home/default.asp?page=livinglabs).

In Kenya, the following LLs exist (cf. Cunningham et al., 2011):

- "East Africa Regional Mobile Application Laboratory": "m:lab East Africa" (http://mlab.co.ke/) - Support Broadband Communication Networks & eServices in Rural Communities;
- "@iLabAfricaLL" (http://www.ilabafrica.ac.ke/) - Support ICT Research, Innovation, Entrepreneurship & Incubation;
- "iHub Nairobi" (http://www.ihub.co.ke/) - Supporting Entrepreneurship & Incubation though Open Innovation;
- "The Nailab" (http://www.nailab.co.ke/) - Supporting Co-Creation;
- "Nguruman Maarifa Centre" (http://ngurumanmaarifa.blogspot.com) - Supporting Rural Connectivity;
- "Map Kibera" (http://mapkibera.org/) - Engaging Youth in Africa's Largest Slum;

In Ghana, the following LL is established:

- "Wenchi Living Lab" - Mobile Applications to Support Market Access for Cashew Farmers

Until now, no LL exists in any Central American Country (e.g. El Salvador), however, the applicants *Uni KO-LD* and *CSIR* have jointly conducted initiate workshops in El Salvador in order to prepare for the establishment of these LLs. In Kenya and Ghana, there already exist LLs. Most of the existing LLs focus on ICT and entrepreneurship and few of them on health-related issues. "Map Kibera" in Kenya focuses on the participatory digital mapping of risks

and vulnerabilities in the context of poverty, safety and criminal prevention programs. Young people are supposed to gain new awareness about their surroundings empowering them to address critical issues. The concept of this LL is close to the planned LL in the present project with respect to a focus on the generation of risk awareness through the creation of risk literacy in the context of the development of risk mitigation strategies. Furthermore, the CiOb-concept is partly addressed in the "Map Kibera" through the participatory digital mapping. The LL planned in the present project goes beyond the concept of "Map Kibera" with regard to the outreach by addressing a larger target group (citizens = the whole target community), the CiOb-Concept, the target locations El Salvador and Ghana beside Kenya, and the focus on different health problems in the three pilot regions. Nevertheless, we can definitely learn from "Map Kibera" and derive best practices. Furthermore, we can provide results gained in the present project (like health map data, concepts or software) that could support "Map Kibera". We can also profit from "Wenchi Living Lab" implemented in Ghana which focuses on the implementation of mobile applications to support the linkage of smallholder farmer cooperatives with sustainable markets in the cashew sector with respect to creating an economical benefit in the agricultural context in El Salvador and thereby creating a short term benefit for the citizens in the CiOb.
Consequently, the planned LLs are the first of this kind in the three mentioned countries and might have the potential to be a model for the implementation of further LLs and envisage building LL-Networks similar to LLiSA (http://llisa.meraka.org.za/index.php/Living_Labs_in_Southern_Africa) in Southern Africa or EnoLL (http://www.openlivinglabs.eu/) in Europe in the future. Additionally, an optimisation of the health situation is strongly required in the pilot regions Kenya, Ghana and El Salvador. Other interventions were already tried but did not work or were not sustainable. The concept of LLs is promising due to the user-centric approach.
The concept of a LL is based on *strong involvement of citizens and citizens' associations together with the industrial sector* (e.g. SMEs). Consequently, *novel partnerships* between the private sector, public bodies, NGOs and citizens are assured by implementing LLs in the present project. By evaluating and optimising the work flow in the LLs, the *system proposed for CiObs is scaled up, demonstrated, deployed, tested in its entirety and validated in real-life conditions*.

1.3.4 Overall Approach and Methodology

The citizen observations are used for risk and resource optimisation in a *One Health approach*. Health observations will be evaluated according to their benefit for the environmental health assessment and vice-versa the environmental observations of citizens will be evaluated according to the benefit for the assessment of health risks. The primary driver is a *short-term economic benefit* that has the potential for a *long-term public health improvement*. We will measure a change in the work-flow of citizens and detect the workload for an *optimised work-flow* to assess the sustainability of proposed CiOb. A requirement of the combination of disciplines is that

- the observing citizens get a *short-term (economic) benefit* (e.g. precision-farming, consequence: less agrochemical with same harvest yield).
- citizens are aware of the *long-term benefit* of a sustainable CiOb (e.g. health related impact of economical benefit and the awareness about the value of citizen observations for a sustainable concept of the CiOb).
- the workflow for integration of citizen observations will create an *acceptable workload* for the citizens.
- the whole process of development is *user-driven*.

Environmental conditions (e.g. exposure to agrochemicals, mosquito breeding places) induce health risks. An integrated approach for One Health uses citizen observations to identify risk mitigation options in the environmental and the health domain, because the health risk can be reduced by intervention for environmental conditions. Furthermore, environmental conditions might not always be changeable completely and additional intervention in the health domain is needed. The citizen observations thus fulfil two tasks:

1. Collection of *regional relevant data* and
2. Implementation and execution an observation plan that creates *permanent awareness* in an in-situ manner.

The *CiOb developed in the present project* consists of / includes the following stages (cf. *figure 1*):

1. Observation of citizens,
2. Reporting of citizens via app,

3. Spatial analysis of risk and resources (by decision support system),
4. Provision of spatial decision support to citizens and
5. Possibility of risk mitigation by citizen.

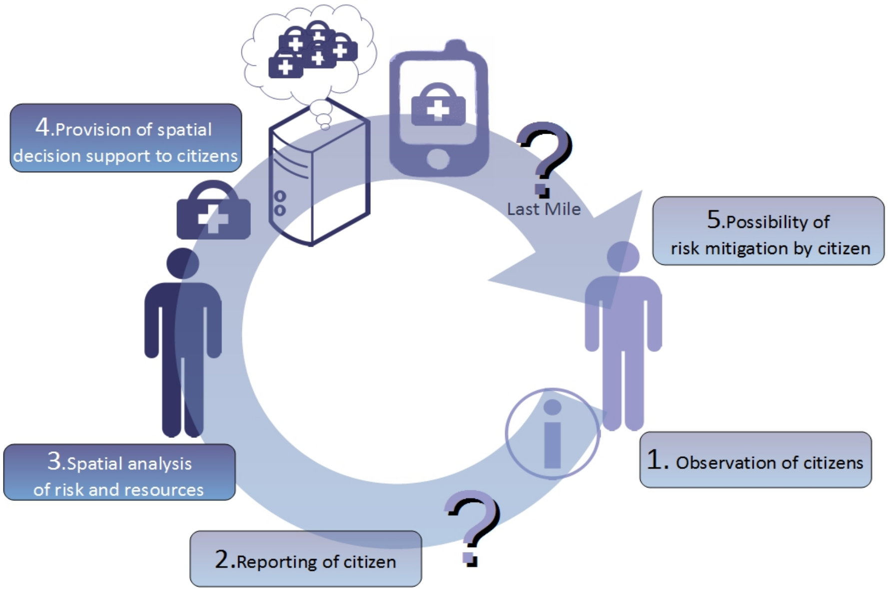

Figure 1: Communication Cycle within the CiOb

1.3.5 Gender Analysis

To implement risk mitigation strategies, the identification of the ICT and non-ICT communication infrastructure is crucial to reach efficiently risk-exposed population. Therefore, effective non-ICT and ICT-channels will be identified. On this basis, options for optimising the communication channels can be derived by conducting a cost-benefit analysis including the last mile problem. The implementation strategy will be evaluated in pilot regions in rural areas. A *gender analysis* will be applied, taking into account structural intersections such as ethnicity, religious affiliations, age, etc. to be able to provide adjusted decision support. This is very important to observe differences between the communication channels used by females and males and to be able to identify and *optimise used communication channels* to reach as many potential users as possible.
Furthermore, the *short-term benefit* that is supposed to be created to support the use of the application, could be of different value dependent on the gender. Additionally, there could be gender-differences in the *diseases* that are under focus in the present project, e.g. CKD occurs mostly in men. Based on such information, the provided decision support and the risk mitigation strategies can be adjusted.

1.4 Ambition

1.4.1 State-of-the-art and Innovation Potential

The aim of the present project is the development of a simple, everyday usable *open source app* for mobile devices, which enables the *communication of risk-incidents* and the *access to risk minimising resources* in the agricultural and health context. This app should enable to receive risk-related information, to communicate risk-related information and a navigation-function should be available, to navigate a user to safe(r) locations or to risk minimising resources. To enable this app to reach as many potential users as possible, the *ICT-infrastructure* will be *renewed and extended* and *new communication channels* will be created.
We will develop this application as *low cost technology* and we will include therefore a combination of existing open content and open source software like:

- Mixare (mix Augmented Reality Engine) is a free open source augmented reality browser. (http://www.mixare.org/);
- Navit is a free navigation software for real-time navigation and GPS-tracking. (http://www.navit-

project.org/);

- OSM, the Free Wiki World Map – An openly licensed map of the world being created by volunteers using local knowledge, GPS tracks and donated sources. (www.openstreetmap.org/);
- Copernicus Land Monitoring Service, which comprises satellite-based earth observation, in-situ data and a services component that combines these in order to provide value added information essential for monitoring the earth's environment. (http://land.copernicus.eu/);
- GEOSS, which provides decision support tools to a wide variety of users. (http://www.earthobservations.org/geoss.php).

The application should serve as a *client for spatial decision support*. Several web-based services for decision support have already been developed (cf. Rinner, 2003). McIntosh et al. (2011) dealt with environmental decision support systems development and concluded on challenges and best practices in their paper. In the health context, Eisen & Eisen (2011) developed a GIS-based decision support system for the prediction, prevention, and control of vector-borne diseases. Zhang et al. (2010) developed a decision support tool for variable rate application in the context of Zone mapping application for precision-farming. Ganchenko (2014) provides decision support for hardware and software, complex for precision farming tasks. In the context of spatially-explicit exposure assessments of non-target areas to pesticides, approaches have been developed (Schad & Schulz 2011) and conceptual frameworks for their use in risk assessment have been proposed (Schulz et al. 2009). The use of data-mining and meta-analytical approaches in order to assess and geospatially visualise potential pesticide risks has recently been exemplified by means of agricultural insecticides and surface water resources (Stehle & Schulz 2015).
In contrast to Rinner, 2003, the application developed in the present project will enable *offline use*, as internet connection will not be available continuously everywhere in the world. Furthermore, solutions for the *last mile problem* are supposed to be found, which might not be web-based. Additionally, the application is supposed to be developed as *low cost technology* and includes therefore a combination of existing open content and open source software.
Additionally, the development *cost* of SMEs is *lowered* by building on existing open source modules. Consequently, the use of open source and open content is essential for the involved SMEs to keep the total cost of ownership as low as possible and consequently to reach a target group as large as possible. Furthermore, the use of open source and open content allows to make the application available *free of charge*. This is important in order to make the application available to everyone. Accordingly, the financial circumstances of the user do not matter, which in El Salvador, Kenya and Ghana is of great importance, because many potential users would be otherwise unable to afford it. By delivering an open source application, already developed components of other open source software and open content can be used, and the developed application can, in turn, be used in other open source software and open content. The advantage of this approach is faster development, faster improvement and, eventually, faster distribution of the application. Nevertheless, suitable research and development concepts (McIntosh et al. (2011), Eisen & Eisen (2011), Zhang et al. (2010) and Ganchenko (2014)) will be involved into and used as a basis for the application development in the context of the present project.
Consequently, we will ensure the *effective transfer of environmental knowledge for policy, industrial, research and societal use, with a focus on the domain of land cover/land use, both in rural and urban areas* by implementing an everyday usable open source app for citizens' own devices and solutions for bridging the last mile, where the transferred environmental knowledge is tailored to the user and improving the risk literacy of citizens. The open-source app is first of all a free communicator with a *familiar, easily comprehensible user interface*, to support frequent use and to have large numbers of users by renewing and extending the *ICT-infrastructure* and by creating *new communication channels*.

1.4.2 Problems to be addressed

One problem identified is the *language barrier* (Spanish language in El Salvador, indigenous languages in Kenya (Kiswahili) and Ghana). As the CiOb and the LL concepts are not well-known problem solving approaches, the concepts require a lot of explanation effort. Therefore, *translators* will be needed to ensure all involved persons to understand the concept, to convince the participants, to build trust and to enable as many potential users as possible to use the app.
Additionally, problems like *low literacy* have to be addressed during software development. Therefore, *speech recognition* is required to simplify data collection within the meaning of the CiOb. In order to support data

collection and information provision within the meaning of the CiOb from a broader range of users, including children, low literate, illiterate, elderly people and users in risk situations, a *speech-based user interface* will be developed in addition to the traditional, touch-based system. The speech model will be developed specifically for the target languages (e.g. Spanish, English and Kiswahili) and take local dialects, as well as the task specific vocabulary into account.
Furthermore, solutions to bridge the *last mile problem* have to be found to reach as many potential users located in risk situations as possible. In Kenya, Ghana and in El Salvador, Smartphone penetration is very low. The communication channels in the rural communities are others than Smartphones. The common communication channels even differ between these three countries. Therefore, individual solutions have to be found to bridge the last mile problem in all three pilot regions. Consequently, to implement risk mitigation strategies, the identification of the ICT and non-ICT communication infrastructure is crucial to reach efficiently risk-exposed population. Therefore, effective *non-ICT and ICT-channels* will be identified. On this basis, options for *optimising the communication channels* can be derived by conducting a cost-benefit analysis including the last mile problem. Once again, the LL is considered a suitable option in order to reach persons with user´s own devices as representatives of others not having this access. This will considerably help to alleviate the last mile problem.

2. Impact

2.1 Expected Impacts

With a simple, everyday usable open source app for the user's own devices, the communication of risk-incidents and the access to risk minimising resources will be enabled to optimise the health-situation in the context of a CiOb. With the developed method, a *short-term benefit* shall be created, which has a *long-term impact on health*.
Thereby, we focus on the three different pilot regions Kenya, Ghana and El Salvador to be able to derive a generative concept that can be applied to other pilot regions facing a problem with a similar structure and to profit from synergy-effects. It is well known that other areas, such as South-east Asia, also suffer from severe CKD problems.
The citizens' own digital devices serve to communicate risk mitigation strategies to citizens in risk situations.
We will develop the *basic principles for a client for spatial decision support with already existing open source applications* as proof of concept and implement a *client for spatial decision support.*
The reduction of disease-rates, e.g. CKD in El Salvador, can only be measured in the long run. The aim to reduce the disease-rates can be achieved by means of the *sustainability of the LLs* and the created *SME-networks*.
The following milestones are supposed to be reached within the project:

Milestone 1: Identification and definition of IT requirements for an efficient medical and agricultural use of an application for digital devices. Consequently, the present project concerns the *establishment of a sustainable information channel* the population uses.

Milestone 2: Optimisation of the usage of the developed information channel for *medical and agricultural needs*.

Milestone 3: *Implementation of a client for spatial decision support.*

2.1.1 Lowered Cost and Extension of the in-situ Component

In the project we follow the hypothesis, that with the CiOb establishment and the developed method a larger number of people can be reached for risk minimisation compared to the current situation.
We will test the Hypothesis with *measurements* at critical dates of the project. Based on the results of the measurement, the methods applied in the CiOb will be optimised in an *in-situ* manner.
Within the LLs, digital devices are used for distributing and collecting information in the context of CiObs. This has two advantages:

- Knowledge collection about *opportunities and limitations of the communication channel* and
- *Optimisation of this communication channel* for communicating environmental, agricultural and health information.

We can determine how many people use the developed method on their digital devices by *quantifying the user traffic* and thus we can derive conclusions on the *quality of the developed method*. If the survey is led by the community-members with digital devices, we also know *how far the IT bears* and where other forms of communication must be used for data collection. The support of non-telecommunications can also be supported by IT, i.e. it is shown how to contact with whom in the best way, or how to transmit data without an internet connection or without suitable hardware.
Furthermore, through encouraging the citizens to assist in *(electronic) waste removal* to eliminate e.g. empty contaminated pesticide containers (risk source for pesticide poisoning) or potential breeding places for mosquitoes (mosquitoes as vector for several diseases), we can measure the *visible change* and thus we can derive conclusions concerning the impact of the project.

The app, that will be developed in the present project is a combination of

- a “WhatsApp” analogue messenger operating with standard e-mail servers,
- an augmented reality tool like “Mixare” and
- an offline & online navigation tool like “Navit” including e.g. “OSM”, “Copernicus Land Monitoring Service” and “GEOSS”.

Together with a commercial plug-in, the concept provides a health and agrochemical crowd sourcing interface which reports back regional and local relevant health and environmental risks. The crowd sourcing concept provides also feedback for the usability, acceptance and reported benefits of citizens using the app. Furthermore, the use of open source and open content enables to offer the application free of charge.
Additionally, the development *cost* of SMEs is *lowered* by building on *existing open source modules*. We will assess and optimise the work-flow integration of CiObs in an everyday workflow to show a measurable and reported reduction of agrochemicals according to regional needs and local environmental conditions.
In the present project, *data and information sharing* is a very important aspect, as the Open Community Approach is pursued. Therefore, we will make the developed application available as open source software and we will use the open content of e.g. OSM and *the Copernicus Land Monitoring Service*. The gathered data and information in the context of the present project will be used to *extent the in-situ component of the GEOSS and Copernicus initiatives.*

2.1.2 Better Decision Making through the Empowerment and active Role of Citizen's Associations with special Impact on Land Resources Management

Access to risk minimising resources and rare risk-incidents can be reported with an everyday usable open source app for *citizens' own devices* (e.g. mobile devices) by the citizens in the context of CiObs. The app shall be used in the context of health and environment (agriculture). Especially the agricultural use of pesticides in developing countries poses high risks to the environment and human health, which can effectively be reduced using low-cost precision agricultural techniques. Currently, lack of pesticide regulations and environmental awareness, pesticide misuse, lack of farmers` training and knowledge and lack of the awareness of pesticide side-effects for the human health (i.e., human health effects on farmers and citizens living near treated fields), often lead to incautious handling and application of pesticides in developing countries. The proposed in-situ observatory uses citizens' own mobile devices as a spatial decision support client for e.g. low-cost precision agriculture for the optimisation of health service delivery, to *optimise decision making*. Therefore, *digital devices* (e.g. smartphones, feature phones, tablets, PCs, etc.) combined with a last mile solution will be integrated into the LL to enable the provision of tailored information on risk mitigation to the community-members (risk literacy).

Ground-based data collection by citizens (e.g., information on pesticide application by visual observations; discovering of empty pesticide cans which indicate recent pesticide application), direct information from local farmers on spraying plans, data (e.g., aerial images) on crops and information on typical application intervals and rates, dates, and amounts (taken e.g., from regulatory documents, information from respective pesticide labels, scientific publications), or spectral analyses that are able to identify a pesticide compound applied, enables an estimation of the pesticides applied in a given area, e.g., near a local village.
These information can subsequently be used to

1. assess the risks for the environment (e.g., spray drift deposits or run-off transport of pesticides into adjacent non-target ecosystems) and human health (e.g., human health risks due to direct contact with pesticide spray drift or consumption of water contaminated during pesticide application) by evaluating respective ecotoxicological and human health-related toxicological information (these are freely available e.g. from US or EU governmental pesticide registration reports), and
2. to inform/warn the local citizens to stay inside their houses during pesticide application thereby avoiding contact with pesticide spray drift, or not to consume potentially pesticide-contaminated surface water.

Low-cost precision agricultural approaches (e.g., based on proximal soil and crop sensing (visual inspection) and adapted/reduced pesticide applications) or remote sensing (GIS analyses that monitor plant health and give information if pesticide applications are advisable) can in turn be used to effectively reduce the pesticide amounts applied to agricultural fields and therefore also the pesticide exposure of the environment and humans. Moreover, such an approach could effectively reduce the (over)use of pesticides in developing countries and help farmers to optimise their agricultural production while simultaneously reducing the costs for agrochemical inputs of individual farmers. At the same time, the ecotoxicological approach should as well be linked e.g. with NDUI Crop Health Data in order to improve sustainable crop protection.

We will determine the deviation between global health goals and community needs and we will develop and implement a solution with the *maximum acceptance of the community* including issues like potential language barriers or low literacy. In the course of this, we will negotiate the health goals within the LL. Afterwards, we will develop and implement methods to reach those health goals with the available resources.
In order to create a short term benefit in the context of improving occupational health in an agricultural context, research on *low-cost techniques* to mitigate health risks has to be performed and the production processes have to be improved through land use optimisation and optimised *land resources management.*
Through the *user-centric* concept of a LL (see *chapter 1.3.1*), *the empowerment and active role of citizens and citizen's associations in environmental monitoring, co-operative planning and environmental stewardship, with special impact on land resources management* is supported. The success of this method shall be secured by creating a short-term benefit, which has a long-term impact on health.

2.1.3 Enhanced Implementation of Governance and global Policy Objectives

Through the concept of a LL, *the empowerment and active role of citizens and citizen's associations in environmental monitoring, co-operative planning and environmental stewardship, with special impact on land resources management* is supported, as well as the *implementation of governance and global policy objectives* by focusing on the *optimisation of the health situation.*

For the diseases described on p. 4 the only effective risk mitigation strategy - *early recognition*- faces numerous obstacles:

- insufficient awareness of the disease and its cause (which is probably most important);
- physical (poor road conditions, inadequate public transport);
- economic (user fees, transportation costs) and social (disease perception) gaps between patients and health care providers;
- inadequate staff training;
- insufficient material supply;
- unreliable salary provision and
- unknown transmission modes.

Therefore, solutions to overcome these obstacles have to be developed.
In order to address the health problems in *El Salvador* mentioned in *chapter 1.3.1*, research on low-cost techniques to mitigate exposure to pesticides and other chemicals in the environment has to be performed (*precision farming*), to improve the production processes (*land use optimisation*) and to improve the care of kidney patients in rural areas (*usability work-flow optimisation*). The present project has the aim to reduce the risk to human health, to local farmers and community members, caused by the exposure to pesticides, through a *One Health approach*. The project also has the objective to find agricultural production alternatives without agrochemical inputs or with a rational use of them. By doing so, *human health and the socio-economic situation*

are supposed to be optimised, as well as the *environmental situation*. We mainly focus on mitigating occupational factors and environmental risks for CKD affecting Salvadoran farmers in endemic and epidemic proportions. The research will be conducted with the involvement of local experts in agriculture, health and environment, as well as the affected population. (cf. project LLinES: http://llines.weebly.com/).
Kenya has a vision to create a *globally competitive and prospective nation* with a high quality of life by the year 2030. The recent Kenya economic Health Survey shows that the rate at which improvements in the health sector are currently progressing is very low. With the present project we are prepared to *contribute to this vision* by ensuring that health related information is accessible to all through an affordable and flexible solution. There is need to examine how to ensure that the health information supplied is contextualised to address five key requirements regardless of the target audience or platform: accuracy, timeliness, relevance, security and accessibility.
An unprecedented *spread of mobile communication technology* has now opened even remote rural areas in Kenya and *Ghana* to the ever increasing possibilities of modern "smart" mobile phones including

- (picture) documentation and data exchange;
- GPS based epidemiology;
- supply chain management;
- e-learning and
- payment systems.

With these techniques the treatment of the diseases BU and bronchitis, lung infections, nasal problems, etc. can be optimised.
This *mix of technology available in remote areas* can potentially also prove useful for the control of dengue fever, CiObs can create awareness by documenting potential or proven mosquito breeding sites, which can then be geo-located and made available for public health agencies. This data can be used for creating small-scale GIS-based maps of dengue risk as perceived by CiObs and in a second step compared and validated against the reported cases over time from the same area. The research question we pursue in this case is two-fold:

1. Can CiObs create awareness for a more timely response and control of dengue transmission?;
2. Does the data collected by CiObs on dengue risk/transmission correlate well with reported dengue cases in the same time period?

2.1.4 Increased European SME Role in the Business of in-situ Monitoring

We will develop an open source communication app for mobile devices that allow *EU-SMEs* to provide *regional relevant services* utilising existing server infrastructure for mapping, mail server communication, offline routing, risk mapping and resource mapping and augmented reality visualisation.
The citizens in the CiOb receive a commercial benefit via the application of the spatial decision support provided by the app developed in this project.

We focus on three different pilot regions to be able to derive a *generative concept* that can be applied to other pilot regions facing a problem with a similar structure and to profit from synergy-effects. At the same time, in the three pilot regions the deviation between risk and available resources is relatively large, consequently the success of the applied method emerge faster than in European Countries, where this deviation is not that large. Nevertheless, through the development of a generative concept, the applied methods can be *transferred also to structurally weak regions in EU-countries.*

An *SME-network of EU and non-EU SMEs* is supposed to arise from the requirements and the structure of the LLs. Through the sustainable character of LLs, the project concept shall *persist after the end of the project*. That is, continuous feedback-inquiry of the citizens and provision and adjustment of the services to the user requirements by the SMEs after the end of the project. Thus, SMEs will provide the commercial spatial decision support services after the end of the present project.
The concept of a LL is based on *strong involvement of citizens and citizens' associations together with the industrial sector* (e.g. SMEs). SMEs which offer regional decision support for CiObs do not exist. Therefore, a Master Plus Programme at the *Uni KO-LD* is initiated to combine the competences for this service with a

customised education program. Together with the Business Startup Office of the University, persons will be educated that will be able to found EU-SMEs with the required profile. Consequently, the *development of EU-SMEs* for the compiled project tasks will be supported and the *role of EU-SMEs in the business of in-situ monitoring will be increased*. This economic development is strongly linked with the academic sector in the EU.
Furthermore, the ICT infrastructure is renewed and extended and new communication channels will be created, which can be used by *EU and non-EU SMEs to transfer their information* e.g. advertisement to market their products.

In conclusion, *increased deployment and market uptake of innovative in-situ monitoring techniques and an increased European role in the business of in-situ monitoring of the environment* is enabled through a process of a *long-term environmental and human health improvement with a global perspective*.

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