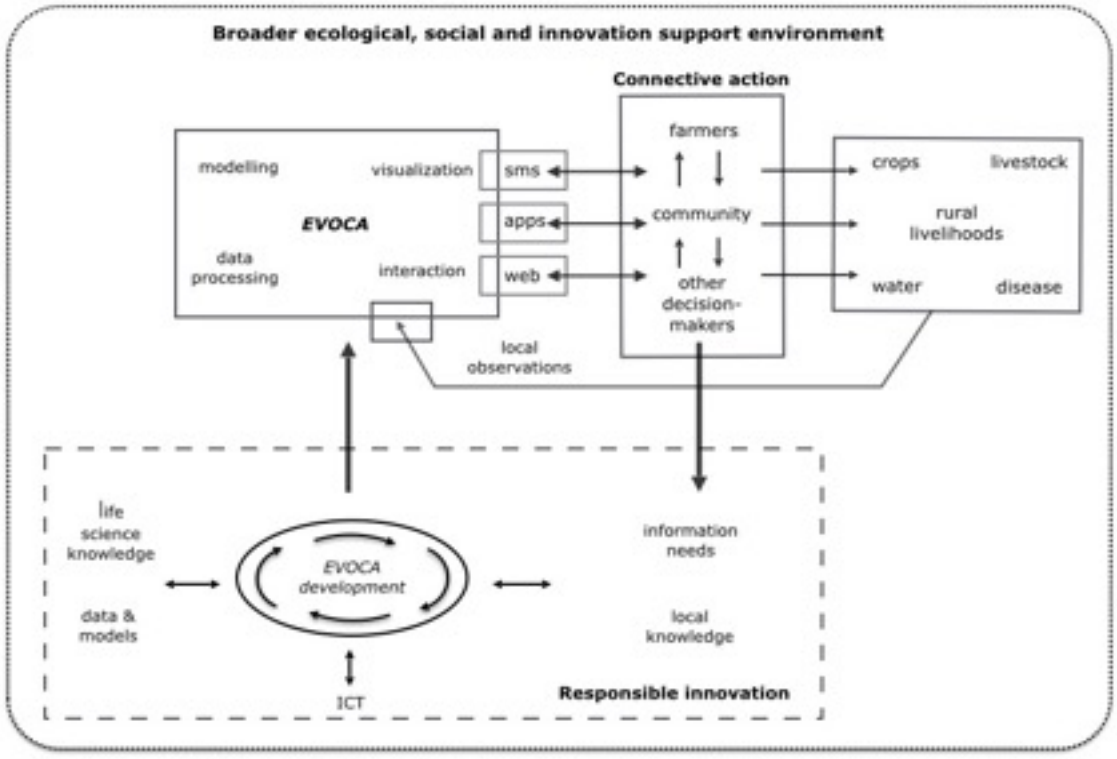
Responsible life-sciences innovations for development in the digital age: Environmental Virtual Observatories for Connective Action (EVOCA) in crop, water, livestock and disease management



1. Title of the programme: EVOCA

Responsible life-sciences innovations for development in the digital age: Environmental Virtual Observatories for Connective Action (EVOCA) in crop, water, livestock and disease management

2. Applicant(s)

WU Graduate Schools: WASS: Building 201, Hollandseweg 1, 6706 KN, Wageningen
WIMEK and PE&RC: both Building 100, Droevendaalsesteeg 3a, 6708 PB, Wageningen

Programme leader

Prof. dr. Cees Leeuwis
Chair Knowledge, Technology and Innovation
Both: Hollandseweg 1, P.O. Box 8130, NL-6700
T: 0031 (0)317 484310; cees.leeuwis@wur.nl

Daily programme management

Prof. dr. Peter H. Feindt
Chair Strategic Communication
EW Wageningen
T: 0031 (0)317 486035; peter.feindt@wur.nl

3. Programme Summary

People in rural Africa face social, economic and political challenges in sustaining their livelihoods. But also the natural environments on which they depend are under pressure. Global environmental change increases the spatial and temporal variability and sensitivity of many natural processes affecting biodiversity, health, agriculture and water systems. Timely information on relevant environmental dynamics (such as water levels, spread of plant pests or prevalence of disease-carrying insects) is often lacking because of limited understanding of local system dynamics. This in turn reinforces collective action problems, i.e., collaboration deficits due to relatively high individual costs of contribution to common goods with marginal or uncertain individual benefits. Recent developments in web-based and mobile technologies hold considerable promise to overcome these problems. They allow linking science-based models of dynamic natural processes with participatory monitoring and broad information accessibility. ICT-based virtual platforms enable and encourage users to share relevant environmental information such as the observation of infected crops, rainfall and water availability or a malaria-mosquito densities. Digital media complement traditional organising agents for collective action; they set in motion a "logic of connective action" where even fragmented populations share (often personalized) content across media networks; the shared content in turn contributes to collective knowledge and coordinated action. Our central research question is: How can life-science knowledge, digital technologies and responsible innovation concepts be leveraged in development contexts to build inclusive virtual platforms for environmental information that enable connective action for addressing development challenges in crop, water, health and wildlife management?

The implications for development in rural Africa are potentially dramatic. If citizens, farmers and decision-makers are enabled to share and access high-quality, updated and locally tailored information on natural processes that are relevant to their needs and ambitions, they are in a much better position to master the development challenges they face. While so-called environmental virtual observatories (EVOs) have been shown to effectively assemble and distribute user-relevant information on dynamic environmental phenomena, systematic attempts to involve users in content sharing and to link user content to science-based models so as to generate connective action are novel. The EVOCA programme aims to boost and study the development of Environmental Virtual Observatories for Connective Action (EVOCAs) in West and East Africa. This entails the development of participatory monitoring systems, virtual platforms and digital applications, whereby both the development process and the resulting EVOCAs are geared towards evoking connective action in five cases:

- a crop and disease management expert system in potato production in Ethiopia;
- water monitoring and irrigation management for food production in Ghana;
- a malaria mosquito radar as a digital citizen science platform in Rwanda;
- tick-born disease and livestock-wildlife management in Kenya;
- sustainable intensification of cocoa and food crop farming systems in Ghana.

To maximize local relevance, usability and equitable access to these technologies, we apply and further develop the responsible innovation approach, characterized by anticipation of future scenarios, reflexivity about innovation choices, inclusion of different actors and viewpoints, and responsiveness to changing societal demands and concerns. By applying responsible innovation concepts across different life-science domains, the EVOCA programme will generate a thorough understanding of the conditions for successful virtual platforms that enable participatory monitoring and effective action in development contexts. It will thereby make a major contribution to the combination of ICT-based participatory technologies and life-science knowledge, and to our understanding of how inclusive digital platforms can enable connective action for irrigation, livestock, crop and animal disease control and resource management strategies that effectively address rural development challenges.

In a nutshell, the proposed programme will: (a) develop and apply a design framework for responsible digital innovations for development; (b) (further) develop promising participatory virtual platforms and digital applications for resource management in African rural communities; (c) study the systemic conditions for the successful embedding of such innovations in development contexts; (d) compare five cases and draw lessons for successful digital innovations for connective action in crop, water, livestock and disease management; and (e) assess how digital applications depend on and/or change innovation and research for development R4D systems.

4. Detailed programme description

4.1 Background and problem horizon

Information and communication technologies (ICTs), such as internet and mobile phone technology, have a profound effect on production processes, knowledge exchange and social relations worldwide. Their perceived capacity to support far-reaching socio-economic change has brought ICT to the centre of the development discourse (Brown & Grant, 2010). To "significantly increase access to ICT and strive to provide universal and affordable access to internet in LDCs by 2020" is one of the proposed sustainable development goals [1]. Some donor agencies' treatment of ICTs as a panacea for poverty reduction, socio-economic development and sustainability [2] might be exaggerated, ICTs are creating profound and often rapid changes in many societies, raising the question how they can be leveraged for sustainable resource management.

Various concepts are currently developed for decentralised and open virtual platforms that enable knowledge generation and exchange, allowing for participation and information access by rural communities. These virtual platforms bring together data and observations from different sources, process them and provide tailored information output for individual and collective decision-making. The concept of environmental virtual observatories for connective action (EVOCA) has been inspired by Environmental Virtual Observatories (EVOs), a new area where interactive Information and Communication Technologies (ICT) converge with life-science approaches to develop participatory solutions for pressing social-environmental problems. EVOCA builds on EVO but adds emphasis on connecting and integrating knowledge and information from various sources as a stimulant for collective and/or coordinated action and response. These virtual platforms may rely on cloud computing or be based on expert centres collecting information, and may be accessed via internet or mobile phones. Examples are flood warning and water management systems in Belgium and the Andes or interactive tools for climate scenarios [3]. However, few such applications can be found in the developing world. This raises questions about the conditions for the successful development of ICT-based life-science innovations in general, and EVOCAs specifically, in development contexts.

The approach taken in this project goes beyond overcoming the digital divide, because experience has shown that a narrow focus on access to ICTs is unlikely to achieve development outcome [4]. Responsible innovation [5] entails an integrated and context-specific approach, which starts from specific development challenges in a particular area and explores the potential of EVOCAs to address these challenges. Through the case studies on crop, water, wildlife and disease management, this project has potential to contribute to the proposed sustainable development goals on food security (goal 2), health (goal 3), and water (goal 6).

Several observations suggest that the context conditions for innovations have improved. The past 10 years have witnessed remarkable growth in the presence and use of mobile phones, internet and computers in developing countries. This has already transformed many societal domains and practices. In agriculture and natural resource management, mobile phones now play an important role in financial transactions and credit systems [6-8]. Mobile phones and internet have also increased price transparency in agricultural markets [9]. Currently, interest in using ICT for agricultural information provision and extension purposes is increasing, as exemplified in the international conference on 'ICT4ag' held in Rwanda in November 2013, including a regional 'Agrihack Championship' (organised by The Technical Centre for Agricultural and Rural Cooperation (CTA), based on the idea of a hackathon) in which young entrepreneurs were competing with concepts and prototypes for ICT solutions for agricultural challenges. However, life-science research has been less engaged in such transformation processes despite great potential for combining novel ICT with life-science applications to address major challenges such as food security, disease prevention and climate change adaptation [10, 11]. Such challenges typically require the altering of interaction patterns in networks of stakeholders (e.g. farmers, value chain actors, consumers, local and national authorities, as well as research, extension and media) based on accumulating insights and informed negotiation. Forging new forms of connectivity around information gathering, analysis and exchange can be highly relevant to support social learning [12, 13] needed to arrive at joint preventive action or problem solving and to go beyond the individual advise offered by classical agricultural extension practices (regardless of whether they include ICT-based or conventional media strategies).

In this context, ICT can be instrumental in the effective provision and integration of life-science and other knowledge where and when it is needed, thereby improving individual and collective decision making and influencing patterns of behaviour and interaction among interdependent actors. The unprecedented speed of data processing allows for real-time generation and distribution of information in the face of threats such as disease, floods, or cyclones, improving the chances for timely response and precaution. Participatory and de-central data generation by citizens can improve the knowledge base for effective governance, e.g., in wildlife and natural resource management. The interactive potential of many digital tools also opens up new avenues for enhancing connectivity, integrating different types of expertise, (collaborative) learning and exchange, and citizen science [14]. From this perspective, there is great potential for EVOCAs to enhance individuals' awareness of choices and their capabilities [15]. An important criterion then becomes whether and how they expand the real freedom that people enjoy to lead the lives that they have reason to value [16].

However, challenges are enormous regarding data quality, operational reliability, effectiveness and equity to end-users' sustainable access, integration of different bodies of knowledge, or adaptation to user needs and capacities [17-20]. Given its participatory and inclusive intentions, EVOCAs require very careful consideration of how interfaces are built and results are communicated, to ensure that the mobilised, shared and integrated knowledge serves the purpose of local people and decision-makers and is not hijacked by technological elites or skimmed by outside actors (such as poachers tracing wildlife). The accumulation of data and the creation of novel information flows also raises questions about informational governance [21], a concept that refers to the observation that information technologies and informational processes are fundamentally restructuring relations, processes, institutions and practices [22].

4.2 Relevance, justification and programme level research questions

The management of crops, water, livestock and diseases is situated at the interface of fundamental development challenges, i.e., food security, disease prevention and climate change adaptation. Attempts to address these challenges typically face a number of coordination problems: a) Knowledge and information is often scattered and insufficiently shared, leading to diverging or ill-informed perceptions of the situation. b) Participation requires sufficient motivation through either individual benefits, incentives, social norms, or shared values. c) Coordination is often impeded by lack of available venues and mechanisms for negotiation among interdependent stakeholders. d) Societal learning required to adapt to complex processes of change is insufficiently enabled through lack of opportunities for exchange and experimentation. In sum, information, perspectives and knowledge from different sources and disciplines need to be brought together and processed to generate and share new insights and enable new ways of acting.

The availability of digital technologies has generated novel opportunities to support knowledge creation in the life sciences in general and in Research for Development (R4D) in particular. The increasing availability of internet and mobile phones – the 'digital revolution' – enables new avenues for the generation, processing and communication of knowledge, the coordination of actions and the creation of communities. Virtual platforms and digital applications are powerful because they: (i) provide real-time access to information for large numbers of people at low cost, (ii) facilitate decentralised and participatory collection and analysis of data (enabling crowdsourcing, citizen science), (iii) personalise and contextualise information provision, (iv) catalyse new forms of dialogue, exchange, learning, network-building and accountability. Consequently, such systems could help to address coordination problems in the management of crops, water, livestock and diseases.

However, to be effective, such information and communication systems require embedding in existing social systems, alignment with user practices and remedies against unwanted data use. Moreover, while digital technology may have the potential to make R4D more inclusive and democratic, it may also create new forms of selectivity and exclusion, e.g. through elite capture of new technology [23]. Moreover, experience with ICT in the development sector suggest that benefits may be short-lived, and that everyday user practices and feedbacks are often insufficiently anticipated and captured during the development process, and hence that there is considerable scope for improving the conceptualisation and design of digital applications [24, 25].

Until now, little is known about the conditions for successful development of virtual platforms and digital applications for crop, water, livestock and disease management that include users in development contexts. Neither do we have insight in how such applications depend on broader innovation support systems, including R4D. This is partly due to the dearth of such projects, and partly to the lack of inquiry into the characteristics of the social-technical systems which enable and shape such innovations and move them from lower to higher levels of technology readiness. Against this background, the programme will address the following research questions.

Research questions - The main question of the programme is: How can life-science knowledge, digital technologies and responsible innovation concepts be leveraged to build inclusive virtual platforms for

environmental information that enable connective action for addressing development challenges in crop, water, health and wildlife management?

This main question is supported by a set of more detailed questions at programme level:

a. Technology characteristics: What capabilities of digital technology (real-time access, crowdsourcing of data, personalisation, social media integration, etc.) are most significant and promising in contributing to responsible innovation in resources, crop and disease management?
b. Design choices: What combinations of life-science knowledge, technology and social organisation are effective to address development challenges and user needs and to contribute to poverty alleviation, sustainable rural livelihoods and social equity?
c. Innovation context: How are design choices enabled or constrained by the broader societal and innovation support environment in which the EVOCA is embedded?
d. Impact: How does the use of EVOCAs affect crop, water, livestock and disease management in the experimental pilots, and what are intended and unintended outcomes at individual, community and innovation support system level (including R4D, agricultural extension, knowledge brokers, media, etc.)?
e. Responsible innovation: What is the contribution of responsible innovation methods and principles in different stages of designing digital life-science innovations, taking into account different contexts and starting points in terms of technology readiness?

4.3 Objectives

We make a distinction between short-term objectives (within the programme period) and long-term objectives. The short-term objectives are:

1. To create and/or further develop environmental virtual observatories for connective action (EVOCAs) as proof of concept for a wider range of participatory digital applications in R4D;
2. To understand the mechanisms and processes through which EVOCAs lead to effective individual and collective responses in crop, water, livestock and disease management;
3. To understand the context conditions for participatory, connective and bottom-up uses of ICT in R4D and to contribute to the realisation of such potentials in life-science innovations in development contexts.
4. To understand and address the development-specific challenges in aligning science-based models, virtual platforms and user inclusion for building EVOCAs in rural Africa.

Long-term objectives are:

5. To improve and upscale user-integrated digital innovation practices in R4D in the life sciences, in particular decentralised knowledge creation, sharing and processing;
6. To enhance the human and institutional capacity of life-sciences and societal actors to collaborate and generate new insights that are relevant to addressing development challenges in crop, water, health and wildlife management.
7. To improve the conditions for effective individual and collective responses to development challenges in and beyond the research sites included in the programme.

4.4 Conceptual framework: responsible innovation

Insights from Innovation Studies and Science, Technology and Society Studies suggest that technological and societal developments are highly interwoven and mutually shape each other [26, 27]. Meaningful innovations inherently involve changes in modes of thinking and social organisation, including changes in the formal and informal rules and arrangements that orient the way humans act and interact, i.e. through institutional change [28]. To this end we conceptualise innovations as a (re-) configuration of 'hardware' (the biophysical dimension: e.g. technical devices, physical practices, ecological feedbacks, bodily skills), 'orgware' (the social dimension: relationships, institutions, organisational forms) and 'software' (the symbolic dimension: knowledge, meanings, visions, discourses) [29]. This analogy is also useful to understand digital innovations. As evidenced by, for example, the significant impact that mobile phones have had on markets and financial systems in developing countries, and the profound influence that digital technology has had on science itself, and society at large, it is clear that we are dealing with innovations that potentially go along with substantial re-ordering of relationships in social systems. In our cases the 'hardware' side of the innovation process relates to both the natural phenomena under investigation (crops, water, livestock, diseases) and the technical aspects of the digital applications that will be developed (mobile telephones, internet infrastructures, bandwidth, etc.). The 'software' dimensions relates to human sense-making and understanding, as connected to information, knowledge, social learning and individual and collective decision-making in the face of challenges and opportunities. Finally, the 'orgware' aspect relates to how social contexts, conditions and relations (including power relations) may shape design choices and

consequences of technology use, as well as to how technological choices and features influence social relationships and connective action.

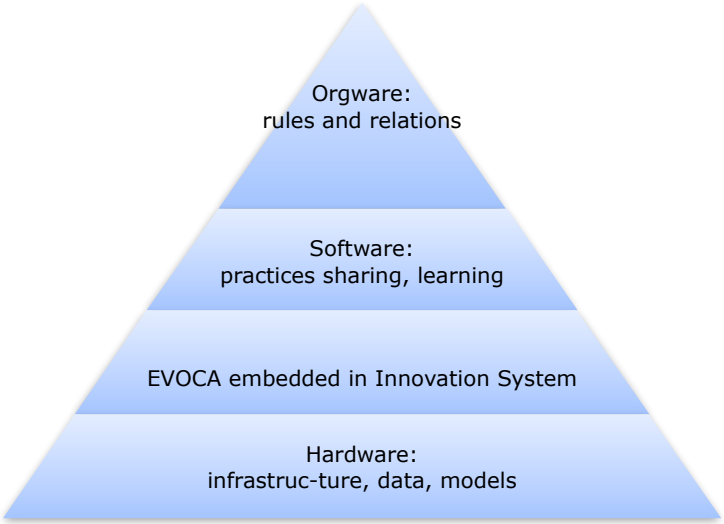


Figure 1: An EVOCA embedded in an Innovation System consisting of hard-, soft- and orgware

To anticipate the intended and unintended societal and developmental consequences that EVOCAs may have on social systems, we will apply a responsible innovation framework [5, 30] in the interactive design component of this programme. The responsible innovation framework systematically addresses questions about the impacts of the *product*, the management of the innovation *process* and the *purpose* of an innovation. Applying this framework means that we will explore and address a number of questions during the design trajectory (see Table 1).

Product questions	**Process questions**	**Purpose questions**
How will the risks and benefits be distributed?	How should standards be drawn up and applied?	Why are researchers doing it?
What other impacts can we anticipate?	How should risks and benefits be defined and measured?	Are these motivations transparent and in the public interest?
How might these change in the future?	Who is in control?	Who will benefit?
What don't we know about?	Who is taking part?	What are they going to gain?
What might we never know about?	Who will take responsibility if things go wrong? How do we know we are right?	What are the alternatives?

Table 1: Lines of questioning on responsible innovation (source: [5]).

Four dimensions of process design are central to responsible innovation [5]:

1. *Anticipation* of potential consequences of the innovation
2. *Reflexivity* on values and assumptions underlying design choices
3. *Inclusion* of all affected parties and viewpoints
4. *Responsiveness* to changing societal demands and concerns

We will operationalise the four dimensions of responsible innovation and apply these during interactions with innovation/R4D platforms that operate at multiple levels. The design process that we envisage aims to move away from linear models of innovation in which public sector agricultural research and extension were seen to deliver new technology in a pipe line configuration, towards a systems approach in which innovation is the result of a process of networking, interactive learning and negotiation among a heterogeneous set of actors [31-33].

The connective action stimulated by both innovation processes and products (EVOCA platforms) may well extend into governance networks, and require the reconfiguration of networks and changes in policies as a precondition for success. Thus, we build upon insights regarding the role of knowledge and information in governance processes [34-36]. Knowledge and information are never neutral because they assume particular problem frames and plausible action strategies. Attention to such situatedness of knowledge is essential to ensure that EVOCAs are meaningful to the intended users and to avoid politicized controversies about the credibility of the

knowledge base Informational governance research [21] has shown that generating new streams of information can fundamentally restructure processes, institutions and practices of environmental governance, because information becomes a crucial resource with transformative power for a variety of actors and networks. The responsible innovation principles will help to assess the impact of EVOCAs on the multi-layered governance systems in which they are embedded. Finally, it is quite clear that science and research systems themselves are transformed as a result of various forms of digitization, both related to scientific methods (e.g. data collection, modelling, genome sequencing, big data), scientific communication (e.g. publishing, network formation) and scientific disciplines (e.g. bio-informatics). Hence, it is important to reflect critically on how we as scientists are conditioned by new opportunities, incentives systems and the politics of scientific agenda setting, and on how digital innovation may affect the organization of the very systems and practices of which we are part as scientists [37].

4.5 Research activities, case selection, programme set-up and staffing

The programme is organised around five case-studies representing different life-science domains and development challenges.

Logic and criteria for case-selection_

A number of considerations played a role in the selection of cases for this programme.

- Life-science domain – cases needed to have a clear link to the Wageningen domains.
- Citizen-science potential – likely relevance of decentralised and participatory data-collection and knowledge integration;
- Need for connective action – challenges addressed by the case should be likely to benefit from greater connectivity and decentralised sharing of information and experience
- Potential for reconfiguration of practices among interdependent stakeholders, leading to more effective preventative and/or curative action.
- Development relevance – cases chosen should have a plausible relevance for improving the position of vulnerable groups.
- Availability and interest of reliable partners – in order to secure co-funding and create optimal conditions for PhD students we prefer to work with partners with whom we have good relations.
- A sufficient degree of technology/software readiness – cases selected should build on pre-existing experiences including the development of prototypes, not necessarily in a development context (see Table for more details).

Ad. Diversity in technology/software readiness – An important concern by the reviewers of the pre-proposal was that developing totally new virtual platforms would be too ambitious, require too much time from PhD students, and hence not allow them to study (un)intended consequences and effects of EVOCAs developed. We have addressed this concern through the following considerations:

- Focusing on digital technologies of varying readiness (see Table 2) rather than on fully matured ones, allows us to implement and study participatory and interdisciplinary design processes according to the principles of responsible innovation.
- This will allow PhD students to generate insights into the social-technical dynamics of the design process, e.g., the background of user preferences, emerging tensions around information and knowledge and their resolution, changing relations among participants, institutional constraints to the development and use of EVOCAs, etc. Thus, we align technical and social science research questions in each PhD project to the degree of knowledge, technology and software readiness.
- In all case studies, the EVOCA will in one way or another be linked to already available technologies such as websites, SMS, Facebook, Twitter or E-mail which will function as an interface for collecting and distributing information. These interfaces can be studied in terms of their potential and implications.

Eventually, we have converged to taking the following actions:

First, we have selected a mixture of cases in terms of knowledge, technology and software readiness. Most cases build on existing experiences and prototypes, albeit not always in a development setting (see Table).

Second, we have added a programme level research question on the contribution of responsible innovation methods and principles in different stages of designing digital life-science innovations, and will pay careful attention to calibrating research questions of individual PhD projects with different degrees of readiness.

Finally, we have acquired co-funding through our involvement with the 'Nature Today' project that is being implemented from November 2014 onwards. Nature Today will build a multi-purpose virtual platform architecture that will allow for:

- easy construction of environmental citizen science observatories with advanced options for observation submission, analysis and visualization options for devices ranging from simple mobile phones, smartphones, tablets to normal desktops;
- integration and visualisation of data and information from external sources;
- content generation, marketing and communication modules that support, guide and stimulate experts to easily communicate news, information and data to the general public or specific stakeholders via mass/ social media;
- various crowd funding / payment services to allow sustainable funding for the developed applications and services after the end of the project and to test business models.

As the EVOCA project also wants to test the usability and acceptance of the digital products, the information produced and the response of society we will develop tools to do these tests properly. In addition, the platform will generate a substantial amount of user data that will become available for the experts involved. The Nature Today platform can be flexibly used for the different digital innovations/ EVOCAs. This software will be ready well before the PhD students start their work. Thus we will have a ready-made basic software infrastructure to build on those cases where no previous prototypes are available.

Cases selected

On the basis of the above criteria we have selected the 5 cases in the following table. Further details for each case are provided in the following section of this proposal.

Case	Software/platform on which the application builds	Application further development	Final product aspired	Final TRL aspired*
Disease management in potato production, Ethiopia	DACOM system in South Africa	DACOM, CIP, PhD candidate in cooperation with local partner.	EVOCA adjusted for smallholder systems	PhD1: TRL 5 PhD2: TRL 3
Water-food-climate nexus in irrigated rice production systems in Ghana	Euporias (EU-FP7 project) seasonal and decadal climate, water and yield forecasting system	PhD students in collaboration with Euporias project, Wienco and KITE	EVOCA with locally specific seasonal to decadal forecasts for rainfall, crop yield & water availability	TRL 6
Malaria mosquito radar in Rwanda	Web-based platforms in NL, SMS-service in Rwandese health context	PhDs in collaboration with local partners Rwanda	EVOCA with Rapid-SMS platform	TRL 5
Tick(borne disease) management with livestock-wildlife interaction in Kenya	Nature Today platform, with sms, suitable Apps (smartphone, WiFi) and web applications. Supported by radio broadcasts.	PhD1 and PhD2 in collaboration with supervision team and Evoca-partners	Operational, tested digital EVOCA built on Nature Today platform, enabling 2-way communication	TRL 7
Sustainable intensification of cocoa and food crop farming systems in Ghana	Grameen Applab based on SMS, pictures, voice messaging, and video; further developed by IITA for farm organization Kuapa Koko	PhDs, IITA, Grameen and SNV	EVOCA for data gathering and visualization supporting learning for farmers, NGO and policy makers	TRL6

*TRL: technology readiness level; TRL 3 – experimental proof of concept; TRL 5 – Technology validated in relevant environment; TRL 6 – Technology demonstrated in relevant environment; TRL 7 - System prototype demonstration in operational environment.

Table 2: Case overview with technology readiness levels

Staffing, team formation and set-up (including number of PhD and MSc students)

This programme will be implemented by 10 PhD students, about 35 (co-)supervisors, a coordinator at Wageningen as well as complementary staff that are added to the programme by partners. In the first phase of the programme a postdoc will play an important role in team building and in acquainting students with the common research framework (see Section 5 Integration and comparison at programme level). In addition, we anticipate that at least 10 MSc students will take on specific research tasks linked to the cases and PhD projects.

Team formation and cross-cutting activities per case - For each case a team will be formed around 2 PhD students (1 with a technical background and 1 with a social science background). All PhDs will have dual supervision, provided by technical and social scientist. The case teams that are formed in this way will go through a joint integral design process [38] inspired by the responsible innovation framework [5] and prototyping [39] (see Methods and Approaches for further details). This process of interactive technology design and experimentation will be embedded in a case-specific multi-stakeholder innovation / Research for Development (R4D) platform (see Section 5 Methods and Approaches).

PhD project specific themes - In addition to the lines of inquiry that derive from the common framework and process, each PhD project has one or more specific technical and/or social science themes.

For PhD students starting from a technical science perspective, this theme is defined by scientific challenges implied by the domain of the case (i.e. crop, disease, water and livestock & wildlife dimensions). Social science inputs and analysis helps these students to align technical research questions to the social context, gain insight in the social implications of technical design choices and generate social science lines of inquiry that are suitable for students with a technical background.

PhD students starting from a social science perspective take on a specific thematic that increases insight in a specific aspect or social dynamic related to e.g. responsibility, innovation systems, the digital revolution or connective action. Input from the technical sciences will help these students to understand the bio-material dimensions and influences of social realities, and align their questions to these.

Comparative research – The programme includes different types and levels of comparison. Within each case relevant dimensions of comparison will be defined as the process evolves. This may lead to comparison between research sites, between user-categories, between design choices, between societal goals and interests, etc.

In addition, PhD students that start from a social science perspective will not only pursue their specific thematic line of research within the primary case to which the student is assigned, but also in at least one other case (see Section 4.2 Comparative research). This comparative dimension will deepen the social science insights generated, enhance programme wide reflection and foster collaboration and cross-fertilization among PhD students.

Broader cross-case comparison along the programme level research questions will primarily be the responsibility of the PhD supervisors, with support of a postdoc that will be acquired through co-funding in the second half of the project period. The overall synthesis will involve cross-case and cross country comparison in view of the programme level research questions.

4.6 Short description of the five case-studies

Case 1: EVOCAs for disease management in potato production, Ethiopia

This case study develops and analyses a model-based decision-support system for potato plant protection with real-time observations in Ethiopia. It features research on the design implications of the bio-physical features of bacterial wilt and late blight, and the way EVOCA can be embedded in existing innovation systems.

Potatoes are a crucial staple food in Ethiopia. The major diseases impeding production are the oomycete *Phytophthora infestans* which causes late blight, and bacterial wilt with the causal agent *Ralstonia solanacearum*. The latter is indigenous in Ethiopia and is becoming increasingly important, also in areas designated for seed production. Late blight is very aggressive and can wipe out a crop within a few weeks if not controlled and when environmental conditions are conducive to sporulation and infestation. Yield losses might be as high as 80%. Available fungicides can control the disease but need to be applied frequently to protect newly formed leaves. For large-scale commercial farms around the world, sophisticated decision-support tools provide advice when to spray. These tools aim to reduce the number of fungicide applications and to optimize their effectiveness in a preventive manner. On the basis of weather forecasts and the occurrence of *Phytophthora* the models predict crop canopy development (how much unprotected canopy is present), inoculum pressure (sporulation intensity), and infection likelihood, and derive advice to farmers.

The system requires a dense network of observations by farmers (and extension officers) on crop infestation. It is therefore a good example of an EVOCA. Its use requires farmers to have direct access to a computer with the appropriate decision-making software. However, an emerging option is to receive text messages with advice through mobile phones by a central office that collects and evaluates information. The Dutch company DACOM has tested such a system for advising local farmers from its central office in the Netherlands, based on weather station and crop information on the ground in South Africa. This test was rather useful but was only evaluated for its potential success in agronomic terms. It is not yet known what is needed to make such a warning system accurate and reliable, how to organize the local set-up (including crop monitoring) and expertise to create the centre providing the advice, and what training for farmers is needed to provide the right information and take proper action.

Bacterial wilt (a.k.a. brown rot, agent: *Ralstonia solanacearum*) is, after late blight, the most important potato disease in Ethiopia. The disease is both seed-borne and soil-borne, and according to some Ethiopian farmers, also vector-borne. As Ethiopia does not have a formal seed potato certification scheme yet and regional quarantine measures are usually lacking in this country, bacterial wilt is rapidly developing into a very serious threat. The disease is currently also encroaching on the highlands, which are supposed to be the perfect environment for the production of healthy seed potatoes. This new development frustrates the programmes aimed at the production of quality declared seed.

Bacterial wilt kills the haulm suddenly and causes the tubers to rot as well. Yield depressions can be 100% and infested seed cannot be used. Moreover, infested land should not be used for potato production for quite some while. Research on control or containment of the disease in Eastern Africa has been carried out but has not led to any significant success.

Regarding both diseases, in order to be effective, the design of an EVOCA needs to be embedded in the current innovation system of potato production, including its hardware, orgware, and software. Employment of responsible innovation approaches will ensure this adaptation is done in a systematic and democratic way. Testing of the EVOCA for Phytophtora will shed light on the effectiveness of mobile phone communication in crop management in the African context, and the conditions for effectiveness.

Case 2: A hydro-climatic EVOCA for the water-food-climate nexus: enabling adaptive action in irrigated rice production systems in Ghana

This case study develops and analyses a virtual platform that links water-climate models and local knowledge to facilitate innovative adaptation to climate change in rice production in Ghana. While decision-making on farming activities (e.g. choice of crops, planting date, irrigation, etc.) in developing countries rely heavily on accumulated experiential knowledge, climate change, is making water availability and crop production more unpredictable. Past experiences on for example timing of the wet season, rainfall intensity, temperatures and availability of river, reservoir and groundwater become less reliable. To improve food security and sustain livelihoods it is important to integrate water and food production systems, thereby taking into account knowledge and information about current and future climate variability.

Recently, forecasting climate variability and change at seasonal to century timescales has seen important advancements. Especially in Africa forecasting has improved substantially over the last few years. While forecasting information is potentially valuable for farmers and water managers, it needs to be translated into locally relevant information and communicated in appropriate formats to allow for coherent planning (planting, fertilizing, etc.). Structural interactions between forecast experts and local knowledge experts – and providing a platform to do so – are therefore essential. However, developing business opportunities for farming and water management from such knowledge exchange and the resulting information services is demanding. In addition, little is known under which conditions these innovative information systems can develop around the water-food-climate nexus so as to empower farmers to innovate management, and perhaps change water and food system governance at large.

This case study focusses on the co-production of a hydro-climatic EVOCA, which integrates seasonal and decadal projections from water and climate models with local knowledge and observations for irrigated rice production systems in Ghana. Increasing rice production in Northern Ghana in particular has become an important governmental objective to reduce its agricultural import and ensure future domestic food security. It is an increasing source of income for smallholder farmers. In Ghana, water supply for irrigated rice production is becoming less reliable due to both increased climate variability and higher water demands. Uncertain water availability undermine agricultural practices resulting in amongst others reduced yields, low quality of rice, and rice production systems that are under pressure. In addition, land tenure and traditional land use systems are poorly documented, hampering irrigation development and support. Addressing these challenges requires improved information on future soil and surface water availability so as to allow for more adaptive management of the water and food systems. But the fully developed EVOCA will provide not only information. The case study will help to

understand whether the connective action enabled by the EVOCA can help to build ownership of the information system, and stimulate the development of a participatory innovation system in the context of an irrigated agricultural system under stress.

The proposed information system is based on an on-line platform, which links up with mobile phone and internet technology (text messaging, apps) and off-line information channels for information input and output to relevant user groups (farmers, water managers and local governments).

The main question this case study will address is: How can an Environmental Virtual Observatory for Connective Action (EVOCA) be developed and implemented to make the water-food-climate nexus in Ghana's rice production systems more sustainable, resilient and secure? Sub-questions are:

- How can hydro-meteorological forecasts in combination with predictions of agricultural production be integrated into an EVOCA enabling connective action for stakeholders and adaptive strategies for irrigated rice production systems in Ghana?
- How can a hydro-climatic EVOCA be embedded in local decision-making and help to develop a responsible innovation system so as to create actionable knowledge for adaptive governance of the food-water-climate nexus in Ghana's rice production systems?

The proposed project will (a) co-develop novel EVOCA for adaptive management of synergies and trade-offs between water and food in irrigated rice production systems in Ghana under changing climate, (b) identify systemic conditions for success of these platforms.

Case study 3: The Malaria Mosquito Radar

Much progress has been made over the past decade in tackling malaria as a global health threat. The recent World Malaria Report from December 2014 (WHO, 2014) estimates that malaria mortality rates have decreased worldwide by 47% between 2000 and 2013. This is largely the result of massive scaling-up of coverage with long-lasting insecticide treated nets (from 3% in 2004 to 49% in 2013), indoor residual spraying with insecticides and the use of artemisinin combination therapies. Despite increased global funding (estimated at 2.7 billion in 2013), the World Health Organization recognizes, however, that emerging resistance to insecticides and to malaria medication may jeopardize current efforts. Importantly, much of the remaining transmission is attributed to 'outdoor' or 'residual' transmission. This is the result of strong selective pressure on the Anopheles mosquitoes that are vectors of the Plasmodium parasite. In response, innovative and unconventional initiatives are needed to eradicate malaria in geographies where pockets of malaria transmission are no longer decreasing. Whereas the research team has been strongly involved in the development of alternative vector control tools [51, 52], the team recognizes that there is a strong need for the active engagement of citizens in a final push that aims for a complete eradication of malaria.

Successful malaria eradication requires that the relevant stakeholders (people at risk, medical staff, ministries, pest control organisations, farmers, etc.) know how, when and where to take which action. At the level of the innovation system, successful malaria prevention requires (1) thorough knowledge about the ecology of the species, (2) detailed spatially and geographically sensitive information about incidences of malaria mosquitoes and their infection status and (3) user-directed information about effective ways to avoid mosquito bites. Gathering the relevant information and communicating to the right people in time is difficult and expensive, posing a major obstacle to effective treatment and prevention. This case study will develop an EVOCA, termed 'Malaria Mosquito Radar' as a tool for the surveillance, analysis and communication of malaria mosquito populations and for the assessment of outdoor malaria transmission.

The Radar will fill a gap in existing Integrated Vector Management programs. The Radar builds on innovative ICT projects in The Netherlands like Tekenradar.nl (Tick), Allergieradar.nl (Allergy), Muggenradar.nl (Mosquitoes) and Natuurkalender.nl (Nature's Calendar). All these have demonstrated that it is possible to involve tens of thousands of 'citizen scientists' and school children in the monitoring of spatial and temporal variation in the occurrence of vectors (ticks and mosquitoes), vegetation (flowering and leaf unfolding), diseases (Lyme disease, hay fever) or nuisance (mosquito bites). The observations are made directly available to the public via websites and mobile applications. The success of these projects is largely due to frequent and active communication of (real-time) observations, forecasts and interpretations to stakeholders and the public via social and mass media. Media attention supports the recruitment, training and motivation of observers and in the dissemination of advice for prevention and treatment.

The main objective of the Malaria Mosquito Radar project is to monitor, analyse, forecast and communicate mosquito population/activity, malaria cases/symptoms and to actively inform stakeholders on when, where and how to implement malaria prevention and treatment activities. The Malaria Mosquito Radar will be developed in close collaboration with the other digital innovations described elsewhere in this proposal. PhD students will work on the social and communication aspects and on the biological and epidemiological aspects.

Case 4: EVOCA for tick (borne disease) management with livestock-wildlife interaction in Kenya

This case creates and analyses an EVOCA that links mobile-phone based observations and Companion Modelling to enable the participatory development of coordinated tick management strategies. In developing countries, livestock is mostly owned by smallholders. Disease reduction in livestock is constrained by domestic animals sharing disease vectors, diseases and grazing lands with wildlife. Besides tsetse flies, ticks are the most widespread vectors and transmit high-impact diseases like East Coast fever, heartwater, bovine babesiosis, and bovine anaplasmosis. E.g., in eastern and much of southern Africa, East Coast fever has a reported a mortality rate of up to 80% in susceptible animals or epizootic situations. The multi-host system makes vectored diseases far more difficult to eradicate than directly transmitted diseases like rinderpest. Moreover, wildlife is an asset, generating important revenues through tourism. Having both wildlife and livestock production zones makes the local control or eradication of animal diseases more difficult and brings wildlife and livestock production into conflict. In addition, sectoral policy development further contributes to high inefficiency in controlling disease transfer.

There are several technologies to reduce tick prevalence such as applying acaricides to livestock, including tick 'mopping' (although the reported effectivity is still debated), treating wildlife by using feeding stations that apply acaricides to larger wild herbivores, vaccination against tick-borne disease such as East Coast fever (ECF) and/or grass sward height reduction through grazing by coarse grazers and/or burning. However, both traditional and modern methods to eradicate ticks and related diseases remain inadequate and prohibitively costly. Tick control measures are often hampered by lack of information on ectoparasite and disease distribution. Acaricide-resistance, high frequency acaricide treatments, and a lack of information and motivation of livestock owners leads to ineffective application. While each of these technologies has some effect, coordinated and well supported action is needed to attain a satisfactory level of tick load management. To ensure a proper design and implementation of coordinated tick management, we need to involve representative actors in the EVOCA design process for (a) local tick data collection, and (b) coordinated tick load management.

The study is primarily located in the Laikipia District, Kenya, where mobile broadband is available. Using mobile phone applications, data on tick abundance is collected by stakeholders. This is fed into technical experiments to assess the effectiveness of the technology for the specific area, after which a conceptual model for multi-stakeholder, coordinated tick management is made. The model includes various types of tick reduction technologies, to explore the effectiveness of various combinations of tick reduction practices, simultaneously executed by different actors in a coordinated manner. Then stakeholder representatives engage in Companion Modelling (COmMod) to discuss and design the most optimal tick management strategy (i.e. a combinations of tick reduction technologies). By means of a Multi Agent System (MAS) simulation model, observations, reflections and actions of agents, and their effect on (geo-referenced) natural resource dynamics (such as vegetation, wildlife, livestock, ticks) are simulated. This allows actors to virtually explore the costs and benefits of various coordinated action scenarios from an individual as well as a collective, coordinated perspective. After an exploration of the trade-offs, the stakeholders propose the tick management strategies they want to include in a real life experiment, with non-participating cattle herders and selected wildlife areas as controls. Careful design of the ComMod model and process, applying principles of responsible innovation, are needed to ensure a feasible, effective and fair contribution of all to the data generation and sharing (connective action), as well as the application of tick reduction measures in the field (coordinated action). Using Nature Today, the integration of the mobile phone application, the technical experiments and the ComMod exercise will result in a web-based EVOCA.

Case 5: Connectivity for sustainable agricultural intensification of cocoa and food crop farming systems in Ghana

In Ghana, the International Institute of Tropical Agriculture (IITA), the Dutch development organisation SNV and the Grameen Foundation use the opportunity of a 84% mobile phone penetration to establish an EVOCA for sustainable intensification in cocoa based farming systems. This case study concerns the further development and analysis of this emerging virtual platform that links science-based geographical maps and climate variability and change forecasts with locality and farm-system specific data. The information generated is aimed at enhancing farmer and community level learning and action, and also at strengthening the position of farmer organisations in influencing policy change.

The large cocoa export sector in Ghana is one of the main drivers of deforestation. Poverty and the migration of youngsters to the urban area lead to labour scarcity and extensive farm practices, and climate change is further decreasing agricultural productivity and driving deforestation, due to temperature stress, variable precipitation patterns and a decrease in reliable crop growing days to critical levels. Meanwhile, extension organisations continue to provide science-based generic advice, rather than locality and farm system specific advice. Hence, farmers heavily rely on their own experiential knowledge.

At this moment, IITA has made a start with baseline data collection to initiate the envisaged ECOVA. Scientists have gathered data on farm systems (number and location of fields, crops, practices, pests incidences, outputs etc., of about 150 farms) which they will combine with climate change forecasts to characterise the diversity of cocoa production systems on climate and intensification gradients in terms of production efficiency, climate change adaptation and mitigation. This information will be used to generate locality and farm-system specific 'best bets' for operational farm practices as well as longer term investments (such as diversification into agro-forestry, rejuvenation and improvement of tree quality). The ICT formats of the Grameen AppLab will be used to make the information available to 35 Farmer Field School Trainers from Kuapa Koko, a farmer-based support organisation in the cocoa sector. The idea is to equip these extension workers with smart phones, train them in the uploading of farm information as well as ICT-based extension activities. Meanwhile, Grameen also looks for another partner to improve the knowledge base and agricultural extension activities of about 50 extension officers in food production via smart-phone applications. So far, Grameen's 'last mile' extension activities consist of a Community Knowledge worker providing general information on best farm practices, decision-support tools and price and weather forecasts transmitted via mobile-phone SMS; pictures, voice messaging, radio listening groups and video uploading. With the assistance of our PhDs, SNV, IITA and Grameen now want to take up the challenge of connectivity: (a) to integrate science-based data bases with user uploaded data, to create a more dynamic and place-specific database, (b) to be able to identify locality and farm system 'best bets' for operational farm practices and longer term investments, and (c) develop communication tools such as SMS, voice, pictures, videos, scenario simulation, games etc. that fit the users' way of knowing, that attract attention and engagement for knowledge exchange/uploading and learning, and stimulate interaction for agricultural intensification.

We hypothesise that the EVOCA concept will enhance connectivity and planning for sustainable agricultural intensification through knowledge exchange, coalition building and cooperation between scientists, farmers (or so-called placeholders), farmer-support organisation and policy makers. We will explore this assumption through participatory action research, deploying different approaches to knowledge integration (hybrid forms of scientific and placeholder knowledge) and communication formats for different and mixed groups.

PhD research will focus on the engagement of scientists, extension workers, and various types of farmers (varying in gender, age, level of education and poverty) in EVOCA-supported knowledge exchange, learning and cooperation for sustainable farm intensification. Specific attention will be paid to analysing and ameliorating new forms of inclusion and exclusion that may be associated with the EVOCA. In addition PhD research will focus on the value of EVOCA – and especially geo-referenced visualisations generated by it – for learning and coalition building among farmer-support organisations, regional agricultural planners and policy makers.

4.7 Location of the programme activities

We will work mainly in two Action Areas of the CGIAR Research Programme Humidtropics (CRP 1.2), namely the 'East and Central Africa' Action Area and the 'West Africa' Action Area. This means that activities will be concentrated in Kenya, Rwanda, Ethiopia and Ghana. See Section 7 on Partnership.

4.8 Expected results and outcomes

Results and outcomes are detailed in the Logical Framework (see Annex 3)

- At least five EVOCA platforms developed and experimented with to the level of technology readiness indicated in Table *2*.
- At least 43 publications in international peer reviewed journals (4 per PhD project plus at least 3 cross-cutting publications).
- 10 PhD theses completed and successfully defended.
- Human and institutional capacity built to capitalise on the potential of integrated EVOCA in at least 15 core partner organisations, and within 5 stakeholder networks around the cases
- 25 Master theses completed
- Sustainable partnerships between Wageningen University, the CGIAR network and participating partner institutions.
- At least 9 educational modules prepared for teaching programmes across Wageningen University, and made available to partner Universities and others.

5. Methods and approaches

Common building blocks per case

The case teams that are formed will go through a joint process inspired by principles of 'integral design' [38], the responsible innovation framework [5] and prototyping [39].

General building blocks of each case include:

1. Diagnosis of technical and social dimensions of the problematic situation, with special emphasis on informational dimensions that hamper effective preventive action and response (individual and collective);
2. Assessment of existing information and knowledge infrastructures, explicit and latent needs and knowledge gaps, and pre-existing initiatives and experiences with digital applications;
3. Interactive conceptualisation and (further) prototype development using the Nature Today ICT platform and/or building on already available software environments;
4. Complementary research on end-users, intermediaries and social-organisational aspects relevant to addressing issues pertaining to responsibility;
5. Societal contextualisation and collaborative experimentation with these digital innovations (as action research, i.e., the research intervenes in social contexts and these interventions are evaluated considering lines of questioning on responsible innovation, see Table 1);
6. Further specification of relevant precise specifications and functionalities of EVOCA as an outcome of the process of experimentation, dialogue and implementation;
7. Assessment of social conditions (constraining and enabling) for successful maturing and use of the digital innovation;
8. Research on induced processes of change and consequences associated with the development and use of digital innovations in the (a) the relevant domain (crop, disease, water and livestock & wildlife management) and (b) the innovation support processes and R4D systems involved.

The PhD students and their supervisors will collaborate closely in the implementation of these building blocks, and divide tasks and leadership roles according to their expertise.

Transdisciplinarity through action research with innovation platforms

This process of interactive technology design and experimentation will be embedded in a case-specific multi-stakeholder innovation / Research for Development (R4D) platforms [66]. These platforms will play an important role in the conceptualisation and design of the EVOCAs, by ensuring that the relevant everyday realities, routines, and implicit and explicit needs of users and stakeholders come to the surface and are taken into account in the design process. Moreover, these platforms form the springboard for working towards effective connective action in dealing with development challenges. Through our experiences with Convergence of Sciences and several CGIAR programme we have a lot of experience with both the potential and pitfalls of such platforms, have led the development of an overview of critical issues to think about when managing such platforms [67], and conducted several training workshops based on these ideas for several partners in this programme. Platforms will be set-up and managed primarily by our partners.

Interdisciplinarity

The essence a good interdisciplinary process is that staff and students are enabled to discover connections between technical, natural and social processes and issues, leading to the formulation of coherent sets of context-sensitive social and natural science research questions [68]. This will be facilitated through various mechanisms: (a) Dual supervision of all PhD's by natural and social scientists; (b) formation of pairs of PhD students with inter-disciplinary composition, cooperating closely in a geographical area leading to mutual cross-fertilization (see also under 'Staffing of the research programme'); (c) sufficient space for field visits by the students and supervisory teams, combined with considerable time for informal interaction; and (d) conducting the integral design process [38] according to the principles and questions of the responsible innovation framework [5] and prototyping [39]. In the phase were PhD students further develop their PhD proposals, we will organise an internal peer review in which special attention will be paid to the coherence and integration of natural and social science questions. This internal peer review process will be continued during the yearly programme workshops.

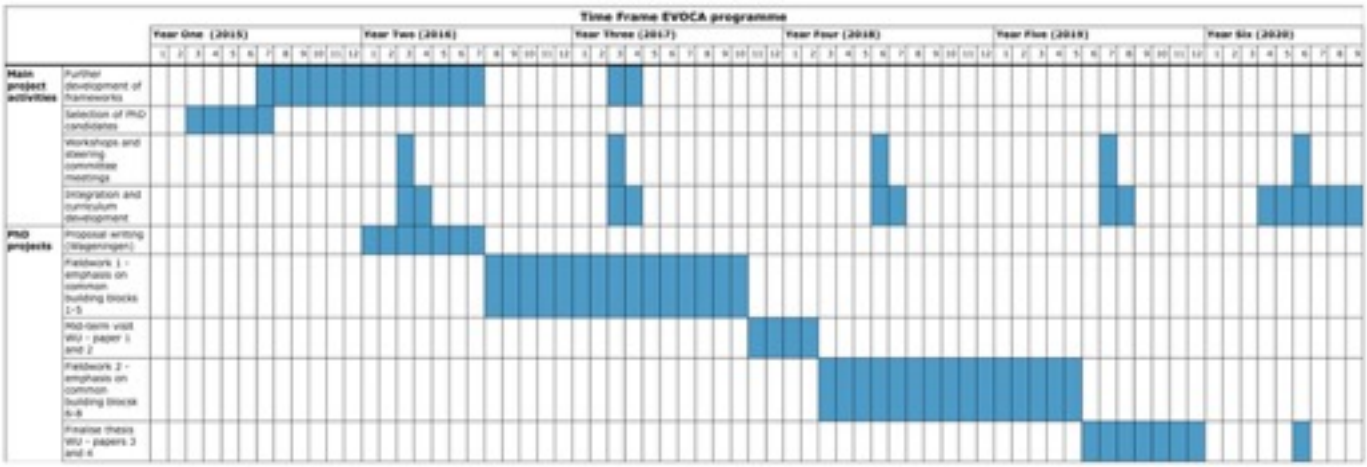
Integration and comparison at programme level

Integration at programme level will dovetail with comparative analysis across cases and geographies (in addition to comparative research within cases; see also under 'Staffing of the research programme'). This will be

carried out by the PhD supervisors (with support of a co-funded postdoc in the second phase of the programme), and to some extent by especially social science PhD students (see . To enhance integration and comparability of cases, all PhDs will be trained in their first year to adopt a common framework which includes the responsible innovation framework, analysis of institutional constraints in the broader environment, and the opportunities and risks framework associated with digital innovation. All PhDs will also be trained in a key set of analytical methods, including documentation of critical events around the design process through 'innovation histories' [69], causal process tracing [70] and interpretive analysis [71]. The programme leaders with support by the postdoc and the supervisors ensure the use of such common frameworks and analytical methods.

Integration at programme level will be organised through (a) cross-cutting working groups around research questions with PhDs, the postdoc and members of the programme team; (b) annual comparative analysis workshops with all PhD students; (c) a four-day 'writeshop' at in year 6 for systematic comparison and case analysis, resulting in identification of patterns in relation to the core questions addressed by the programme. (d) In year 6, the project team will aim to publish three joint special issues on cross-cutting themes, e.g., virtual knowledge platforms for integration of scientists and citizen knowledge and information, design choices for integrated environmental monitoring for connective action, or digital participation in environmental management. Practical integration will be enhanced through guidelines for practitioners for setting up EVOCAs in a responsible manner.

6. Time frame



7. Partnership

Main partners - For reasons pertaining to strategy, practical organisation (available operational infrastructures), enhancing impact and obtaining co-funding, this programme will link closely with the CGIAR Research Programme Humidtropics. This programme is oriented to achieving development impact, and is currently working with innovation and R4D platforms in 4 Action Areas across the world. We will work together with both CGIAR institutes and the case specific actors (including NARES, FOs, GOs and NGOs) that are gathered in already existing innovation and R4D platforms. KTI and COM are already a core partner in Humidtropics since 2012, and leading a Strategic Research Theme on 'Scaling and Institutional Innovation'. Humidtropics core partners who have committed funds to this new initiative are IITA (International Institute of Tropical Agriculture; Icipe (International Centre of Insect Physiology and Ecology); ILRI (International Livestock Research Institute) and FARA (Forum for Agricultural Research in Africa). Associated partners who have committed resources in this context are Grameen Bank, SNV, CIRAD, AfricaRice and CIP (International Potato Centre). In the near future, we hope to add CORAF/ WECARD (West and Central African Council for Agricultural Research and Development) and Addessium as main partners (see Section 9 on co-funding strategy).

The role of the CGIAR institutes and other selected research partners is to fund and provide access to innovation and R4D platforms, give logistic support on the ground, identify and co-fund sandwich PhD students, and collaborate scientifically (e.g. provide daily supervision). See Annex 2 for further information about partners.

Other partners – We will collaborate with several Universities with whom we already have long-standing relationships (including University of Ghana; Université National du Benin, Faculté des Sciences Agronomique; Hawassa University; Arba Minch University in Ethiopia). Through our contacts at these Universities we will recruit

suitable PhD candidates for the programme, and identify complementary scientific backstopping accordingly. The eventual University partners will hence depend on the PhD candidate selection process in year 1. We will also collaborate with CTA (The Technical Centre for Agricultural and Rural Cooperation). Our capacity building efforts at PhD level can be closely aligned with CTA's capacity building efforts in the field of ICT4ag aimed at rural youth. Through CTA we will get in touch with young people who are interested the development of EVOCAs, and be able to disseminate our experiences through a range of channels aimed at professionals. Finally, we can tap into the network of partners form the Information Governance programme coordinated in Wageningen University.

Case-study	**International Partners**
Disease management in potato production in Ethiopia	CIP, Arba Minch University, Irish Aid, Awassa Agricultural Research Center
Water-food-climate nexus in irrigated rice production systems in Ghana	AfricaRice, USD, IWAD, KITE
Malaria mosquito radar in Rwanda	University of Rwanda, Icipe
Tick (borne disease) management with livestock-wildlife interaction in Kenya	ILRI, CIRAD, Veterinary Services Kenya
Sustainable intensification of cocoa and food crop farming systems in Ghana	Grameen Foundation, SNV, IITA

Table 3: Overview of international partners per case (see for details Annex 2)

Strategic importance – The partnership between CGIAR Humidtropics and WU(-INREF) around 'Responsible life-sciences innovations for development in the digital age' and EVOCAs is of strategic importance for both partners. The re-organised CGIAR is under high pressure to demonstrate development relevance, integrate context-sensitive stakeholder knowledge and information, and find ways to reach out to many stakeholders. Enhancing insight in the potential and limitations of digital technologies is critical to this endeavour. Demonstrating relevance is also becoming more and more important for Wageningen University. However, Wageningen University does not (want to) have permanent presence in developing countries, and has relatively limited contact with NARES and other development partners. Here WU and CGIAR can structurally complement each other. Collaboration with Humidtropics is also important because this is one of the few CRPs with an *integrated systems* (instead of commodity or technology) orientation, and hence a structural interest in interdisciplinary and transdisciplinary research. Strengthening the collaboration between WU and CGIAR in this area helps to maintain this (ever contested) niche within the CGIAR and dovetails well with INREF objectives.

The thematic of digital transformation in developing countries, responsible innovation and citizen science will continue to remain important in the next decade. Investing in this topic and the proposed collaborative partnership with the CGIAR, Southern Universities and development partners will allow Wageningen to become a visible and leading international player in this field.

8. Organisation and management of the programme

International Programme Committee - The principal steering and decision body of the programme is the International Programme Committee (IPC). The IPC will be chaired by Prof. Cees Leeuwis (the programme leader) and will include representatives from the collaborating institutes (Dr. Atta-Krah, Dr. Fatunbi, W. Gantt), Wageningen University supervisors (P. Feindt, A van Vliet) and PhD students (Mrs. Munthali). The IPC will meet several times a year through skype meetings, and physically during the yearly programme workshop. Responsibilities include elaboration of workplans, safeguarding quality of interdisciplinary science and academic climate, definition of broad boundaries and criteria for PhD and MSc projects, eventual allocation of supervisory teams, securing of sufficient stakeholder involvement, and attracting additional funds.

Programme management - Daily programme management and coordination will be performed from Wageningen by Prof. Peter Feindt, who is assisted by a programme postdoc during the first year (and beyond, pending co-funding) and an administrator. Responsibilities include orchestrating the further development of the common research framework and process, team building, developing and organising specific trainings for the cohort of PhD students, organisation of yearly workshops, managing relations with partners, internal and external

communication, progress monitoring, financial management and reporting. Daily operations will be coordinated by partner institutes.

PhD selection committee – The selection of PhD candidates is a critically important tasks. A special committee will be appointed to oversee this process. We will insist on open procedures and broad advertising of the positions. Candidates suggested by partners will have to compete with others, and new partners (e.g. Universities or Research Institutes) may join the programme depending on where the selected candidates work or aim to work in the future.

Case Teams - Around each case we will organise a Case Team that consist of the involved PhD students, their supervisors, including a representative of a partner institute. One of the supervisors will act as Team Chair, and is responsible for ensuring regular informal communication and meetings. The responsibilities of the Case Teams include the securing of good working conditions for PhD students, ensuring progress of the responsible innovation and PhD research process, identifying and resolving everyday challenges, and agenda setting for programme management.

Innovation/R4D Platforms - The case-specific multi-stakeholder innovation platforms will – through the responsible design approaches used – play an important role in driving the development of the EVOCAs. The everyday field level coordination and orchestration of these spaces for interaction is provided by the collaborating partners. These partners are already working with and through innovation/R4D platforms or similar spaces for embedding research in society. We will work with and from these existing stakeholder platforms, and foster new linkages and partnerships if appropriate.

Workshops - The yearly workshops are meant to form the key social and intellectual glue and stimulant between the various cases and levels of organisation. Except for the kick-off workshop (which is held in Wageningen), these workshops will be held in one of the research sites. The workshops will provide a safe and stimulating environment for students to: present their work, acquire tailored feedback from several sources, and gain insight in relevant theoretical frameworks and analytical approaches. The workshops will include field visits, and reserve sufficient time for informal in-depth interaction between students and supervisors. Experience shows that informal space for interaction is key for creating an inspiring interdisciplinary environment.

Ongoing web-based interaction: To facilitate ongoing exchange and collaboration, we will create a web-based project platform. Programme member and in particular PhD students will interact through webinars. They are also encouraged to share monthly short video messages about their project.

9. Budget (in €)

The detailed budget is available upon request.

10. WU- Senior Staff/Researchers involved in the programme

WU- Senior Staff/Researchers involved in the EVOCA programme				
WASS	Prof. dr. Cees Leeuwis (KTI)	Prof. dr. Peter H. Feindt (COM)	Prof. dr. Phil MacNaghten (KTI)	Prof. Katrien Termeer (PAP)
	Dr. Robbert Biesbroek (PAP)	Dr. Barbara van Mierlo (KTI)	Dr. Ir. Severine van Bommel (COM)	Dr. Margit van Wessel
	Dr. Art Dewulf (PAP)	Dr. ir. Annemarie van Paassen (KTI)	Dr. Marijn Poortvliet (COM)	Dr. Rico Lie (KTI)
WIMEK	Prof. dr. Rik Leemans (ESA)	Dr. Erik van Slobbe (ESS)	Dr. ir. Arnold J.H. van Vliet (ESA)	Dr. Fulco Ludwig (ESS)
PE&RC	Prof. dr. H.H.T. Prins (REG)	Prof. dr. ir. Paul Struik (CSA)	Prof. dr. ir. Arnold Bregt (GRS)	Prof. dr. ir. Willem Takken (ENT)
	Dr. Frank van Langevelde (REG)	Dr. ir. Ignas Heitkönig (REG)	Dr. ir. Ron van Lammeren (GRS)	Dr. Sander Koenraadt (ENT)
	Dr. Fred de Boer (REG)			

Table 5: WU staff involved in the programme. See for details and roles Annex 6, and for publications Annex 7.

11. Related Programme(s) of Graduate School(s) involved

The programme fits seamlessly with several themes in the graduate schools that are involved. Its focus on linking life-science models with everyday practices and observations makes a key contribution to the WASS research them 'Knowledge in society'. The programme will generate novel insights into innovative valorisation of scientific insights and new ways of co-creation of knowledge between science and society. The realisation, evaluation and comparison of various responsible innovation processes will deliver strongly on the WASS theme 'Responsible Production and Consumption' by understanding the practices and conditions for context-sensitive and participatory innovation systems and their effects.

By underwriting science-based models of social-ecological systems with decentral collection of data and observations, the programme will make an equally strong contribution to the PE&RC theme 'Complex adaptive systems/Innovative nature'. By creating novel connections between scientific knowledge and collaborative management practices, the programme will enable innovate uses of agro-ecological systems.

The citizen science approach of the EVOCAs will enhance the understanding of dynamic ecological systems and their interaction with human activities. The projects will create new data and models about various ecological processes and ecosystems and address key questions of the WIMEK research theme 'Environmental processes and ecosystem dynamics'.

12. Relation with WU education programmes

The programme will liaise with the Informational Governance programme in developing 1 or 2 minors that can be followed by a broad range of Wageningen BSc students, including those from the natural sciences. In any case, findings will become integrated in the existing minor course 'Science Communication and Learning in the Digital Age' (part of the Environmental Education minor). More generally, the findings of this programme will be highly attractive for inclusion in existing courses about communication, innovation and governance that are part of the Wageningen programmes in International Development, Communication Science, Environmental Sciences and Development and Rural Innovation.

Into each of the 10 PhD studies, at least two MSc thesis studies will be integrated so that research under the programme will feed into a range of WUR MSc programmes in practical and mutually productive ways. Master thesis projects will be set up for students from the following programmes: Master of Geo-Information Sciences (MGI); Master of International Development Studies (MID); Master of Development and Rural Innovation (MDR); Master Forest and Nature Conservation (MFN); Master Biology (MBI); Master Plant Sciences (MPS); Master Communication Science (MCS); Master International Land and Water Management (MIL); Master of Environmental Sciences (MES).

Moreover, each contributing group in Wageningen will be tasked to develop at least one educational module of 1 ECTS credit that can be included in an existing Wageningen MSc course under their jurisdiction. These modules will also be made available to our Southern partners for inclusion in their curricula and training activities, and communicated to wider audiences through various channels operated by CTA and Humidtropics.

13. References

1. United Nations, 2014, *Sustainable Development Goals*.
2. Brown, A. and G. Grant, 2010. *Highlighting the Duality of the ICT and Development Research Agenda.* Information Technology for Development, 16(2): 96–111.
3. Buytaert, W., et al., 2012. *Web-Based Environmental Simulation: Bridging the Gap between Scientific Modeling and Decision-Making.* Environmental science & technology, 46: 1971–1976.
4. Galperin, H., 2010. *Goodbye digital divide, Hello digital confusion? A critical embrace of the emerging ICT4D consensus.* Information Technologies & International Development, 6: 53–55.
5. Stilgoe, J., R. Owen, and P. P. Macnaghten, 2013. *Developing a Framework for Responsible Innovation.* Research Policy, 42(9): 1568-1580.
6. Qiang, C.Z., et al., 2012, *Mobile Applications for Agriculture and Rural Development*. Washington, DC: World Bank.
7. Torera, N. and J. Van Braun, 2006, *Information and Communication Technologies for Development and Poverty Reduction. The Potential of Telecommunications*. Baltimore, ML: Johns Hopkins Univ. Press.
8. Chowdhury, S.K., 2006. *Investment in ICT Capital and Economic Performance of Small and Medium Scale Enterprises in East Africa.* Journal of International development, 18: 533-552.
9. Muto, M. and T. Yamano, 2009. *The impact of mobile phone coverage expansion on market participation: Panel data evidence from Uganda.* World Development, 37(12): 1887–1896.
10. Chapman, R. and T. Slaymaker, 2002, *ICTs and Rural development: Review of the Literature, Current Interventions and Opportunities for Action. ODI Working paper 192*. London: ODI.
11. Asenso-Okyere, K. and A. Mekonnen, 2012, *The Importance of ICT in the Provision of Information for Improving Agricultural Productivity and Rural Incomes in Africa. WP 15*. New York: UNDP.

12. Leeuwis, C. and P. R., eds. 2002, *Wheelbarrows full of frogs. Social learning in rural resource management*. Royal Van Gorcum: Assen.
13. Pahl-Wostl, C., et al., 2007. *Social learning and water resources management.* Ecology and Society, 12(2).
14. Buytaert, W., et al., 2014. *Citizen science in hydrology and water resources: opportunities for knowledge generation, ecosystem service management, and sustainable development.* Frontiers in Earth Science, 2: 1–21.
15. Kleine, D., 2010. *ICT4WHAT?-Using the choice framework to operationalise the capability approach to development.* Journal of International Development, 22(5): 674-692.
16. Sen, A.K., 1999, *Development as freedom*. Oxford: Oxford University Press.
17. Hamel, J.-Y., 2010, *ICT4D and the Human Development Capabilities Approach: the Potentials of Information and Communication Technology. Hum. Dev. Res. Paper 2010/37*. New York: UNDP.
18. Madon, S., et al., 2009. *Digital Inclusion Projects in Developing Countries: Process of Institutionalization.* Information technology for development, 15(2): 95-107.
19. Unwin, P.T.H., 2009, *ICT4D: Information and Communication Technology for Development*. Cambridge Cambridge University Press.
20. Heeks, R., 2002, *E-governance in Africa: Promise and Practice*. Manchester: Institute for Development Policy and Management.
21. Mol, A.P.J., 2008, *Environmental Reform in the Information Age: The Contours of Informational Governance*. Cambridge: Cambridge University Press.
22. Gray, D. and T. Vander Wal, 2012, *The connected company*. Sebastopol: O'Reilly Media.
23. Platteau, J.-P., 2004. *Monitoring Elite Capture in Community-Driven Development.* Development and Change, 35(2): 223–246.
24. IDS, 2013, *Understanding 'the users' in technology for transparency and accountability initiatives. IDS Policy Briefing 40, October 2013*.
25. McGee, R. and R. Carlitz, 2013, *Learning study on 'The users' in Technology for Transparency and Accountability Initiatives*. Brighton, The Hague & Nairobi: IDS, Hivos & ATTI.
26. Bijker, W.E. and J. Law, 1992, *Shaping technology/building society: Studies in sociotechnical change*. Cambridge MA: MIT Press.
27. Geels, F., 2002, *Understanding the dynamics of technological transitions. A co-evolutionary and socio-technical analysis*. Enschede: Twente University Press.
28. North, D.C., 1990, *Institutions, Institutional Change and Economic Performance*. Cambridge: Cambridge University Press.
29. Leeuwis, C., 2013, *Coupled Performance and Change in the Making. Inaugural lecture*. Wageningen University: Wageningen University.
30. Von Schomberg, R., 2011, *Towards Responsible Research and Innovation in the Information and Communication Technologies and Security Technologies Fields*. Available at SSRN 2436399.
31. Dewulf, A., et al., 2005. *How indigenous farmers and university engineers create actionable knowledge for sustainable irrigation.* Action Research, 3(2): 175–192.
32. Rivera, W.M. and R.V. Sulaiman, 2009. *Extension: Object of reform, engine for innovation.* Outlook on Agriculture, 38: 267–273.
33. Röling, N., 2009. *Pathways for impact: Scientists' different perspectives on agricultural innovation.* International Journal of Agricultural Sustainability, 7: 83–94.
34. Gerritsen, a.L., M. Stuiver, and C.J.A.M. Termeer, 2013. *Knowledge governance: An exploration of principles, impact, and barriers.* Science and Public Policy, 40(5): 604–615.
35. Mol, A.P.J., 2006. *Environmental governance in the Information Age: the emergence of informational governance.* Environment and Planning C, 24(4): 497–514.
36. Soomai, S.S., P.G. Wells, and B.H. MacDonald, 2011. *Multi-stakeholder perspectives on the use and influence of "grey" scientific information in fisheries management.* Marine Policy, 35(1): 50–62.
37. Sumberg, J. and J. Thompson, eds. 2012, *Contested agronomy. Agricultural research in a changing world*. Routledge & Earthscan: New York & London.
38. Leeuwis, C., 1999, *Integral design: innovation in agriculture and resource management*. Wageningen/ Leiden: Mansholt Institute / Backhuys Publishers.
39. Dey, A.K., G.D. Abowd, and D. Salber, 2001. *A conceptual framework and a toolkit for supporting the rapid prototyping of context-aware applications.* Human-computer interaction, 16(2): 97-166.
40. Cooke, L.R., et al., 2011. *Epidemiology and Integrated Control of Potato Late Blight in Europe.* Potato Research, 54: 183–222.
41. DACOM, undated. undated; Available from: http://en.dacom.nl/content/uploads/2014/03/Factsheet-Emerging-Farmers-South-Africa.pdf.
42. Gorfu, D., G. Woldegiorgis, and B. Kassa, 2013. *Bacterial wilt: an emerging threat to Ethiopian potato industry*, in *Seed potato tuber production and dissemination experiences, challenges and prospects. Proceedings of the National Workshop on Seed Potato Tuber Production and Dissemination, 12-14 March 2012*, G. Woldegiorgis and et al. , Editors: Bahir Dar, Ethiopia.
43. Foster, C. and R. Heeks, 2013. *Conceptualising inclusive innovation: modifying systems of innovation frameworks to understand diffusion of new technology to low-income consumers.* European Journal of Development Research, 25(3): 333-355.
44. IPCC, 2014, *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Working Group II Contribution to the IPCC 5th Assessment Report*.

45. Rodrigues, L.R.L. and et al., 2014. *Seasonal forecast quality of the West African monsoon rainfall regimes by multiple forecast systems.* J. Geophys. Res. Atmos., 119.
46. Patt, A., P. Suarez, and C. Gwata, 2005. *Effects of seasonal climate forecasts and participatory workshops among subsistence farmers in Zimbabwe.* Proceedings of the National Academy of Sciences of the United States of America, 102(35): 12623-12628.
47. Angelucci, F., A. Asante-Poku, and P. Anaadumba, 2013, *Analysis of incentives and disincentives for rice in Ghana. Technical notes series, MAFAP*. Rome: FAO.
48. De Pinto, A., et al., 2012, *Climate change, agriculture, and foodcrop production in Ghana. Policy note #3, International Food Policy Research Institute (IFPRI)*.
49. USAID, 2011, *Ghana climate change vulnerability and adaptation assessment*. Washington, DC: United States Agency for International Development (USAID).
50. Yaro, J.A., 2013. *The perception of and adaptation to climate variability/change in Ghana by small-scale and commercial farmers.* Reg. Environ. Change, 13: 1259–1272.
51. Bukhari, T., W. Takken, and C.J.M. Koenraadt, 2013. *Biological tools for control of larval stages of malaria vectors - a review.* Biocontrol Science and Technology 23: 987-1023.
52. Takken, W. and B.G.J. Knols, 2009. *Malaria vector control: current and future strategies. .* Trends in Parasitology, 25(3): 101–104.
53. Ingabire, C.M.e.a., 2014. *Community mobilization for malaria elimination: application of an open space methodology in Ruhuha sector*
Rwanda. Malar. J. , 13: 167.
54. Van den Berg, H. and W. Takken, 2009. *Evaluation of integrated vector management.* Trends in Parasitology, 25: 71–76.
55. Berggoetz, M., et al., 2014. *Tick-borne pathogens in the blood of wild and domestic ungulates in South Africa: interplay of game and livestock.* Ticks and tick-borne diseases, 5: 166-175.
56. Homewood, K., et al., 2006. *Livestock health and socio-economic impacts of a veterinary intervention in Maasailand: infection-and-treatment vaccine against East Coast fever.* Agricultural Systems, 89: 248-271.
57. Swai, E.S., et al., 2005. *Farm constraints, cattle disease perception and tick management practices in pastoral Maasai community-Ngorongoro, Tanzania.* Livestock Research for Rural Development, 17(2).
58. Ogden, N.H., et al., 2005. *Risk factors for tick attachment to smallholder dairy cattle in Tanzania.* Preventive veterinary medicine, 67: 157-170.
59. Barreteau, O., C. Le Page, and P. D'Aquino, 2003. *Role-playing games, models and negotiation processes.* Journal of Artificial Societies and Social Simulation, 6(2).
60. Barnaud, C. and A. van Paassen, 2013. *Equity, power games and legitimacy: Dilemmas of participatory natural resource management.* Ecology and Society, 18(2): 21.
61. Deloitte and GSMA, 2012, *Sub-Sahara Mobile Observatory 2012*.
62. Van Paassen, A., N. De Ridder, and L. Stroosnijder, 2011. *The role of an explorative model SHARES for social learning about agricultural development in Burkina Faso.* International Journal for Sustainable Agriculture, 9(2): 310-321.
63. DeLyser, D. and D. D. Sui, 2014. *Crossing the qualitative-quantitative chasm II: Enduring methods, open geography, participatory research and the fourth paradigm.* Progress in Human Geography 38(2): 294-307.
64. Sui, D. and D. DeLyser, 2012. *Crossing the qualitative-quantitative chasm I: Hybrid geographies, the spatial turn, and volunteered geographic information (VGI).* Progress in Human Geography, 36(1): 111-124.
65. Askins, K. and R. Pain, 2012. *Contact zones: participation, materiality, and the messiness of interaction.* Environment & Planning D, 29: 803-821.
66. Adekunle, A.A. and A.O. Fatunbi, 2012. *Approaches for setting-up multi-stakeholder platforms for agricultural research and development.* World Applied Sciences Journal, 16(7): 981-988.
67. Boogaard, B., et al., 2013, *Critical Issues for Reflection when Designing and Implementing Research for Development in Innovation Platforms. Report for the CGIAR Research Program on Integrated Systems for the Humidtropics*. Wageningen: Knowledge, Technology & Innovation Group.
68. Leeuwis, C. and (with contributions by A. Van den Ban), 2004, *Communication for rural innovation. Rethinking agricultural extension*. Oxford: Blackwell Science.
69. Klerkx, L., N. Aarts, and C. Leeuwis, 2010. *Adaptive management in agricultural innovation systems: the interactions between innovation networks and their environment.* Agricultural Systems, 103: 390–400.
70. Pawson, R. and N. Tilley, 1997, *Realistic evaluation*. London: Sage.
71. Dewulf, A., B. , et al., 2009. *Disentangling approaches to framing in conflict and negotiation research: A meta-paradigmatic perspective.* Human Relations, 62(2): 155-193.