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Systems Action Design Research

Delineation of an Application to Develop Hybrid Local Climate Services

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SYSTEMS ACTION DESIGN RESEARCH – DELINEATION OF AN APPLICATION TO DEVELOP HYBRID LOCAL CLIMATE SERVICES

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Abstract

In this thesis, a Systems Action Design Research (SADR) model was developed, which allows the Action Design Research Paradigm to be extended to process hybrid systems of stationary or changing interacting systems; including both quantitative and qualitative aspects. The crucial challenge is to get the experts and grass-root end-users to work together actively in a participatory and co-creative way instead of the foremost current expert dominated practices. Hence the basic model is engaged with an epistemic Delphi entry process, which considers the particular application. This study delineates a unique application to develop hybrid local climate services, which take into account also humanitarian values and presents three case studies done in Mozambique, Kenya, and Tanzania conducted by design thinking.

Keywords: action design research, hybridity, interacting systems, epistemic Delphi process, humanitarian values, case study

Tiivistelmä

Tutkimuksessa on kehitetty vuorovaikutteisten järjestelmien toiminnan suunnittelun tutkimusmalli, joka laajentaa aikaisempia toiminnan suunnittelun tutkimusmalleja stationaarisiin tai muuttuviin vuorovaikutteisiin mahdollisimman kokonaisvaltaisiin eli hybrideihin järjestelmiin. Malli ottaa huomioon sekä määrällisiä että laadullisia tekijöitä.

Vielä nykyisin vallalla olevien asiantuntijapainotteisten käytäntöjen välttämättömänä haasteena on saattaa asiantuntijat ja ruohonjuuritason loppukäyttäjät työskentelemään yhteisen luovuuden merkeissä osallistavalla tavalla. Tästä syystä kehitetyn mallin olennaisena osana on episteeminen, sovelluskohtainen Delphi-prosessi.

Sovelluksena toteutettavien hybridien paikallisten loppukäyttäjien tietotarpeita palvelevien mobiili-ilmastomallien osalta viitoitetaan tämän sovelluksen pääpiirteet tutkimuksessa esitetyn mallin näkökulmasta sekä esitetään kolmen Itä-Afrikassa (Mosambik, Kenia ja Tansania) suunnitteluajattelun mukaisesti toteutetun ideointiprojektin ehdotukset. Kehitettävissä mobiili-ilmastopalveluissa otetaan soveltuvin osin huomioon myös humanitaariset arvot. Tulokset osoittavat, että kehitetty malli voi avata uusia näköaloja hybridien paikallisten mobiili-ilmastopalvelujen kehittämiseen ruohonjuuritason viljelijöille.

Avainsanat: toiminnallinen suunnittelututkimus, kokonaisvaltaisuus/hybridisyys, vuorovaikutteiset järjestelmät, episteeminen Delphi-prosessi, humanitaariset arvot, tapaustutkimus

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It was in Maputo in 2010 when my coming supervisor Prof. Erkki Sutinen who was the Chief Technical Advisor of the Programme of Cooperation in Science, Technology and Innovation between Finland and Mozambique (STIFIMO) asked me to join the program where this journey began. His invitation led to a collaboration with the Mozambique National Meteorological Institute (INAM), District Services of Economic Activities of the Chókwè District Administration/Gaza Province (SDAE/CDA), the South Zone Center of the Mozambican Institute of Agricultural Research (SZC/IIAM) and Instituto Politechnico de Gaza (ISPG). Our aim was to develop innovative community climate services for agriculture (DICCLISEAG) for Chókwè District in Limpopo Delta Area. My sincere thanks to MCT, INAM, SDAE/CDA, SZC/IIAM, and ISPG for the accomplishment of DICCLISEAG. From these institutes and organizations, I would like to thank, Prof. António Leão, Dr. Moises Benessene, BSc (Tech) Inacio Mugabe, BSc (Tech) Zacarias Massango (Vet Med) and Dr. Horténcio Commisiona. In addition, my thanks to Mr. Gabriel Chongo for interpretation.

After my return from DICCLISEAG I started my doctoral program as a remote student at the School of Computing, University of Eastern Finland, Joensuu under the supervision of Prof. Erkki Sutinen and anthropologist, Dr. Silvia Gaiani. During the years 2012-2015 I drafted the theory of Systems Action Design Research (SADR) and joined the second mission to Sub-Saharan Eastern Africa to Eldoret and Marigat, Kenya. This was a joint project of the School of Forestry of the University of Eldoret (SF/UOE), the School of Forestry, University of Eastern Finland, Joensuu (SF/UEF) and the School of Computing, University of Eastern Finland, Joensuu (SC/UEF). The project was funded by the Centre for International Mobility, Helsinki, Finland (CIMO) under its Higher Education Institutions Institutional Cooperation Instrument (HEI ICI) and North-South-South Higher Education Institution Network Programme (North-South-South) programs.

Under the umbrella project "Building further capacity in Kenya: Strengthening practical and ICT aspects towards multidisciplinary and community-engaged forestry education" (SFEK) together with SF/UOE and the Marigat Research Sub Centre of Kenyan Forest Research Institute (MRSC/KEFRI) as local hosts a joint project "Holistic grass-root mobile climate services" (HGMCSs) was started with SF/UEF and SC/UEF. Following mission two of SFEK "Improvement of forest education curricula at MSc and PhD levels" they jointly carried through a new MSc (Forestry) course "Forest Management in a Varying and Changing Climate" (FMVCC).

From the Kenyan partners I would like to thank Prof. Balozi Kirongo and the Faculty Dean, Prof. Lazare Etiegni for facilitating FMVCC, and MSc (Environmental economy) Simon Choge of MRSC/KEFRI for establishing the contacts to the Njemps and Tugen communities and choosing their interviewees. Interpreters allocated by the local hosts helped us in the interviews, which they translated to us from the local language to English.

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The last and completing phase of my remote doctoral studies started in the spring term of 2016 at the Department of Information Technology and with its current name Department of Future Technologies of the University of Turku. First, I wrapped up the early and incomplete development of my SADR concept together with my supervisor, Prof. Erkki Sutinen, as a research in progress article for the DESRIST 2017 conference (article PV in my doctoral thesis).

Taking into account the outcomes and experiences of our former two missions we started to plan our third mission to Sub-Saharan Eastern Africa, this time to Tanzania by contacting the Sokoine University of Agriculture (SUA) in Morogoro City. After agreeing to start a joint test experiment we sought after an appropriate local community within a reasonable distance from Morogoro City. Knowing of the sustainable work of Christian missionaries in Tanzania we contacted FELM, the renamed Finnish Missionary Society, with its traditions. Thanks to Dr. Jyri Kamppainan of FELM we were lucky to establish contacts with the Tanganyika Christian Refugee Service (TCRS) and more precisely with its Morogoro Office (MO/TCRS). By utilizing former co-workers of Prof. Sutinen we contacted also College of Business Education (CBE) in Dar es Salaam and got help from them in visa formalities to enter Tanzania.

Both TCRS and SUA facilitated our mission in Morogoro. I would like to thank Dr. Emmanuel Shangweli, the Director of TCRS, BBA (Finance) Nguno Chugga, then Director of TCRS Morogoro office, and the then Tambuu Area Facilitator of TCRS (TAF/TCRS), Ms. Mwanamina Jumanne for their sincere devotion to our project, to make our mission a success. Taking into account the limited time and funding of our mission Ms Jumanne had chosen collaborative and representative interviewees of Tambuu community for our interviews. This meant also formal approval and support by Ward Councilor of Tambuu Ward, Mr. Ponsian Kolwa, Tambuu Village Executive Officer, Mr. John Paschal, and Tambuu Village Chairperson, Mr. Omary Mfaume. My thanks go to all of them as well as Ms Viola Lema, the Second Teacher – Tambuu Primary School and the Team Leader to Fish Ponds, Mr. Madaraka Ally. Mr. Chugga, and MSc (Economy) & MSc (Sociology) Ezra Misaki of CBE worked as our interpreters during the interviews held in Swahili. With our team of three persons the collected data of the mission in April 2018 consisted of video-recorded interviews in Swahili. Thank you, Dr. Ernest Mauya of SUA who helped us at the very beginning to establish our contacts to SUA and to get in contact with our principal focal person, Senior Librarian Dr. Wulystan Mtega. Our team thanks SUA for facilitating our three one-day trips from Morogoro City to Tambuu Village. I thank the Rector, Prof. Emanuel Mjema and Dr. Emmanuel Munishi of CBE for their invaluable help in our visa arrangements, arrival and trip from Dar es Salaam to Morogoro.

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List of original publications

PI: Helminen, Jaakko, Antonio José Leão, Ville Myllynpää, Silvia Gaiani, Mikko Apiola, and Erkki Sutinen 2019a 'Towards a Design Research Model for Climate Services: Experiences from a Development Project in Mozambique.' In: Fisseha Mekuria, Ethiopia Nigussie, Tesfa Tegegne (Eds.) Information and Communication Technology for Development for Africa, Second International Conference, ICT4DA 2019, Bahir Dar, Ethiopia, 28 – 30 May 2019. Revised Selected Papers. Communications in Computer and Information Science, 1026, pp. 260-269. Springer Nature Switzerland AG, Cham, Switzerland.

PII: Helminen, Jaakko, Balozi Bekuta Kirongo, Silvia Gaiani, Ezra Misaki, Mikko Apiola and Erkki Sutinen 2019b 'Experiences from a Development Project in Kenya – Baselines for Future Climate Information Systems.' In: Nielsen, Petter, and Honest Christopher Kimaro (eds.) Information and Communication Technologies for Development. Strengthening Southern-Driven Cooperation as a Catalyst for ICT4D. 15th IFIP WG 9.4 International Conference on Social Implications of Computers in Developing Countries, ICT4D 2019, Dar es Salaam, Tanzania, 1 – 3 May 2019, Proceedings, Part I. IFIP Advances in Information and Communication Technology, IFIPAICT, 551, pp. 366-377. Springer Nature Switzerland AG, Cham, Switzerland.

PIII: Helminen, Jaakko, Ville Myllynpää, Mikko Apiola, Moammar Dayoub, Tomi Westerlund, and Erkki Sutinen 2018 'Community Climate services for Small-Scale Farmers in Tanzania.' In: 2018 IST-Africa Week Conference, Gaborone, Botswana 9 – 11 May, IST-Africa 2018, IEEE.

PIV: Helminen, Jaakko, Werner Ravyse, Mikko Apiola, Silvia Gaiani, Ezra Misaki, Nguno Chugga and Erkki Sutinen 2019c 'Experiences from Tanzania – interview experiment in co-designing future local climate services.' In: Proceedings of the IEEE Africon Conference, AFRICON 2019, Accra, Ghana, 25 – 27 Sep 2019.

PV: Helminen, J., and Sutinen, E., 2017. 'Design of Science Research for Holistic Climate Services.' In: Maedche, A., vom Brocke, J., Hevner, A. (eds.) Designing the Digital Transformation: DESRIST 2017. Research-in-Progress Proceedings of the 12th International Conference on Design Science Research in Information Systems and Technology. Karlsruhe, Germany 30 May – 1 Jun. Karlsruhe: Karlsruher Institut für Technologie (KIT). pp. 83-91. Cork Open Research Archive (CORA), University College Cork, Ireland.

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Chapter 1

Introduction

During this research, the author developed a Systems Action Design Research (SADR)-model for a better understanding of stationary and interacting systems. The developed SADR-model consists of two parts, the management part (MT/SADR), which manages the application, and the application part (DPP/SADR), which is a model for a, particularly practical solution. Besides, DPP/SADR steers, to a certain extent, the MT/SADR.

Before presenting the SADR model, this thesis discusses the background of the demands of local climate services, which cover the needs of grass-root end-users. The objective of the developed services is to get them to fulfill the demands to a feasible and balanced extent, as holistic as possible. Such services we call hybrid local climate services. By feasible and balanced extent, the author of this thesis means climate services, which meet the current scientific knowledge and also, favors the promotion to enhance the respect of fundamental humanitarian values.

After discussing the background, this thesis proceeds with the SADR model and its components MT/SADR as well as DPP/SADR. The author of this thesis delineates the development of hybrid local climate services to meet demands of grass-root end-users in a feasible and balanced way. As the first step, the author of the thesis and his research groups have implemented three exploratory ideation projects in East Africa: in Mozambique, Kenya, and Tanzania. This thesis presents and discusses the outcomes, recommendations, and lessons learned from these projects.

1.1 Background and motivation for the research

The idea for this thesis originated from the need to develop hybrid grass-root mobile local climate services (HMLCSs) for smallholder farmers in developing countries, especially in Africa. The recent advances in design science research (DSR) offered a good starting point for this demanding task

Several recent milestones guided these efforts noted amid the discourse with regards to the ongoing climate change and changes in climate variability as well as in regards to the growing concerns of humanity.

First, the World Humanitarian Summit (WHS) 2016 released the Agenda for Humanity (UN Office for the Coordination to Humanitarian Affairs, 2016a) and emphasized the role of climate in High-Level Leaders' Round Table Five "Natural Disasters and Climate Change: Managing Risks & Crises Differently" (UN Office for the Coordination to Humanitarian Affairs, 2016b). Secondly, the United Nations (UN) General Assembly (UN, 2015) updated the Sustainable Development Goals (SDGs) as "The 2030 Agenda for Sustainable

Development". Its Goal 13 (Climate Action) states, "take urgent action to combat climate change and its impacts."

Thirdly, the UN Framework Convention on Climate Change (UNFCCC) approved, at its Conference of Parties (COP) (COP21; Paris 30 November – 12 December 2015) the Paris Agreement (UNFCCC, 2015), in which a vast majority of UN members initially agreed to keep the global mean temperature rise well below 2 degrees of centigrade above the pre-industrial level and to pursue the rise to be dropped to 1.5 degrees of centigrade. With regards to the continued climate change, three kinds of changes are present:

i) The trend-like climate warming, about which the climatologists have warned already for several decades. In its global climate monitoring, the World Meteorological Organization (WMO) has confirmed the climate warming to take place with uneven spatial distribution;

ii) The Intergovernmental Panel on Climate Change (IPCC) has reported (IPCC, 2018), among many other aspects, changes in climate variability, which have affected, e.g., agriculture and even more so the rain-fed agriculture. People in Sub-Saharan Eastern Africa have been confused about the irregularities of rainfall during recent rain seasons with prolonged dry spells in between. Also, the pronounced annual variation of precipitation has affected crop yields in extra-tropical regions. Recently it has been pointed out that climate mitigation and adaptation are interacting processes in the context of land-use management, and

iii) changes in climate variability have caused increases in uncertainties of climate changes. Instead of attributing successes or failures to luck in various business decisions and medical treatments (Kahneman, 2011), the expert information on climate changes is becoming increasingly useful. Therefore we should talk about uncertainty rather than referring to factors such as luck in climate discourses.

World Meteorological Organization (WMO) paid attention to the demand of hybrid climate services by organizing two early conferences: WMO Conference of Living with Climate Variability and Change: Understanding the Uncertainties and Managing the Risks (LWCVC) (17-21 July 2006; Espoo, Finland) (WMO, 2009a), and International Conference on Secure and Sustainable Living: Social and Economic Benefits of Weather , Climate and Water Services (19-22 March 2007; Madrid, Spain) (WMO, 2009b). The outcome of the previous conference was expressed in its Espoo Statement (WMO, 2009, 1-2), which is still valid and reads as follows:

“Espoo Statement

The participants of the WMO Conference, cosponsored by FMI and IRI, on "Living with Climate Variability and Change", held in Espoo, Finland July 17-21 2006, being experts in natural disasters, public health, energy and the built environment, water resources, agriculture and food security, decision-related sciences, and policy and climate, declare as follows:

We recognize that every primary social, economic, and environmental sector is sensitive to climate variability and change, both of which are significant factors in each sector's sustainable development.

We agree that policy formulation and operational decision-making in climate-sensitive sectors will be improved by the more widespread use of climate knowledge and information in managing risks and exploiting opportunities (collectively referred to as climate-related risk management).

We recognize that the process of developing effective climate-related risk management works best if it is:

- *driven by the needs and requirements expressed by relevant decision sectors*
- *developed within real-world decision contexts*
- *enabled through facilitating institutions and policies*
- *based on environmental, sectoral and socioeconomic data*
- *based on tailored climate information*
- *supported by local capacity*
- *supported by sector-specific services from National Meteorological and Hydrological Services and related institutions.*

We note that climate-related risk management requires multidisciplinary collaborations and the cross-disciplinary exchange of information, such as can be achieved through interfacing institutes and processes.

We believe that on-going collaboration at national and regional scales between sectoral partners and climate information providers will benefit all parties.

We note further that the practice of climate-related risk management is not widespread within many sectors and that there is a lack of awareness of climate-related risk management opportunities among numerous communities that would benefit.

We recognize the need for efforts to assemble disparate knowledge, to identify good practice, and to assess the value of and give visibility to climate-related risk management.

We recommend that collaborative mechanisms be developed that facilitate needs and requirements driven activities in climate-related risk management, and that they be used to improve the quality of climate-related risk management to the benefit of all.

These mechanisms could promote:

- *valuation of current climate-related risk management in all relevant sectors*
- *better assessments of the value of climate-related risk management*
- *establishment of data sets necessary to inform decision making*
- *research to improve climate-related risk management*
- *development of decision-support tools*
- *capacity building in climate-related risk management*
- *on-going evaluation of outcomes*
- *the use of suitable financial mechanisms in support climate-related risk management.*

We request that these recommendations be considered by WMO, other UN System organizations, and sectoral and development organizations operating at national, regional and international levels."

The first conferences triggered WMO to organize the World Climate Conference-3 (WCC-3) (31 August – 4 September 2009; Geneva, Switzerland), which established the Global Framework of Climate Services (GFCS) (WMO, 2011). Since then GFCS has been the flagship of WMO in climate service developments.

World Bank also made efforts to widen the views of hybrid climate services towards the interests of their end-users (Tall, 2013). Beside aspects related to climate services, the author of this thesis had the opportunity to explore new ways to develop hybrid climate services so that the products would meet the demands of end-users. This approach motivated the consideration of relevant philosophical aspects and social patterns, which established the grounds and structure for the work presented in this thesis. The author set the following action lines.

First, the need for a rigid logical framework was recognized. Such a framework allows one to study the development of HMLCSs iteratively by considering and following-up the current impacts of trend-like climate change and changes in its variability. Secondly, we need to look into the response of grass-root people to climate changes and prevailing practices of development work in developing countries in Sub-Saharan Eastern Africa. A strong argument of this thesis is that it is crucial to break down the omission of interaction with grass-root people and to take them into account as vital and equal partners. Inaction is significantly more costly than well-planned action.

IPCC and the ICT, Climate and Development (ICCD) Research Group of the University of Manchester, UK (IPCC, 2014a-b, Heeks & Ospina, 2012a-b, Ospina & Heeks, 2012c-f) have studied the baselines extensively for coping with climate impacts and have given suggestions for strategic actions. However, so far, the actions along the suggested lines have been sparse and limited. Notwithstanding this, IPCC (2014b) has lifted the concept of Climate-Resilient Pathways (CRPs), which combine mitigation, adaptation, and sustainable development in a balanced way. The answer to the Frequently Asked Question FAQ 20.4 (IPCC, 2014b, 1123) clarifies CRP further.

Two relevant details in the context of CRP are: a clear understanding of resilience in terms of the RABIT approach of Heeks and Ospina (2016) as well as the pertinence of local traditional knowledge in the adaptation of agriculture (Swiderska et al, 2011), who point out traditional knowledge to be a relevant element in local adaptive capacity. O'Brien and Sygna (2013) have characterized the CRP transformation process by three nested spheres, i) personal as the outermost sphere with beliefs, values, worldviews and paradigms, ii) political as the mid-sphere responsible for systems and structures and iii) practical as the innermost sphere on behavior and technical responses (see also IPCC (2014b, Fig 20-2, 1125).

CRP is not only about actions to be taken in the future, but importantly also about strategies and choices taken today. Here the author of this thesis and his research group explore the possibilities of DSR and 'Systems Action Design Research' (SADR) model, introduced later in this chapter, and offer suggestions along the discussed lines. The latest available Summary for Policymakers (SPM) (IPCC, 2014a) discussed future risks of and opportunities for adaptation. In addition to its Assessment Box SPM.1 (IPCC, 2014a, 12) and Figure SPM8 (IPCC, 2014a, 26) with their significant challenges, SPM pointed out the relatively weak connections between climate changes and economics with its predominant drivers and time scales.

Shared Socio-Economic Pathways (SSPs) and Representative Concentration Pathways (RCPs) to assess the interaction of the pertinent aspects of human behavior, economics, and climate impacts was introduced (van Vuuren et al., 2011, Moss et al., 2010). Here also SSPs and RCPs interact with each other and contribute to the outcome of climate impacts. The goal to achieve sustainable land management has lately changed our views on the interactive mitigation of and adaptation to climate change. It would be interesting to develop a SADR application to study land-use management in the context of climate change and changes in climate variability.

To summarize, the ongoing climate changes and their impacts to the humanity and the environment motivated this work to explore the possibilities of how DSR can help us to combat these issues, which are of high global priority. This thesis is article-based, which uses DSR as its guiding framework. The thesis comprises of the introduction, a chapter on the developed methodology and data as well as of five articles, referred to as PI, PII, PIII, PIV, and PV. The work progressed in phases and included first an article (PI) on the early development of the DSR model by the author of this thesis and then three case studies, one in Mozambique (PIV), one in Kenya (PIII), and one in Tanzania

(PII and PV). This layout follows in the timely order of the execution of the studies.

1.2 Reseach questions

The first research question of this thesis, which is based article PI of this thesis, was set as follows:

RQ1. What are the current baselines for crucial information needs, current strengths, infrastructure, skillsets, climate information, and mobile usage patterns in Chókwè District, Mozambique?

Answering the research question above was necessary in order to gain a picture of the daily life, especially from the viewpoint of understanding and utilizing climate information, and of mobile usage patterns. The research design of PI was qualitative exploration.

The second case-study included in this thesis was conducted in Kenya and reported in article PII of this thesis. The research question for this case was as follows:

RQ2. What are the current baselines for crucial information needs, current strengths, infrastructure, skillsets, climate information, and mobile usage patterns in Njemps- and Tugen-communities in Marigat?

RQ3. How could we apply the evaluation method of Heeks (2002) in order to get a hybrid evaluation of the MSc (Forestry) course on "Forest Management in a Varying and Changing Climate (FMVCC)" and its forest information system in Eldoret and Marigat?

The objective of research questions RQ1 and RQ2 was two-fold; i) to gain a picture of the daily life of end-users in Marigat, especially from the viewpoint of understanding and utilization of climate information and mobile usage patterns and ii) to evaluate the given MSc (Forestry) course FMVCC and its forest information system at the School of Forestry, University of Eldoret. The research design of PII was qualitative exploration.

The research efforts then progressed to the case-study in Tanzania, reported in papers PIII and PIV of this thesis. The research questions for Tanzania were:

RQ4. What are acute the needs for sustainable development and action in Tambuu community?

RQ5. What are the current mobile usage patterns of farmers and demands to improve them in terms of boosting the local cooperation in Tambuu community?

These research questions were necessary to clarify the acute needs for sustainable development and action in Tambuu community as well as the current mobile usage patterns of farmers and demands to improve them. The research design of PII and PIV was qualitative exploration.

1.3 Thesis structure

The present introduction-part of this thesis discusses the background of the work and the motivation for the research. The definitions of key concepts are presented, followed by a chapter on methods and data. The whole thesis is linked together by considering what qualities the theoretical design science framework has to meet. As we followed qualitative, along with quantitative approaches, the philosophical basis underlying the approach is also discussed.

The philosophical underpinning of the research supported the development of the iterative model, which the author has named 'Systems Action Design Research' (SADR) model, for a system of interacting systems. According to the third definition in 1.4 MT/SADR represents the action line of Mullarkey and Hevner (2015) and works as a general framework with slight modifications for both stationary/semi-stationary and changing systems. In its essence, MP/SADR does not depend on the application under consideration. The DPP/SADR reflects the particular application and forms an entry process as well as steers the SADR.

The data consists of both quantitative and qualitative data. Measured variables present quantitative data, whereas the conducted interviews qualitatively reveal aspects of behavior in the form of various themes. First, the author discusses the three exploratory projects in Mozambique, Kenya, and Tanzania, each case in its own chapter. The author also reflects on the methodology and fundamental research paradigms, which form part of the methods used in this research as well as part of the most relevant results.

The thesis also highlights the core learning gained about local circumstances and cultures and how the author of this thesis and his research groups can make use of these experiences. The discussion chapter replies to the research questions and reflects on the methods used.

The concluding chapter of this thesis wraps up the core features of the SADR model and emphasizes the hybrid need for seamless and participatory teamwork as well as resilience and agility.

1.4 Definitions of key concepts

Hybrid grass-root mobile local climate services (HMLCS) are local climate services for a region, period, and purpose demanded and specified by end-users. To be produced as hybrid, they are as holistic as possible and require seamless, participatory, resilient, and agile teamwork.

Anticipated rationale (compared with a forecast) is a modest and feasible concept for the epistemology of expertise about the future. The expertise in anticipation recognizes explicit that choices made today can shape or create the future.

Systems action design research (SADR) model is an iterative process model, which recognizes a system of various stationery or changing interacting systems. The management part of the model (MT/SADR) resembles the model of Mullarkey and Hevner (2015), but its entry points are replaced by an entry process of Delphi part process (DPP/SADR), which the author of this thesis and his research group in their particular application replace by Action-Inducing Epistemic Utility Delphi Process of Argumentation (DPP/SADR) (Kuusi, 1999) entry process for seeking optional rational action lines.

The entry process, Action-Inducing Epistemic Utility Delphi Process of Argumentation (DPP/SADR) in this thesis, is a Delphi process with an epistemic utility function of impact, feasibility, validity, and relevancy (Kuusi, 1999). Under the process, the expert and management teams of SADR build and rank the optional action lines to be processed by SADR.

Climate change in its broad sense is understood to cover all changes taking place in the climate system. In the context of developing hybrid grass-root mobile local climate services (HMLCS) for farmers the author of this thesis is primarily interested in climate changes of the atmosphere, especially in temperature and precipitation. Here two climate changes are of particular interest. First, the trend-like climate warming is well-documented by IPCC (2018). Second, IPCC (2018) has pointed out the ongoing changes in climate variability, e.g. changes in rainfall patterns during the rain season in tropical regions and more so in the Sub-Saharan Eastern Africa. In addition the author of this thesis expects the forthcoming IPCC Special Report on Climate Change and Land with the changes indicated therein to affect the development of HMLCS.

In this thesis its author considers climate services to be hybrid outcomes of a developer team of science experts in invariances, experts of human and social behavior, experts in decision-making and synthesizers, who in an open and interactive way contribute to a resilient and agile service accepted with ownership by its end-user. The developed service should facilitate transparent and participatory cooperation all the way from the grass-root level to the top-down level and vice versa.

Design science research (DSR) and its framework (DSRF) have been presented well by Hevner et al (2004) and the development of HMLCS follows these ideas. In the delineation of the development work the author of this thesis points out that the outcomes of climate models include unavoidable uncertainties. The consensus reached by IPCC (2018) about the human influence in the recent climate warming is fundamental even if its quantitative estimates are uncertain. Following the ideas of Kahneman (2011) as well as Ulrich and Reynolds (2010) the author of this thesis has suggested that the DSRF appropriate for the development of HMLCS should include heuristic methods.

Chapter 2

Case Mozambique

The author of this thesis started this exploratory project in Mozambique by exploring local climate services and gathering background information in Chókwè District, Mozambique. This chapter will present the reader with a brief overview of this case. The more interested reader may refer to Paper PI of this thesis for a more detailed account of the conducted research.

At the beginning of this research period, the author of this thesis joined the pre-negotiated "Programme of cooperation in Science, Technology, and Innovation between Finland and Mozambique" (STIFIMO) program. Here he had to adjust his tasks to the overall objectives of the program. Still, this arrangement as an established joint project with the National Meteorology Institute (Instituto Nacional de Meteorologia; (INAM)) left him with the required freedom to explore related problems as well as opportunities to build an appropriate design research framework.

Based on the community's crucial needs for tailored climate services to improve their livelihood sustainably, the author of this thesis sought to gain baseline information about current requirements, strengths, infrastructure, ICT usage patterns, and climate information sources. The information gathered helped to understand the role of future technology in building improving structures. The results of this case contributed to the development of the improved design science models in order to respond to the requirements and demands for projects that were extensively laid out in Chapter 1.

2.1 Qualitative research

For the extensive interviews in Chókwè District, the author of this thesis used a questionnaire as his data collection protocol. We conducted group discussions; thus, one response in the questionnaire represented one group. The objective of the interview was to find out both strengths and gaps in baseline items pertinent to the hybrid approach of the project.

2.2 Overview of the results

Some of the more meaningful results from data collection and analysis (see Paper PI for details) were that due to the lack of mechanized tools, the local cultivation practices were mostly manual. This severely restricted the possibilities of local farmers to enlarge their areas of cultivation. Limited access to seeds of good quality and no access to credit confined the chances to increase their livelihood further. Notwithstanding this, the local community members showed a collective willingness to join open and cooperative efforts to improve the life of their community. The surveys of facilities and interviews of the farmers revealed their restricted knowledge of climate as well as climate and weather services despite the widespread use of mobile technologies. In all demands for systematic joint efforts to improve the local readiness to develop appropriate hybrid climate services underpinning their cultivation practices became evident.

2.3 Conclusions of Case Mozambique

The bottom-up willingness for hybrid development as well as the cooperation with INAM was excellent, whereas all other top-down responses nullified the expectations of the people. At the end of this case study, the researcher did not achieve anything concrete but gained highly valuable information for future project implementation. It seems that climate has to continue its lessons to wake up the administration in its top-down actions to meet the bottom-up demands of the people. Only then pertinent projects based on an appropriate design research framework can be implemented.

Chapter 3

Case Kenya

This chapter presents a brief overview of the second case-study of this thesis, which was implemented in Marigat District, Kenya. This chapter elaborates on Paper PII of this thesis. Paper PII contains all the specifics and details of this case, while this chapter only summarises and highlights the most critical aspects. When this project started, the Kenyan minister of agriculture had declared *Prosopis juliflora* as a noxious weed. The Finnish development aid group and the author of this thesis as a member of the group agreed unanimously with the local colleagues to focus on attempts to replace the invasive Prosopis juliflora deep-root species by another deep-root species, which could be kept easier under control in Marigat District, which is located 100 km east-northeast of Eldoret on the opposite side of the Rift Valley.

Under the Higher Education Institutions Institutional Cooperation Instrument (HEI-ICI) and Higher Education Institution Network Programme (HEI-NP) of the The Centre for International Mobility (CIMO) the School of Forestry and the School of Computing of the University of Eastern Finland together with the School of Forestry of the University of Eldoret, Eldoret, Kenya established the Program "Strengthening ICT-supported Community-Engaged Forestry Education in Kenya", under which the author of this thesis started his preparations to keep a co-conducted MSc (Forestry) course on "Forest Management in a Varying and Changing Climate (FMVCC)" with the deep-root species problem as the application in mind.

3.1 Methods and data

Based on the objectives of this research, the higher aim was to develop future hybrid climate services and to gather crucial data in for future technology projects. The goals for the preliminary data collection were set to understand the available local climate information systems and practices to gain general baselines of the context in Marigat District, Kenya.

We collected data, from two communities: the Tugen-community and the Njemps-community. There were a total of 27 (N=27) respondents (10 females, 17 males). Fifteen (n=15) respondents were from Tugen, and twelve (n=12) respondents from Njemps.

3.2 Overview of findings

The data indicated that among the strengths, farming was the most often mentioned, followed by keeping livestock. One representative example about the situation is that in regards of the interviewees' willingness to settle down, of all the respondents, eleven (n=11) answered yes, no-one no, seven "conditionally yes," and five "conditionally no." In regards to the willingness of the interviewees' to settle down in case that weather and climate information needs would be met, the responses were yes (n=26), and no (n=0).

In order to evaluate the interview data, the author of this thesis applied the method of Heeks (2002). With regards to weather and climate information flow between officials and community people, there were some hints that the information flow was not optimal. The preliminary results indicated that future breakthroughs in technology would most likely happen through co-creation at the grass-root level. Interestingly enough in early 2015 both interviews and surveys revealed that almost nobody spoke of the eradication of the Prosopis juliflora anymore. Hence, he concluded that a lack of trust and commitment in agreed processes constituted a design-reality-gap.

3.3 Conclusions of case Kenya

The findings revealed that in one way or the other, several stakeholders, who may not otherwise communicate very well with each other, need to be included in the design processes. Building commitment and trust is a crucial factor here. Projects that start with good intentions end too often when commitments and priorities change. Regarding his findings, the author of this thesis may ask how he could achieve a reasonable consensus. Should he encourage people for co-creative cooperation and take first steps to absorb, not just climate information, but to process it to climate knowledge in their minds.

In Kenya, the bottom-up willingness to learn to use and benefit from improved local weather and climate information was high. However, the top-down responses were confusing or negative, starting already from the local project leaders. Hence it was hard for the author of this thesis to believe in any sustainable continuation of his project without a serious reconsideration of the process models for future development and technology project implementation, in line with the SADR-model presented in this thesis. No matter the future approaches and related lessons learned, the climate continues with its lesso

Chapter 4

Case Tanzania

With the lessons from the previous case-studies in this thesis learned, the author of this thesis and his research group started planning and related negotiations of a new project in Tanzania. The negotiations with the College of Business Education (CBE) and Sokoine University of Agriculture (SUA) ended positively. Then the task was to find a reliable and motivated local partner. The author of the thesis and his research group selected Tambuu village, Morogoro Region, Tanzania for their third mission, because Tambuu had a relatively functional mobile phone connectivity as well as a history of successful participatory projects, established between Tambuu community and a local non-governmental organization (NGO), Tanganyika Christian Refugee Service (TCRS).

To determine the priorities of the Tambuu community and the potential barriers that it faced, we asked farmers about their daily practices (collecting qualitative data), their satisfaction with current agricultural or technological services, and their particular demands for future services.

After having gained an understanding about acute needs of Tambuu community, it was essential to compile drafts and prototypes of future technology services, which address the technology and information demands. One of the most crucial findings was, in line with the recommendations in Chapter 1; that farmers must be involved throughout the design process, to ensure full participation and create a safe environment of 'nothing about us without us.' This participatory approach resulted in the generation of ideas and prototypes about how to address acute technology and information demands of the Tambuu community.

4.1 Methods and data in case Tanzania

After drafting and discussing jointly the questions to be discussed during the two face-to-face interviews were agreed for visits to Tambuu village in April of 2018. We conducted several semi-structured interviews in the Tambuu region of Tanzania with help from local interpreters, who not only translated questions and answers but also clarified ambiguities and difficulties in understanding some of the questions. The details of these experiments and interviews are presented in articles PIII and PIV. Out of the seven abductive strategies presented by Paavola (2014), we applied the following two to the collected interview material:

i) Searching somehow anomalous, surprising, or disturbing phenomena and observations (abductive strategy 1) and

ii) Searching for "patterns" and connections that fit together to make a reasonable unity (abductive strategy 6).

4.2 Overview of findings

The thematic contents analysis revealed that while the local farmers understood that weather affects their farming, they did not distinguish between weather forecasts useful to guide daily actions and climate outlooks to help them to plan the coming growing season—hence the point of this study. In the interviews, the author of this thesis and his research group also focused on apparent qualitative deviations from the mainstream as well as on the reactions of farmers to their suggestions of co-creative development of hybrid mobile local climate services (HMLCSs) and related training.

Outlying single farmers had already widened the cultivation area of their farms in order to improve their baseline against worsening impacts of climate change and changes in climate variability as well as for resilience in their crop yield production and food safety. The second outlier indicated that the farmers almost unanimously ignored the services of the Agricultural Extension Officers (AEO). According to the third outlier, two farmers out of thirteen farmers owned a smart mobile (locally called touch phone) while the rest of the farmers owned an ordinary button phone. These lacks challenge both the AEOs and the telecommunication authorities into action. It is a significant challenge, but worth to accept in terms of sustainable development as well as food security.

4.3 Discussion and conclusions of case Tanzania

Smartphone ownership is rapidly increasing in developing countries, and smartphones provide a platform to run future climate service applications that may assist small-scale farmers in their daily practices. In this line of action, there is a need for a reconsideration of the role of agricultural extension officer (AEO) in alignment with future projects. AOE, together with improved technologies, may teach how to plan for the farming season effectively, together with improving resilience in regards to exceptional situations such as flash floods or heavy rains. Additionally, there is a need for agricultural mechanics and related services in order to improve the efficiency of agricultural practices. These aspects need to be aligned for future technology projects. Here the author of this thesis and his research group remind that the technical question is not just about having smartphones but also about a sufficient operative base station network for smartphones and proper skills to utilize them.

The implementation of the stages is typically iterative, and each stage, make use of a set of relevant research and engineering methods. These methods include all available quantitative and qualitative research methods, as well as methods of agile software development and use of case engineering. The author of the thesis and his research group ended up to recommend that the authorities would consider the current education and communication lacks seriously among grass-root people and take decisive actions in both of them so that sustainable development could also reach the grass-root level.

Chapter 5

Discussion

The discussion of this chapter begins by replying to the research questions in Chapter 1. Additionally, to the results presented in the articles of this thesis, the author included observations from the local surveys. In many cases, those surveys substantially increased the understanding of local circumstances at the sites of this research. Lastly, before the recommendations and delimitations the author discusses the early research-in-progress article of the developed SADR.

5.1 Case Mozambique

With regards to the research conducted in Mozambique, the research question was set as follows: *"What are the current baselines for crucial information needs, current strengths, infrastructure, skillsets, climate information, and mobile usage patterns in Chókwè District?"*

The results show that most smallholder communities lack large parts of pertinent information, which could relatively easily be offered by local authorities. The current overall level of education was found insufficient, and most people were found to have a restricted idea of their fundamental rights. Coherence was found to be an inherent quality of the smallholder farmers. It was their current strength.

The most important part of the local infrastructure was the Chókwè Irrigation System (CIS), established by the Portuguese to irrigate the profitable area for cultivation called the "Breadbasket of Mozambique." Except at Xilembene community close to the Limpopo river, the other communities of this project neglected the maintenance of CIS due to apparent lack of resources. Hence the CIS stood in the state of renovation. On the contrary, one foreign agro-company, EmWest Ltd, with available high technology, had established its irrigation system and was able to mix fertilizers into irrigation water at the pump station. The lack of maintained resources and international investment in the area indicated local lacks, but also available possibilities.

A joint problem for the cultivators in the area was the relatively frequent occurrence of devastating flash floods in the Limpopo river delta area. Nothing else was needed but an intense rain episode in the upper Limpopo drainage area to release a flash flood event. It was and still is a great challenge to reduce this vulnerability and to upgrade the baseline.

In the context of cultivation, the communities rely on the use of hoe and panga (a knife for clearance of former vegetation). No mechanical tools to help agricultural practices were available. The lack of top-down support and the demand to upgrade the baseline were distinct.

Two out of six communities knew the ways to get seasonal meteorological forecasts as well as agrometeorological forecasts via radio and tv. However, they ignored the use of the forecasts in the context of cultivation practices. According to one comment, a local weather station is needed and could even solve the problem. Hence primary education was needed to upgrade the local climate knowledge.

Mobile phones were essential tools for communication, but the ICT skills to use them were confined to make and receive calls. Consequently, primary education would have been a prerequisite for the establishment of a smart mobile network to have access to hybrid mobile local climate services.

5.2 Case Kenya

In Kenya the task was to give a co-conducted MSc-level forestry course "Forest Management in a Varying and Changing Climate (FMVCC)" as a part to establish a new MSc- and PhD-curriculum to the Forestry School of the University of Eldoret. According to the two-week course plan, the first week covered lectures at the university and the second week a field course in Marigat, Baringo County.

The author of this thesis completed the lecture course according to plan. The author was also able to conduct a part of the interviews in Tugen- and Njemps-communities in Marigat during the first week. However, for practical reasons, the field course was reduced to two days, one day at Tugen-community and one day at Njemps-community. The research group was able to conduct the remaining interviews, but the original idea of the application, to remove Prosopis juliflora plants from a restricted area and replace them by another less invasive deep-root species became ambivalent as we at our arrival to Marigat noticed a brand new Prosopis juliflora-driven power station with its need for appropriate raw material. Taking into account the limited readiness of the local people to utilize mobiles, not to say smart mobiles, and of the university to establish the needed local smart mobile network we left the choice and implementation of the application to be carried out by the hosts. The first research question for research conducted in Eldoret, Kenya, was as follows:

"What are the current baselines for crucial information needs, current strengths, infrastructure, skillsets, climate information, and mobile usage patterns in Njemps- and Tugen-communities in Marigat?"

In both communities, the prominent information need was education for children. The community members realized that education for children is the key to upgrade the baseline of crucial information. The main current strengths of the two communities were farming and livestock keeping.

The research progressed by asking the interviewees about the following infrastructure items: roads and means of transportation, health centers, housing, and support of nomadism. The interviewees evaluated the current quality of these items to be poor. On seasonal climate outlooks, most interviewees currently trusted traditional knowledge. If they have access to reliable climate and weather services, they would be willing to settle down.

They have no smart mobiles. Hence the establishment of a smart mobile network needs both investments and training. There is a need for the substantial upgrade of the baseline needs. The second research question for Eldoret, Kenya, was set as follows:

"How could we apply the evaluation method of Heeks (2002) in order to get a hybrid evaluation of the FMVCC and its forest information system?"

First, in each dimension of Heeks (2020), it is essential to find a few pertinent aspects of the dimension to be assessed. The information section focused on weather and climate information both to its access and reliability. A clear majority of the interviewees were unsatisfied with the current status of these two qualities. Hence the mode of the answers was "poor."

In technology with the current absence of a smart mobile network and of skills to use it would undoubtedly give "poor," but the author of this thesis needed to consider the growing willingness for co-creation to build the system. Hence, he scored it "fair." The hardcore process in the agreed plan of the author of this thesis was the replacement of *Prosopis juliflora* by another less invasive deep-root species. However, the ambivalent change of the process led to a drop of trust and constituted a wide design-reality gap. The mode of the answer was "poor."

Objectives and values among the participants became deeply fragmented after the ambivalent change of the process. Trust and willingness for co-creation as well as participatory work remained high on the bottom-up grass-root level, whereas higher up at the top-down level it became obscure. Hence the mode of answers was "poor." In staffing and skills, many indicated their willingness to improve personal skills. It gave hope to the author of this thesis of sustainable development towards co-creation. Hence, he gave "fair."

Management systems and structures suffered from inconsistency, which led to "poor." Other resources revealed partly misleading responses in the interviews. It downgraded the reliability of the interviews and should be considered carefully with the planning of new projects. Overall mode of the answers was "fair."

Both in the discussions with the academic staff of the School of Forestry of the University of Eldoret (SF/UOE) as well as the staff of the Marigat Research sub-center of Kenyan Forest Research Institute (MRSC/KEFRI) and with FMVCC class students one joint point of concern was the increasingly violent competition of weeds for livestock. Hence in line with the outcome of the interviews that people were willing to settle down, if they can get reliable weather forecasts and climate outlooks, that would enhance the demand to develop local weather and climate services jointly in a broad participatory way among experts and local farmers in order to promote the local safety and humanitarian values.

5.3 Case Tanzania

Also, in Tanzania, two research questions were set. The first one was: *"What are acute needs for sustainable development and action in Tambuu community?"* The traditional and also current cultivation makes use of manual hoe and panga (a knife for the clearance of former vegetation) practices, which limited the area that families could grow food on. The idea was to get enough crop yield to cover the needs of food and necessary expenses, like airtime for mobile phones. The balance between the cultivated area, crop yield, and livelihood rested on semi-stationary climate variability, especially concerning rainfall. However, amid climate change and more so of changes in climate variability the former balance has started to become distorted, e.g., by long dry spells, which the growing crop cannot survive, during the rainy season. Therefore, a basic acute need is training and educating the local farmers about climate and its various forms of change in comparison with the weather.

The distinction between climate and weather is essential for farmers in their efforts to develop sustainable development in Tambuu. The first parties to train and educate the local farmers are the Extension Agriculture Officers (EAOs) with suggested updates in the training activities and the coming of local farmers to the schools, in Tambuu the primary school. Future digital communication platforms may use a network of trusted actors for the dissemination of successful information and farming practices to local farmers. The first and second outliers as well were in line to improve the understanding of local climate impacts.

The second research question was set as follows: *“What are the current mobile usage patterns of farmers and demands to improve them in terms of boosting the local cooperation in Tambuu community?”* By having lost their confidence in traditional knowledge, the smallholder farmers are in real trouble with their livelihood. Further, the current button mobiles are not technically feasible to receive disseminated local climate services. Can the author of this thesis and his research group help them by developing and boosting new appropriate mobile climate services, resting on advances of seasonal climate outlooks, participatory co-creative cooperation as well as the establishment of a technical communication network appropriate for smart mobiles? These are other acute demands. Can the Systems Action Design Research (SADR) model be of help? Implementing SADR in a systematic and resilient as well as agile way, the authors is of the opinion that SADR can be the solution.

SADR and DPP/SADR as an embedded part of it is an iterative model, which also has to keep itself in pace with future changes of the system. In the application to develop local mobile climate services under significant uncertainties in outlooks of the climate system, the application part of the SADR has to be followed up by intervals frequent enough, e.g., by checking the currently most pertinent disciplines to be included.

In contrast to SADR, DPP/SADR is a living application part of the entity and needs to be resilient and agile in attempts to serve the demands of the local farmers. Here resilience and agility mean that not only parameters of DPP/SADR may change but based on the most recent trends and uncertainties the whole structure of it as well. Appliers of SADR need to be open even to abrupt changes in attempts to keep the guiding results close to minimum bias (Kahneman, 2011). In line with this, the author of this thesis and his research group cannot give any formal suggestions to the action lines suggested by DPP/SADR, but rather general outlines for actions under it.

5.4 Research-in-Progress: Design Science Research for Holistic Climate Services

The article PV presents the very first attempt of the author of this thesis to grasp its main subject, Systems Action Design Research. The inspirations for this work came from both the author's experience in climate services and the emergent global awareness of the interplay between the well-recognized and ongoing climate change (UNFCCC, 2015) and human life. These are in realtion to the 2030 Agenda for Sustainable Development (UN, 2015) and of the Agenda for Humanity (UN Office for the Coordination of Humanitarian Affairs, 2016). Although the idea was in many respects still vaguely presented in PV, the golden thread of the later developed SADR could already be discerned.

This article entitled, *Design Science Research for Holistic Climate Services,* discusses holistic climate services, this holistic approach is an ideal and ultimately unattainable tactic. Hence the author of this thesis replaced the term holistic with hybrid in articles PI, PII and PIV.

Elements for balanced processing of social demands in the context of the scope of natural sciences and climate modeling has broadened our views. Among these elements we have aspects of human and social behavior, human values as well as needs for heuristic considerations in the context of unavoidable quantitative uncertainties. Hence the author found it pertinent to explore the possibilities of design science to offer a systematic framework to compile the elements to an interactive entity.

It was evident from the beginning that in the context of climate, which inspired our work, we encounter a system of changing and interacting systems. Parallel to this scientific challenge we have especially in the context of developing countries to confront the demand to explain the solutions in understandable terms to end-users, who are poorly educated or even illiterate.

5.5 Recommendations

Although many details in the interviews varied between the interviewees and the communities, two overarching qualities remained, the need for systematic education and substantially improved communication. The author of the thesis and his research group argue that systematic and balanced actions to improve these qualities are prerequisites to sustainable development and growing respect for humanitarian values. The list is short, but demanding in its details, deserves to accomplishment to its full extent in all communities.

Inspired by the three explorations and the argument presented in the context of "Problem Identification and Encountering" (PIE) box of SADR (cf. chapter 6, Figure 1, and Equation 1) a draft plan for a prototype experiment to develop local HGMCSs in an Eastern African Country could look as follows. As we are interested in the effect of applying updated agriculture and climate knowledge compared with the effect of applying traditional knowledge among not-learning vs. learning community members, based on interviews and surveys we recommend the division of community members into four exclusive groups:

1. not-learning members using updated agriculture and climate knowledge,
2. learning members using updated agriculture and climate knowledge,
3. not-learning members using traditional knowledge and
4. learning members using traditional knowledge.

In such an experiment, the interest is primarily focused on shifts to use updated agriculture and climate knowledge instead of traditional knowledge. Also, the effect of education and willingness to learn new ideas in terms of not-learning and learning community members is of interest.

5.6 Delimitations

The new action design research theory, SADR, is still in its first steps and needs quite a few design thinking oriented prototype experiments to be accomplished before we can demonstrate its value to the full extent. Regardless the researchers think that now is the time for action to systematically designed experiments.

The three cases exploring the reality in Eastern African countries are limited to a few different communities, each with a unique character. Even if the experiments failed in many respects and or at the most reached the status of functioning local climate services, we should always have an open mind for lessons learned. We gained much knowledge on this journey. Our recommendations focus on the essential lacks – education and communication.

Chapter 6

New research methods and paradigm

Recently introduced visions on global humanitarian concerns are intertwined with climate change and changes in climate variability. Broadening the tasks of climate services clearly beyond narrow climatological applications is needed. In all, humanitarian values are at stake as well (WMO, 2011, UN, 2015, UN Office for the Coordination to Humanitarian Affairs, 2016a-b). There is the need for revised climate services and a framework, under which one can consider the problems in a systematic and hybrid way (Mullarkey and Hevner, 2015, Heeks, 2002, ICCD, 2012a-b, Heeks & Ospina, 2016).

The results presented in this thesis have demonstrated that with the current ongoing climate change, one crucially needs to take a constructively critical look at the practices in climate services, where the climate system now is a system of interacting and changing systems. The former temporal stability or semi-stability/ergodicity of climate variability is gone, and uncertainty has increased. Then formerly used long time series and climate normals (WMO, 2017) are not anymore useful for current climate services. In all, one critical issue is to choose representative data with heuristic insight in order to avoid unnecessary biases (Kahneman, 2011).

Another essential feature of the developed model is its feasibility in the context of CRP (IPCC, 2014b, Box 20-1; O'Brien and Sygna, 2013) or more generally resilient pathways in the context of the system under consideration. Here a constructive understanding of resilience is necessary as discussed in the RABIT approach of Heeks and Ospina (2016). In the context of a system of interacting systems, this is a challenge.

6.1 Logical framework

Inspired by the development of HMLCSs, it is warranted for all future technology projects to start with considerations of the logical framework for the development of the Systems Action Design Research (SADR) model.

In the context of general systems theory (GST) and related philosophical aspects, it is essential to recognize the still pertinent insight of Aristotle: "The whole is more than the sum of its parts." Hence to understand an organized entity, it is vital to know both its single components and the interactions between them (von Bertalanffy, 1972).

Instead of presenting SADR as one entity by following Mullarkey and Hevner (2018), the author of this thesis recommends MT/SADR and DPP/SADR in line with the definition of SADR (see Introduction 1.4.) as separate interacting components. From the logical point, it is vital to keep MT/SADR in a form general enough (Mullarkey and Hevner, 2015) to allow it to manage a system of both several stationary and several changing interacting systems. Then the steps of MT/SADR could be relatively independent of the application. In the rest of this subsection, attention predominantly focuses on logical issues pertinent to the application represented by DPP/SADR.

Previously the development of climate services has relied mainly on advances in physics, physical climatology, and sciences pertinent to the application. Under this paradigm, the scientific advance stands alone for the needed knowledge. However, an approach solely from natural sciences leads in most cases to a distorted and fractional vision. The gap between science and humanity needs a bridge to symbols, values, social entities, and cultures so that they become essential ingredients to our hybrid approach (von Bertanlaffy, 1972, Rittel and Webber, 1984, Demetis and Lee, 2016). In case of developing countries we need to take into account the restrictions of local culture and awareness of the people in communication and the participatory work. Demands for the communication skills of the focal experts towards the local end-users become high so that the premises and outcomes of theoretical model results as well as the local demands meet each other in a motivating way. Here appropriate grass-root working mode is essential and should be adjusted to the local circumstances. On the other hand the top-level theoretical expertise should be utilized to its full extent by having skillful expert mediators to facilitate proper communication. The results of this thesis fully support this view.

The use of GST as a model for general aspects of reality helps one to see also previously ignored items (von Bertanlaffy, 1972, Rittel and Webber, 1984, Demetis and Lee, 2016, Baskerville et al, 2018). The chosen hybrid approach uses the Temporal Logic Model (TLM) (den Heyer, 2001) and applies it to an open system, which permits dynamic evolutionary processes of change to be present (Korten and Klauss, 1984). The open system allows for a variety of conceptual frameworks. The social learning paradigm is one and of high interest in the context of the application of this study. The associated learning process comprises iterative learning loops of action, reflection, adaption, and sometimes also abduction, like in this study. As an integral part of the learning, participants can obtain both silent and explicit knowledge. This type of learning is an essential characteristic of open systems (Korten and Klauss, 1984).

In the epistemic context, Kuusi (1999) recommends the paradigm of anticipatory rationale instead of the relay on deterministic forecasts or semi-deterministic outlooks. Notwithstanding, the author of the thesis allows predictions and forecasts to be part of the information, which guides his reasoning. Furthermore, in the epistemic context, the anticipatory rationale is a more feasible approach than the traditional scientific one. In the case of social and political processes being part of the system, a quantitative approach is doomed to give limited results because the original observation data is partly quantitative and partly qualitative. With the anticipated rationale, the author of this thesis and the research teams will explain the results to end-users as laymen.

In the case studies reported in this thesis and for all future technology projects, soft systems approach must focus on a model, which interprets the elaborated open system in iterative feedback, assessment, and adjustment process and which is relevant to real-world situations under scrutiny. The author of this thesis has developed the SADR model and delineated its use in developing hybrid local climate services by demonstrating a few early steps along this path. His research groups joined the elaborations in the two last case studies in Kenya and Tanzania.

6.2 The quest for a theoretical framework

The search for a satisfactory theoretical framework started from appropriate epistemic Delphi methods. It led the author of this thesis to familiarize himself with the Argument Delphi of Kuusi (1999), which inspired him to develop an early version of the DPP/SADR model. However, simultaneously in this context, it became evident that in terms of design science, he needed a widened systematic framework. Here he ended up with the Design Science Research (DSR) framework of Hevner et al. (2004).

The next step was to get the DSR into action for a system of interacting systems. The action design research (ADR) of Sein et al. (2011) together with the entry point suggestions and considerations by Peffers et al. (2008) as well as Mullarkey and Hevner (2015, 2018). Additionaly, Sein and Rossi (2019) with their remark on the proper use of the entry point in ADR and inductivce strategy 2 of Iivari (2015) directed these efforts. They and Kuusi (1999) steered the attempts of the author of this thesis to widen the view of the elaborations to an action design research framework appropriate for his task to develop hybrid grass-root mobile local climate services (HMLCSs) for local farmers.

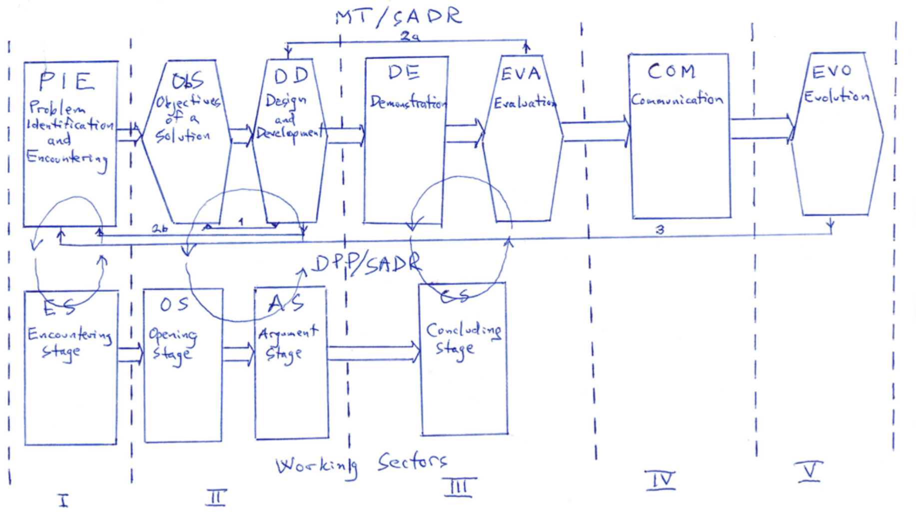

Figure 1. The SADR Process with its main entities, management part (MT/SADR), Delphi process part (DPP/SADR) as the application part, working sectors (I – V) and iteration loops 1, 2a, 2b and 3. For explanations see the text.

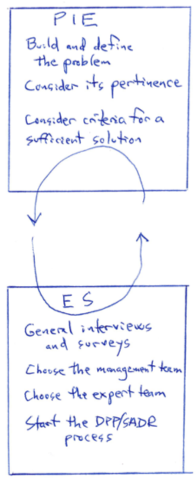

Figure 2. Working Sector I of the SADR Process.

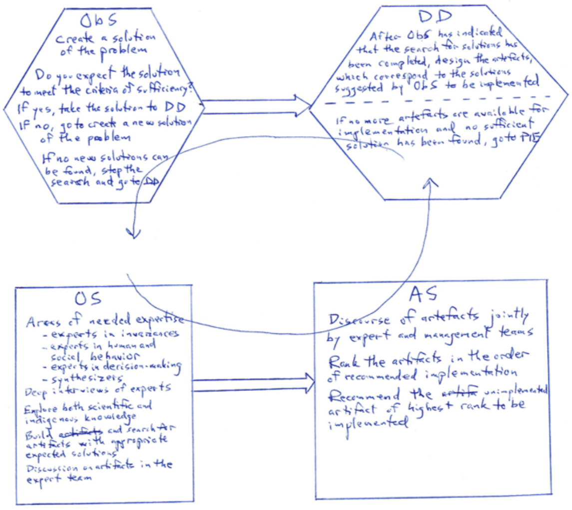

Figure 3. Working Sector II of the SADR process.

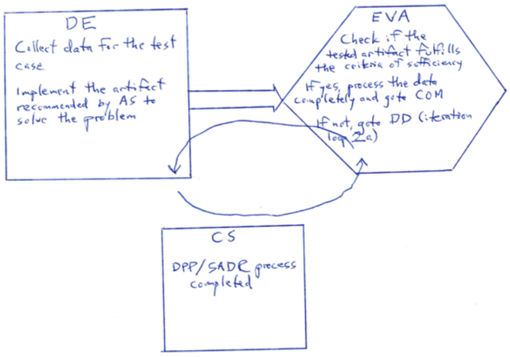

Figure 4. Working Sector III of the SADR process

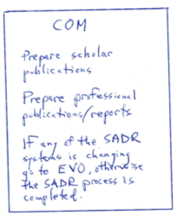

Figure 5. Working Sector IV of the SADR process

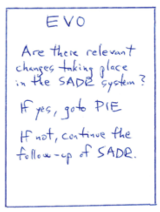

Figure 6. Working Sector V of the SADR process.

Following the ideas of the General Theory of Consistency (GTC) of Kuusi (1999, 247-255) based on in-situ surveys and interviews, it is recommended to divide local community groups to not-learning and learning members by applying the postulates 1-7 of GTC. The concepts not-learning being and learning being are abstract and get their interpretation in the application of DPP/SADR. For example, the initial idea in the Mozambique experiment of this thesis was to divide community members to not-learning members using traditional knowledge to guide their cultivation practices and learning members willing to learn to use practices of updated agriculture and climate knowledge with HMLCSs in mind. However, with the latest experiment in Tanzania, it became evident that a more appropriate line of divide could be based on assessments of the mindset of the interviewed and surveyed members regardless of their current cultivation practices. The author of this thesis hopes that the new line of divide works as a good driver for action, convincing those in doubt to implement the updated knowledge in their practices.

The climate and its globally recognized short-term changes challenge the traditional practices of climate services to take into account the climate system also as a system of changing and interacting systems. In this context, Gill, and Hevner (2011), Kahneman (2011) and Ulrich and Reynolds (2010) have suggested taking into account pertinent design space and heuristic considerations, prompting the author of this thesis to replace the entry points of ADR with the inspirations of DPP/SADR for an epistemic entry process of the generic Systems Action Design Research (SADR) process model.

Inspired by Kuusi (1999) as well as Mullarkey and Hevner (2015), the author of this thesis, depicts the SADR process in fig.1 and the DPP/SADR entry process model in fig.2. A SADR project research group starts its project by seeking contacts to high-level administrators and by negotiating the permission and support for the jointly planned project in terms of broad specifications of needed input, the methodology as well as output demanded by the end-user. Additionally, public confidence to allow for needed resilience and agility (Heeks & Ospina, 2016) while working in a participatory and co-creative working mode is of fundamental importance.

At next stage, a research group following this methodology should search candidates for expert and management teams with the needed expertise and motivated to work in a participatory, co-creative, resilient and agile working mode by recalling that areas of needed expertise include typically

- experts in invariances,
- experts in social and human behavior,
- experts in decision-making, and
- synthesizers of the whole entity.

Among the different expert groups, there is a need for active experts in indigenous knowledge. The experts need to be broad-minded and motivated by following a genuinely participatory and co-creative working mode. Before the

"Problem Identification and Encountering" (PIE) box of SADR, many necessary preparations have to be made. Recalling that a resilient and agile working model is preferred, a well-motivated and confidential relationship of the teams is needed. Inviting team members is a challenging task, which sometimes includes quite painful compromises between different qualities. Whatever is coming up, the final objective should be kept clearly in mind.

After taking the essential prior preparatory steps, the SADR can start from the PIE box. Next is the refining of the comprehensive specifications of the negotiated project with attention to its overall pertinence. One should allow this to take place in iterative steps. After clearly defining the project, criteria for sufficient and acceptable evaluation methods, and the evaluation of the solution should be agreed upon, especially with the end-users.

Following the idea of Kuusi (1999, 93-95) of an appropriate action-inducing epistemic utility function UkiA of argumentation for a chosen cultivation artifact i, and actor k, like the community, and the single argument A that implementation of updated agriculture and climate knowledge leads to better (amount and quality) crop yields than the use of traditional knowledge is formulated in the following adapted and simplified form.

$$UkiA = (I0k - I1ki) + (CA0k - CA1ki) + (CY1ki - CY0k), \qquad (1)$$

where

- I0k and I1ki give the monetary cultivation inputs (land preparation, fertilization, weeding, and harvesting of the chosen artifact i and actor k on the experiment prior and after the presentation of the argument A,
- CA0k and CA1ki represent the cultivation area expansion costs of the chosen artifact i and on the experiment prior and after the presentation of the argument A and
- CY0k and CY1ki are the monetary corn yields of the chosen artifact i and actor k on the experiment prior and after the presentation of the argument A.
- Then UkiA measures the gain in livelihood and can be determined both for single families as well as for the community as a whole.
- The further development of UkiA, both in its theoretical form and number of variables is a recommended iterative exercise for the participatory teams.
- Please, note that UkiA is a strictly quantitative utility function with no dichotomized qualitative variables involved. A critical assignment for the PIE box is to determine the sufficiency criteria of evaluation for the values of UkiA.

The qualitative data should be analyzed by using methods appropriate for qualitative analysis. For example, in our latest exploratory project in Tanzania, we analyzed the recorded video-interviews with a well established and appropriate qualitative software analysis toolkit by applying the method of thematic content analysis (Vaismondi et al., 2013).

Regarding the outcomes of the interview analyses and their evaluation, the PIE box (Figure 1) determines the pertinent qualities to be assessed and criteria of acceptable impressions about their evolution. In case the outcomes of the thematic content analysis do not indicate any quality, which PIE considers pertinent, the particular artifact is not accepted.

Recently abduction, as a kind of an intermediator between deduction and induction, has gained growing attention (Paavola, 2014). In order to point out and to analyze the dynamics of abduction, Paavola (2014) presented the following seven abductive strategies:

1. Searching somehow anomalous, surprising, or disturbing phenomena and observations,
2. Observing details, little clues, and tones,
3. A continuous search for hypotheses and noting their hypothetical status,
4. Aiming at finding what kind or type of explanations or hypotheses might be viable to constrain the search preliminarily,
5. Aiming at finding explanations (or ideas) which themselves can be explained (or be shown to be possible),
6. Searching for "patterns" and connections that fit together to make a reasonable unity and
7. Paying attention to the process of discovery and its different elements and phases.

The author of this thesis has used abductive strategies 1 and 6 to analyze three outliers in the interviews collected in Tanzania and in general recommends the abductive strategies of Paavola (2014) to be used for future technology projects (Peirce, 1931-1958). Even if abductive considerations are optional in APP/SADR, the use of abductive strategies was welcomed and led to bonuses in the evaluation in cases agreed in PIE. Such cases included detections of pertinent outliers in the interviews and surveys (Helminen et al, 2019c). Detections like this should be seen as local creative attempts to resolve the expected lacks in food security.

Parallel with the steps of PIE, the tasks of the Delphi process "Encountering Stage" (ES) are activated with needed extensive interviews and surveys. The interviews help to refine the problem, guiding the project members to encounter each other and discuss their roles and interests in the project. This process will hopefully help each roleplayer to find their natural team membership between the expert and the management teams so that everyone can enhance the participatory and co-creative atmosphere of the project work and further to enter the DPP/SADR, the core part of the epistemic Delphi process.

In terms of work sectors as suggested in fig. 1 PIE and ES together form the sector I, which should be seen as an important preparatory step to establish the whole project. It would be a good slot for a spearhead team to get the elaboration started. The spearhead team takes the responsibility to suggest active expert and management teams to steer and supervise the project.

The dominant box in the second column is the “Opening Stage” (OS) of DPP/SADR. It starts with in-depth interviews of experts, also others than just members of the expert team. Next, the project members with their associates construct their artifacts with appropriate expected solutions in mind in an iterative manner, if needed. In this context, one must consider both scientific and traditional knowledge thoroughly.

After OS in the SADR box "Objectives of a Solution" (ObS) still, a critical look is taken, whether any additional related artifacts can be found. After that, expectations of the solutions of each artifact to meet the criteria of sufficiency are discussed. The third column of SADR starts with the "Argumentation Stage" (AS) of DPP/SADR. In it artifact candidates are discoursed thoroughly by the expert and management teams, approved and ranked in the order of recommended implementation.

In the "Design and Development" (DD) box, designing of the approved artifacts takes place, after which the highest-ranked non-implemented artifact can be implemented. In case all artifact candidates have failed in the evaluation phase, the whole process is returned to the PIE phase for improved problem identification and possibly modified criteria for a satisfactory and acceptable solution.

Working sector II comprises the four boxes ObS, DD, OS and AS. They form the core part of the joint co-creative and participatory work of the project in close cooperation between the expert and management teams. It should be noted that sector II includes one iteration loop between boxes ObS and DD. In addition it is a part of the two-part iteration loop 2a & 2b from EVA to ObS and from ObS to PIE.

In the fourth column of SADR, the implementation of the artifact is released for action by the "Demonstration" (DE) box. Here at the first implementation, the data set for test purposes is processed before the actual test, where the particular artifact is implemented to solve the problem.

The next box of SADR the “Evaluation” (EVA) checks, whether the solution of the just tested artifact meets the quantitative and qualitative sufficiency criteria set in PIE. After fulfilling these criteria, the solution is processed by using the full data set, and the artifact and its results are forwarded to the communication phase. In case the test solution of the artifact fails to meet the criteria of sufficiency, the SADR process goes back to AS, and DD boxes and a new small iteration cycle or a further return back to PIE box and the large iteration cycle is taken.

The last box “Concluding Stage” (CS) confirms at the end of the DE that the solution for the problem test case has been obtained, forwards it to the processing of the full data set and closes the DPP/SADR entry process.

Working sector III with boxes DE, EVA and CS is managed predominantly by the management team. Its primary responsibility is to find out the feasibility of the artifact approved by EVA.

In case a satisfactory solution has been obtained EVA forwards the artifact and its solution to the “Communication” (COM) box, where both scholar and professional publications are written and disseminated. Here in working sector IV all feedback is welcomed and processed further.

In parallel with COM, in working sector V the box "Evolution" (EVO) of the large SADR iteration cycle will continue and kept active continuously in order to keep in pace with the inevitable significant changes in the SADR system after a satisfactory solution has been processed. In case no satisfactory solution has been obtained, EVO activates a return back to PIE with the suggestion to start the long iteration cycle anew. At this point, one question to be considered is the problem and its definition as well as to reconsider them.

In the context of changing systems, SADR must be resilient enough to be able to meet new challenges. The author of this thesis and his research group kept this in mind, confident of the resilience of SADR.

6.3 Suggestions

In the current ongoing climate change, the developers of climate services have two main climate information sources: observational data and climate model outlooks. The author of this thesis could recognize during the field missions that the grass-root awareness of climate services in the visited East African developing countries was non-existent. Small-holder farmers relied predominantly on indigenous knowledge of local climate. In addition, some farmers followed weather forecasts and in most cases at very irregularl intervals. Therefore the national climate services and schools face a basic challenge to cope with this lack of knowledge about climate information, to not even mention the climate knowledge as a mature utilization of climate information and related communication.

The climate change both in terms of climate warming and of changes in climate variability, especially precipitation, are of concern in tropical regions, where people are dependent on rain-fed agriculture. The local farmers are aware of these changes and also of the unavoidable and real uncertainties in them. Help by the DSR community would be more than welcomed, also in developed countries.

As one can expect that the primary interest of end-users lies in the impacts, those experienced by the system of interacting systems, it is recommended to analyze the impact in detail in order to find out the scientific and behavioral reasons. In terms of climatological variables, their new ranges can be useful measures instead of traditional characteristic values. The same applies certainly to other pertinent disciplines as well. In all, an open mind is vital in carrying out the analysis. To keep up with proper baselines is not an easy task and brings us back to the need for a genuinely participatory and co-creative working mode. A challenge set in front of us that we hopefully can address.

Chapter 7

Future possibilities

This work anticipates three kinds of prospects, a genuinely generic presentation of SADR as a framework for interacting systems in design science research. Here the SADR concept should be pulled off from the particular application, which has inspired the current effort to develop hybrid grass-root mobile climate services (HGMCSs) for local farmers. Formulating the generic aspect in properly abstract terms will evoke inspiration for other, totally different applications.

The development of HGMCSs and related development of technologies in the scientific domain, communication domain, as well as the educational domain, is undoubtedly another strongly needed prospect for growing humanitarian demands. We have to face, how to cope with the inevitable climate changes and associated uncertainties as well as to put the developed HGMCSs into action predominantly from the bottom-up perspective. In doing this, we have to use the whole spectrum of quantitative and qualitative data, proper methods to analyze them, and widen the use of abductive strategies (Paavola, 2014). Right now, the author of this thesis and his research group move on from the beginning stages of APP/SADR to demonstrating its feasibility for developing beneficial HGMCSs and resulting in useful technologies.

As pointed out by Baskerville et al (2018) we need an enhanced interactive development of design science theories and artifacts. That is the way to find out new future possibilities.

Chapter 8

Conclusions

The author of this thesis has presented a Systems Action Design Research (SADR) model for coping with systems of interacting systems. SADR consists of two parts, the MT/SADR, which takes care of the management of the model both in case of stationary systems and systems under change. The other part is the application part DPP/SADR, which tunes the SADR to the particular application under consideration. By the three cases of the author of this thesis and his research groups are delineating the development of mobile local climate services with DPP/SADR under the current climate change and changes in climate variability.

Another user of SADR with a different application in mind might choose another Delphi process appropriate for the particular application. As mentioned in the future possibilities of SADR, the challenge is thrown to elaborate it in a genuinely generic form. This generic form would help other users to become aware of its usefulness. SADR widens the scope of design science research substantially towards various interacting systems. SADR can most definitely play an essential role in the current climate change dilemma, which beyond its climatological aspects has numerous impacts in other fields of interest for the humanity (WMO, 2011, UN, 2015, UN Office for the Coordination to Humanitarian Affairs, 2016a & 2016b). In practice, this means that the DPP/SADR has to cope with both quantitative and qualitative data.

The author of this thesis hopes his contribution with other recent advances in design science research can help us in attempts to mitigate climate change and to adapt ourselves to it by taking into account also the fundamental humanitarian values.

The challenge is therefore to engage the whole DSR community to work collaboratively in the implementation of climate service solutions.

List of references

Baskerville, R., Baiyere, A., Gregor, S., Hevner, A. and Rossi M. (2018) “Design science research contributions: Finding a balance between artifact and theory,” Journal of the Association for Information Systems, 19(5), pp. 358-376.

Demetis, D. S, and Lee, A. S, (2016) “Crafting theory to satisfy the requirements of systems science,” Information and Organization, 26(4), pp. 116-126.

Demetis, D. S, and Lee, A. S, (2017) “Taking the first step with systems theorizing in information systems: A response,” Information and Organization, 27(3), pp. 163-170.

den Heyer, Molly (2001) “Temporal Logic Model,” Evaluation Unit, International Development Research Center (IDRC), Ottawa, Canada.

FAO (2011) “FAO-Adapt: Framework Programme on Climate Change Adaptation,” Food and Agriculture Organization of the United Nations, Rome, Italy. http://www.fao.org/docrep/014/i2316e/i2316e00.pdf

Gill, Grandon T., and Hevner, Alan R. (2011) "A Fitness-Utility Model for Design Science Research," in DESRIST 2011, LNCS 6627, H. Jain, A. P. Sinha and P. Vitharana (eds), Springer-Verlag, Berlin, Heidelberg, Germany, pp. 237-252, 2011.

Heeks, Richard (2002) "Information Systems and Developing Countries: Failure, Success, and Local Improvisations," The Information Society, (18:2), pp. 101-112. DOI: 10.1080/01972240290075039.

Heeks, Richard & Angelica V. Ospina (2016) “Measuring and Intervening on Resilience: The RABIT Approach,” Centre for Development Informatics, University of Manchester, Manchester, UK. Available at: www.niccd.org(wp-content/uploads/2017/11/RABITBriefingDocument.pdf

Hevner, Alan R., March, Salvatore T., Park, Jinsoo, and Ram, Sudha (2004) “Design Science in Information Systems Research,” MIS Quarterly, (28:1), pp. 75-105.

ICCD (2012a) "ICTs, Climate Change, and Development: Themes and Strategic Actions,” Richard Heeks and Angelica Valeria Ospina (eds), Centre for Development Informatics, Institute for Development Policy and Management, SED, University of Manchester, Manchester, UK. Available at: www.niccd.org/ wp-content/uploads/2017/11/Book_ICCD_Themes_Actions.pdf.

ICCD (2012b) “ICTs, Climate Change and Development: Case Evidence,” Richard Heeks and Angelica Valeria Ospina (eds), Centre for Development Informatics, Institute for Development Policy and Management, SED, University of Manchester, Manchester, UK. Available at: www.niccd.org/wp-content/uploads/2017/11/Book_Themes_Actions.pdf.

Iivari, J. (2015) “Distinguishing and contrasting two strategies for design science

research," European Journal of Information Systems, 24(1), 107-115.
IPCC (2014a) "Summary for Policymakers. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)," [Edendorfer, O., R. Pichs-Madruga, Y. Sokona, E. Furuhani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]," IPCC, Geneva, Switzerland. http://www.ipcc.ch
IPCC (2014b) "Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)," [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastandrea, T.E. Blair, M. Chatterjee, K.L. Ebi, V.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastandrea and L.L. White (eds.)]," IPCC, Geneva, Switzerland, 1132 pp. http://www.ipcc.ch
Climate Change (IPCC), Geneva, Switzerland. http://www.ipcc.ch
IPCC (2018) "Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related globalgreenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty – Summary for Policymakers". Intergovernmental Panel on Climate Change (IPCC), Switzerland. http://www.ipcc.ch
Kahneman, Daniel (2011) "Thinking, fast and slow," Farrar, Straus and Giroux, New York, USA
Korten, David C. and Rudi Klauss (1984) "people-centered Development," Kumarian Press, West Hartford, USA.
Kuusi, Osmo (1999) "Expertise in the Future Use of Generic Technologies – Epistemic and Methodological Considerations Concerning Delphi Studies," VATT Research Reports 59, Government Institute for Economic Research, Helsinki, Finland. Available at https://core.ac.uk/download/pdf/153491932.pdf
Moss, Richard H., Jae A. Edmonds, Kathy A. Hibbard, Martin R. Manning, Steven K. Rose, Detlef P. van Vuuren, Timothy R. Carter, Seita Emorr, Mikiko Kainuma, Tom Kram, Gerald A. Meehl, John F. B. Mitchell, Nebojsa Nakicenovic, Keywan Riahi, Steven J. Smith, Ronald J. Stouffer, Allison M. Thomson, John P. Weyant and Thomas J. Wilbanks (2010) "The next generation of scenarios for climate change research and assessment," Nature, 463, pp. 747-756.
Mullarkey, Matthew T., and Hevner, Alan R. (2015) "Entering Action Design Research." in DESRIST in DESRIST 2015, Heidelberg, Germany, 2015, DOI: 10.1007/978-3-3198-18718-3_8.

Mullarkey, Matthew T. and Hevner, Alan R. (2018) "An Elaborated Action Design Research Process Model." European Journal of Information Systems, DOI: 10.1080/0960085X.2018.1451811.

Nakicenovic, Steven J. Smith, Steven K. Rose (2011) "The represeantative concentration pathways: an overview," Climatic Change, 109, pp. 5-31. https://doi.org/10.1007/s10584-011-0148-z

O'Brien, K. and L. Sygna (2013) "Responding to Climate Change: The Three Spheres of Transformation," In: Proceedings of Transformation in a Changing Climate, 19-21 June 2013, University of Oslo, Department of Sociology and Human Geography, Oslo, Norway, pp. 16-23.

Ospina, Angelica Valeria & Richard Heeks (2012c) "Chapter 11: Making Police on ICTs and Climate Change in Developing Countries," in ICTs, Climate Change and Development: Themes and Strategic Actions," Richard Heeks & Angelica Valeria Ospina (eds), pp. 321-356, Centre for Development Informatics, Institute for Development Policy and Management, SED, University of Manchester, Manchester, UK. Available at: www.niccd.org/ wp-content/uploads/2017/11/Book_ICCD_Themes_Actions.pdf.

Ospina, Angelica Valeria & Richard Heeks (2012d) "Chapter 13: ICTs and Climate Change Adaptation – Enabling Innovative Strategies," in ICTs, Climate Change and Development: Themes and Strategic Actions," Richard Heeks & Angelica Valeria Ospina (eds), pp. 369 - 378, Centre for Development Informatics, Institute for Development Policy and Management, SED, University of Manchester, Manchester, UK. Available at: www.niccd.org/ wp-content/uploads/2017/11/Book_ICCD_Themes_Actions.pdf.

Ospina, Angelica Valeria & Richard Heeks (2012e) "Chapter 14: ICT-Enabled Responses to Climate Change in Rural Agricultural Communities," in ICTs, Climate Change and Development: Themes and Strategic Actions," Richard Heeks & Angelica Valeria Ospina (eds), pp. 379-394, Centre for Development Informatics, Institute for Development Policy and Management, SED, University of Manchester, Manchester, UK. Available at: www.niccd.org/ wp-content/uploads/2017/11/Book_ICCD_Themes_Actions.pdf.

Ospina, Angelica Valeria & Richard Heeks (2012f) "Chapter 15: The Future Research Agenda for ICTs, Climate Change, and Development," in ICTs, Climate Change and Development: Themes and Strategic Actions," Richard Heeks & Angelica Valeria Ospina (eds), pp. 395 - 404, Centre for Development Informatics, Institute for Development Policy and Management, SED, University of Manchester, Manchester, UK. Available at: www.niccd.org/ wp-content/uploads/2017/11/Book_ICCD_Themes_Actions.pdf.

Paavola, Sami (2014) "From Steps and Phases to Dynamically Evolving Abduction," A paper presented at the Charles S. Peirce International

Centennial Congress, 2014. Invigorating Philosophy for the 21st Century. Lowell, USA, 16 - 19 July 2014. The Commens Working Papers, Preprints, Research Reports & Scientific Communications, Edited by Mats Bergman, Sami Paavola & João Queiroz.

Peirce, Charles S. [CP (volume, paragraph, year)] (1931-1958). Collected Papers of Charles Sanders Peirce, vols. 1-6, Hartshorne, C. and Weiss, P., (eds.), vols. 7-8, Burks, A. W., (ed.). Harvard University Press, Cambridge, Mass, USA.

Rittel, H. and Webber, M. (1984) "Planning problems are wicked problems," in Cross, N. (Ed.) "Developments in design methodology," Wiley, New York, NY, USA.

Sein, Maung K., Henfridsson, Ola, Purao, Sandeep, Rossi, Matti, and Lindgren, Rikard (2011) "Action Design Research," MIS Quarterly, (35:1), pp. 37-56.

Sein, Maung K. and Matti Rossi (2019) "Elaborating ADR while drifting away from Its essence: A commentary on Mullarkey and Hevner," European Journal of Information Systems, 28(1), pp. 21-25, DOI: 10.1080/0960085X.2018.1527189

Swiderska, K., Y. Song, J. Li, H. Reid and D. Mutta (2011) "Adapting Agriculture with Traditional Knowledge," Briefing, International Institute for Environment and Development, The Hague, The Netherlands. Available at http://pubs.iied.org/pdfs/17111IIED.pdf

Tall, Arame (2013) "What Do We Mean by Climate Services?" WMO Bulletin (Special Issue) 62 (2013). Available at https://public.wmo.int/en/bulletin/what-do-we-mean-climate-services.

Ulrich, Werner, and Reynolds, Martin (2010) "Critical systems heuristics," in Systems Approaches to Managing Change: A Practical Guide, M. Reynolds and S. Holwell (eds.), Springer-Verlag, London, UK, pp. 243-292. Link to the chapter http://oro.open.ac.uk/21299/1/systems-approaches.

UN (2015) "Transforming our world: the 2030 Agenda for Sustainable Development". Resolution adopted by the General Assembly, New on 25 September 2015, (A/RES/70/1). [Online]. Available: www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E.

UN Office for the Coordination to Humanitarian Affairs (2016a) "Agenda for Humanity," 2016 [Online] Available: http://www.agendaforhumanity.org/summit

UN Office for the Coordination to Humanitarian Affairs (2016b) "Natural Disasters and Climate Change: Managing Risks & Crises Differently". High-Level Leaders' Roundtable #5, Core Responsibility Four of the Agenda for Humanity. [Online]. Available: https://www.worldhumanitariansummit.org/summit/roundtables

Vaismondi, Mojtaba, Hannele Turunen and Terese Bondas (2013)

“Content Analysis and thematic analysis: Implications for conducting a qualitative descriptive study,” Nursing and Health Sciences, 15, pp. 398-405.

van Vuuren, Detlef P., Jae Edmonds, Mikiko Kainuma, Keywan Riahi, Allison Thomson, Kathy Hibbard, Geroge C. Hurtt, Tom Kram, Volker Krey, Jean-Francois Lamarque, Toshihiko Masui, Malte Heinshausen, Nebojsa (2014) “Representative Concentration Pathways.”Planbureau voor de Leefomgeving, Utrecht, The Netherlands

von Bertalanffy, Ludwig (1972) “The History and Status of General Systems Theory,” The Academy of Management Journal, 15, 4, (General Systems Theory (Dec 1972)), pp. 407-426.

WMO (2009a) “Report of WMO conference on Living with climate variability and change: understanding the uncertainties and managing the risks, 17-21 July 2006, Espoo, Finland,” WMO/TD-No. 1512, World Climate Applications and Services Programme (WCASP)- No. 79, World Meteorological Organization, Geneva, Switzerland for Environment and Development, The Hague, The Netherlands. Available at http://pubs.iied.org/pdfs/17111IIED.pdf

WMO (2009b) “Secure and Sustainable Living - The Findings of the International Conference on Secure and Sustaintable Living: Social and Economic Benefits of Weather, Climate and Water Services, 19-22 March 2007; Madrid, Spain,” WMO- No. 1034, World Meteorological Organization Geneva, Switzerland

WMO (2011) “Climate Knowledge for Action: A Global Framework for Climate Services – Empowering the Most Vulnerable," WMO-No. 1065, World Meteorological Organization, Geneva, Switzerland

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Towards a Design Research Model for Climate Services: Experiences from a Development Project in Mozambique

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Abstract. As one part of our research efforts and exploration in Africa, we have visited the Chokwe Irrigation System area in Mozambique in order to develop hybrid grass-root mobile climate services for and with local farmers to support their cultivation practices. The lessons learned along the explorations inspired us to elaborate an appropriate design research framework for the particular action design research process, which would facilitate us to develop holistic grass-root mobile climate services for local farmers in a developing country. The main outcome of the study was the updated design research framework for the task.

Keywords: Climate Change, Mobile technology, Design Science Research

1 Introduction

With the ongoing climate change and changes in climate variability we encounter quite a variety of climate impacts affecting everyday life, especially in a developing countries. In terms of the design science framework introduced by Hevner et al [1] as a milestone of the topic we may ask whether we can apply it, when we in a participatory way with local partners co-create climate services appropriate for end-users. Following the design thinking paradigm [2,3] we started our work with its first stage – empathy within the inspiration space. We acted based on the recommendations of Brown [2], who suggests that the intention during an empathy stage in a project is to experience a problem or opportunity that sets researchers in motion.

We started our project by exploring local climate services and background information in Chókwè District, Mozambique. We had joined a pre-negotiated program, where we had to adjust our tasks to the overall objectives of the program. Still, this arrangement left us with the required freedom to explore pertinent problems as well as opportunities to build an appropriate design research framework.

In the following we briefly describe the situation at the time of our field trip to Chókwè, Mozambique, during August - December 2011. Then we discuss how we processed parts of the interview material and how recent international agreements [4,5,6,7,8], including agenda for humanity [4], and UN Framework Convention on Climate Change [8], which steered our efforts. Thereafter we show relevant results of the interviews as well as the induced inspirations to tune the Design Science Research framework of Hevner et al [1] so that we can apply it to develop appropriate hybrid [9] grass-root mobile climate services for local farmers in Chókwè District. In the conclusions we share these inspirations with the readers.

2 Project consortium

In the context of "Programme of cooperation in Science, Technology and Innovation between Finland and Mozambique" (STIFIMO), we established a joint project "Development of innovative community climate services for agriculture in Chókwè District" (DICCLISEAG) with the Mozambique National Meteorology Institute (INAM) as our local host and together with the District Services of Economic Activities of the Chokwe District Administration (SDAE/CDA), South Zone Center of the Mozambican Institute of Agricultural Research (CZS/IIAM) as well as Instituto Superior Politéchnico de Gaza (ISPG), (Polytechnic Institute of Gaza in English).

3 Trends, evolutions, and challenges of the Chókwè irrigation system and its surroundings

The authors of [10,11,12,13] discussed the history and present stage of the Chókwè Irrigation System (CIS) and its vicinity. The evolution of events led to a situation, where the government of Mozambique favored large-scale rice cultivation in CIS at the expense of land ownership by local smallholder farmers [11,12]. In addition, the local historical and social dynamics contributed to gender imbalance towards women. Conflicts between them and the CIS administrator, A Hidráulica do Chokwe, E.P. (HICEP) [10] led to a further weakening of the status of local smallholder farmers.

Chókwè District is a semi-arid region in the flat Limpopo drainage delta area. More upstream there are large elevation differences and also some reservoirs of limited capacity along the route of the Limpopo river. The volume of the reservoirs is not adequate to damp downstream effects of heavy rain episodes in the upper reaches of Limpopo drainage. Hence Chókwè District as part of Limpopo delta area is prone to relatively frequent recurring flash floods, which in the recent past have caused severe disasters, also in CIS.

As climate, its change and the changes in its variability are pertinent factors in the semi-arid region of Chókwè District, it became clear to us that local people, typically smallholder farmers, needed appropriately tailored climate services for actions to improve their baseline and livelihood in a sustainable manner.

In our research, we drew inspiration from the increasing recognition of the social dynamics in climate issues. The World Humanitarian Summit (WHS) 2016 released the Agenda for Humanity (AH) [4] with its five core responsibilities. In his WHS

Chief's Summary the then UN Secretary-General Ban Ki-Moon urged the nations to stand up for the humanity and to commit themselves to action [5]. In the context of core responsibility four "Change people's lives – From delivering aid to ending need" its roundtable five discussion under the theme "Natural Disasters and Climate Change: Managing risks and crises differently" [6] led to five core commitments related to climate issues as follows: implement the related strategies, reinforce national and local management, invest in climate services, build community resilience, and ensure regional and global humanitarian assistance.

4 Data and methods

4.1 Research Question

Based on the community's crucial needs for tailored climate services to improve their livelihood in a sustainable manner, we sought to gain baseline information about current needs, strengths, infrastructure, ICT usage patterns, and climate information sources. We set the research question as follows:

> *What are the current baselines for crucial information needs, current strengths, infrastructure, skillsets, climate information, and mobile usage patterns in Chókwè District?*

In our reflection of the results, we sought to find pertinent additional local issues to environment, IS research and knowledge base columns of the design science research framework of Hevner et al [1] to tune it for the development of holistic grass-root mobile climate services for local smallholder farmers of Chókwè District.

4.2 Questionnaire and processing responses

For the general interviews in Chókwè District we used a questionnaire as our data collection protocol. Group interviews were conducted, thus one response in the questionnaire represented one group. After the interviews had been conducted we scrutinized the responses and took into account the parts we considered to be relevant for the task of our research question. The questionnaire consisted of a general part and specific sections covering agriculture, climate and ICT items. The objective of the interview was to find out both strengths and gaps in baseline items pertinent to the hybrid approach of the project.

Based on recommendations of our partners, we initiated the project by making group interviews and conducting surveys in five communities (acronyms in parentheses); Lionde (**L**), Chókwè (**S**) and Chilembene (**B**), all within the CIS area. The remaining communities Macino (**M**) and Chekelane (**A**) were outside of CIS. In the large farm premises of two foreign agribusiness companies Mozfoods Industrias Alimentares (MIA), inside CIS, and EmWest (EW), close to the northwestern end of CIS, we surveyed and discussed their automatic weather stations. In the results, one answer represents one community.

5 Results

5.1 Quality of life

In regard to quality of life the communities responded on a scale of "excellent", "good", "fair" and "bad". One community considered their life to be "Good" (B), two communities "Fair" (S and M) and two communities "Bad" (L and A). Thus, there were two modes (Mo), "Fair" and "Bad".

5.2 Prominent main needs

In regard to the main needs of the communities, the following responses were given. All five communities mentioned the need for farm equipments, including ploughs, tractors and water pumps. Four communities mentioned the need for seeds and electricity (L, S, M and A). Two communities mentioned also the need for water and cows (L and A). Individual communities mentioned access to credit, transport, hospital and channel renovation as their main needs. As a secondary need, three communities mentioned local schools.

5.3 Sources of help

When asked if any organizations were currently addressing their prominent main needs, only two communities had received help in meeting their needs. Community (L) had got an offer from the agribusiness company Mozfoods Industrias Alimentares (MIA) to provide improved maize seeds, but as a part of that deal they would need to sell the yield to them at their price. In addition, community (B) had received two excavators, which were donated by HICEP, but there is still need for additional excavators and other machinery.

5.4 Evaluation of infrastructure

In regard to evaluation of infrastructure, on a scale of "Good", "Acceptable" and "Not Good" interviewees gave the following responses. In regards of both *irrigation systems,* as well as *marketing services,* all five communities ranked them as "Not good". Four communities (L, S, M and A) ranked *roads, means of transportation*, and *housing* as "Not good", three communities (L, S, and B) ranked *schools* as "Not good". One community (A) ranked *health centers* as "Not good", while three communities (L, S and B) ranked *health centers* as "Acceptable". Two communities ranked (M and A) *schools* as "Acceptable". *Roads* (B), *housing* (B), *availability of electricity* (B) and *means of transportation* (M) where all ranked as acceptable by one (n=1) community. Only one community (M) ranked one part of infrastructure as "good", which was the *health centers*. Thus, the communities had a relatively negative perception about most infrastructure items in the questionnaire.

5.5 Expectations for the future

In regard to expectations for the future, communities' responses where mainly related to the *ability to grow various plants and keep livestock*. One community (L) wants to *cultivate maize and vegetables*, while one community (S) wanted to *cultivate rice* and *larger quantities of vegetables,* such as tomatoes, cabbages, beans and onions. Community B wanted to *develop agricultural practices* by cultivating larger areas and keeping livestock, such as cows, pigs and goats. Another community (M) wanted to develop agricultural practices, cultivate potatoes and tomatoes, keep cows and be able to sell various agricultural products including meat. Community A wanted to cultivate peanuts, small beans, cassava, potatoes and pineapples. In additional all communities reported that they would like to have *better machines, knowledge* and *orange plants*. Also, many of the interviewees in community A affirmed that they would like to start cashew nut production and to get a better and bigger storage facility for processing cashew nuts.

5.6 Malnutrition situation

When asked if their families had run out of money to buy food in the past 30 days, the following answers where received. Representatives from two communities (L and S) replied that it had happened often (=more than 5 days), whereas representatives from three other communities (B, M and A) replied that it had happened only sometimes (=between 1 to 5 days).

5.7 Cultivation practices

In regard to cultivation responses of the communities brought up following problems. Two communities (L and S) mentioned that the *irrigation system was not functioning well* and there were *not enough available tractors and other machines for seeding, harvesting and transpor*t. S community also pointed out that *uneven regulation of water channels* could cause issues. Other community (B) pointed out the *lack of fertilizers, poor water quality and the lack of credit* as well as *marketing efforts*, while another community (M) faced *issues with land preparation, plant diseases and problems with wild animals*. One community (A) also complained that *plant diseases were out of control* and there was a *lack of saws to cut trees*.

5.8 Production constraints

In terms of production constrains, the following responses we given by the communities. Three communities (L, S and A) mentioned *lack of rain*, two of them (L and S) mentioned also *lack of credit*. Two communities (S and M) mentioned *lack of transportation* and *poor market conditions* as well as *very low prices.* Community B referred to their answer for the previous question.

5.9 Suggestions for changes in community

In regard to *suggestions for changes in the community*, this was presented as an open-ended question. The responses given by the informants were, in most cases, related to *availability of agriculture inputs*, *equipment* and *construction of various facilities*. Two communities (L and S) proposed to have better *availability of tractors*, *fertilizers*, *seeds* and *finances*. One community (B) suggested to have an *agro-center*, while another (M) proposed to have a co*oling house with needed transportation equipment*. One community (A) proposed to have *a borehole based irrigation system*.

5.10 Past and present climate hazards

When asked how severe the impacts of climate hazards to their crops are, all communities uniformly answered that they are severe. In regard to local responses to climate hazards, all communities again uniformly assessed them to be fair.

5.11 Suggestions to improve local responses

When asked how to improve local responses to climate hazards, communities' responses varied quite much. Two communities (L and S) suggested to *update knowledge on hazards and their occurrence*. One community (B) suggested to *establish their own weather station*, whereas another community (M) proposed that *each community should have its own leader*. Community A anticipated that once their own irrigation system would be established, problems could become more manageable. Another option would be to move farms to more humid areas.

5.12 Access to climate and weather information

In terms of access to seasonal meteorological and agro-meteorological forecasts, three communities (L, S and A) had no idea where to get that information, whereas two communities (B and M) knew that Radio Mozambique broadcasts those information. This same ignorance applied also to weather and climate services, since all the other communities were unaware of their existence, expect community S, which mentioned radio and TV.

5.13 ICT Ownership

In regard to ownership of ICT technologies, most commonly owned technologies were mobile phones (63 out of 80 responses), radios (9 responses) and TV (7 responses). Both computer and video-TV got one response.

5.14 Most often used ICT

Most used technologies in the communities were mobile phones, in addition community S used TV and community S used radio. Community M did not respond to this question.

5.15 Willingness to contribute to the ICT development in your village

In regard to being interested to contribute to developing / implementing some ICT uses in their village, the following answers were obtained. Community L did not know and community S did not answer. Community M just said "yes", without further elaboration, while community M said that they could help spread the information. Community A said that a local weather station is needed, as well as other equipment's and education.

6 Discussion

In terms of our research question we focus on items pertinent to the tuning of Hevner design research framework [1]. According to the general questions (sections 5.1-5.9) the administrative practices of the government steered the small-scale farmers to limit their efforts and co-operation among families, neighbors and, outside of the CIS, also among communities. In these circumstances the smallholder farmers remained poor and underdeveloped, as observed by [14]. The organizations, which addressed these needs to some extent, were MIA and HICEP (Section 5.3). For its conditional help in terms of seeds provision MIA kept the right to buy the total crop yield by the price it settled. The farmers of B pointed out their local needs for CIS channel maintenance. The needs for facilities were considerably bigger than the help received from HICEP. Mr. Mugabe of SDAE/CDA said that the whole CIS was in a demand of renovation. The lack of systematic help to smallholder farmers was in line with the preferences of the government to favor large-scale foreign investments and actions. Hence the administrative practices should be included in the environment column of the design research framework.

Another important point inspired by almost all shown responses was the need to establish increasing willingness for open, hybrid, constructive and trans-disciplinary cooperation across the whole society. This aspect should be brought into the environment column of a design model. The surveys and replies in regard to sections 5.7-5.9 on farming indicated that the way farming practices had been organized by the big farms (MIA and EW) could give pertinent ideas for the local farmer communities on how to organize their facilities and activities. The answers in section 5.11 spread widely. Regarding sections 5.10 and 5.11 one pertinent reaction among farmers was the need to improve their own knowledge of floods and draughts and their occurrence. According to section 5.12 the local smallholder farmers did not know anything about weather and climate services. This indicated lack of knowledge in agricultural practices and in basic climate concepts and led us to replace capacities by capacity building in the environment column.

With the surveyed widespread use of mobile phones it was encouraging to recognize that in communication we could rely on modern devices and networks. In addition (section 5.15) many interviewees indicated their interest to develop and implement ICT uses in their village, although they lacked capacities and know-how.

Many responses indicated that the baseline of livelihood and the abilities to meet impacts of climate hazards were inadequate. To improve the general awareness of the communities we suggest baseline to be included in the knowledge base column. In the context of administrative practices we highly suggest that legislation as well as historical, political and social dynamics are actively kept into consideration.

All in all we could say that the interviewees were aware of the impacts of climate variability in their everyday life in farming issues. However, the awareness of basic climate service concepts and communication skills were inadequate if not non-existent. Hence the lack of knowledge about climate and climate services (sections 5.10, 5.11, 5.12) proposes us to emphasize the role of climate knowledge [15] in the context of the baseline in the knowledge base column.

As many of the past flash floods have had severe impacts on the CIS area (section 5.10) proper dimension values e.g. for additional reservoirs upstream from the Limpopo delta area would give a good base for actions to prevent these impacts to occur. Hence also the need of proper dimension values should be emphasized in the context of the baseline in the knowledge base column.

The interviews and assessment of social behavior, like motivation and trust, must be included in the knowledge base column in the design models. With the ongoing climate change and changes in climate variability we used for expert prototype interviews the twelve question set of Critical Systems Heuristics (CSH) [16] and found this approach promising. We suggest heuristics to be part of the knowledge base column.

As we have suggested open, holistic, constructive and trans-disciplinary cooperation across the whole society, we propose synthesis to be added to the justify/evaluate the slot of the IS research column.

With the addition of willingness for an open, hybrid and constructive cooperation, the list of revised and added suggestions to the environment column of the design research framework is as follows:

- capacity building,
- administrative practices as well as
- cooperation.

and to the foundations of the knowledge base column

- baseline as well as
- heuristics.

7 Conclusions

ISPG together with us submitted a proposal to STIFIMO for the project to prepare and discuss the project at the final DICCLISEAG assembly. Due to lack of open, hybrid and constructive cooperation and misunderstandings between local institutes and ministries the proposal was turned down. We were left with our first lesson. Finally, we come to our lesson learned, which can be put in a nutshell as depicted in fig. 1

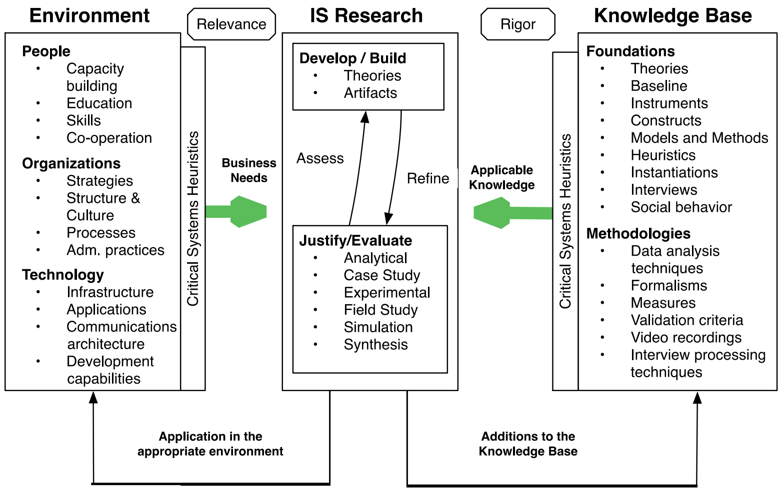

Fig. 1. Elaborated design research framework, based on [1,16].

Both the environment and knowledge base have in front of them the filter "Critical Systems Heuristics" (CSH) of Ulrich and Reynolds [16]. In essence CSH refers to its twelve question set, through which the suggestions for business needs and applicable knowledge are scrutinized before they enter the IS research column.

Regarding the people in the environment column we have replaced capacities with capacity building not to omit the importance of capacities but to emphasize the needs to replace their lack with capacity building. We have also added co-operation to the essential qualities we expect people to have. As for organizations we found administrative practices to be scrutinized and also followed up.

To the foundations of the knowledge base we added heuristics with the need to take into account increasingly hectic changes in the whole system of systems. We renamed the concept frameworks by baseline in order to widen the scope in system considerations, like climate impacts.

With these updates our first lesson turned out to be quite valuable so that we are now ready to proceed with considerations of our Systems Action Design Research (SADR) in our future projects.

References

1. Hevner, Alan R., March, Salvatore T., Park, Jinsoo and Ram, Sudra (2004) "Design Science in Information Systems Research," *MIS Quarterly*, (28:1), pp. 75-105.
2. Brown, Tim (2009) "Change by design: how design thinking transforms organizations and inspires innovation," HarperCollins, New York, USA.
3. Both, Thomas (2016) "Design Project Scoping Guide," Hasso Plattner Institute of Design at Stanford, Stanford University, Palo Alto, California, USA. Open access at https://dschool.stanford.edu/resources/design-project-guide-1

4. Agenda for humanity (2016) "Agenda for Humanity Annex to the Report of the Secretary-General for the World Humanitarian Summit (A/70/709, 2 February 2016)," United Nations (UN) Office for the Coordination of Humanitarian Affairs, New York, USA, 2016. Open access at https://www.agendaforhumanity.org/agendaforhumanity
5. World Humanitarian Summit (2016a) "Chair's Summary by the United Nations Secretary-General: Standing up for Humanity: Committing to Action," in World Humanitarian Summit (WHS), Chair's Summary, Istanbul, Turkey, 2016. Open access at https://www.unocha.org/sites/dms/Documents/Chairs Summary.pdf
6. World Humanitarian Summit (2016b) "Natural Disasters and Climate Change: Managing Risks & Crises Differently," in WHS, Key Documents – High-Level Leaders' Round Tables – Core Commitments. 2016. Open access at http://whsturkey.org/the-summit/key-documents-for-whs
7. United Nations (2015) "Transforming our world: the 2030 Agenda for Sustainable Development A/RES/70/1," Resolution adopted by the General Assembly on 25 September 2015 (A/RES/70/1), UN, New York, USA, 2015, Open access at https://sustainabledevelopment.un.org/content/documents/21252030 Agenda for Sustainable Development web.pdf
8. United Nations Framework Convention on Climate Change (2016) "Report of the Conference of the Parties on its twenty-first session, held in Paris from 30 November to 13 December 2015." FCCC/CP/2015/10/Add.1, UN, New York, USA, 2016, Open access at https://unfccc.int/process/conferences/pastconferences/paris-climate-change-conference-november-2015/paris-agreement
9. Heeks, Richard (2002) "Information Systems and Developing Countries: Failure, Success, and Local Improvisations," The Information Society, (18:2), pp. 101-112. DOI: 10.1080/01972240290075039
10. Pellizoli, Roberta (2010) "'Green revolution' for whom? Women's access to and use of land in the Mozambique Chókwè irrigation scheme," Review of African Political Economy, 37, 124, pp. 213-220.
11. Veldwish, Gert Jan, Wouter Beekman and Alex Bolding (2013) "Smallholder Irrigators, Water Rights and Investments in Agriculture: Three Cases from Rural Mozambique," Water Alternatives, 6(1), pp. 125-141.
12. van der Struijk, Luiz Felipe (2013) "Smallholders' strategies in response to contract farming programs in Chokwe, Mozambique – Farmers' reactions to the process of relocation of land and water access in the Chokwe Irrigation System", Master thesis, Water Resources Management in International Land and Water Management, Wageningen University, The Netherlands
13. Veldwisch, Gert Jan (2015) "Contract farming and the reorganization of agricultural production within the Chókwè Irrigation System, Mozambique," The Journal of Peasant Studies, DOI: 10.1080/03066150.2014.991722
14. Kojo, Amanor and Chichava, Sérgio (2016) "South-South Cooperation, Agribusiness, and African Agricultural Development: Brazil and China in Ghana and Mozambique," World Development, 81, pp. 13-23. DOI: 10.1016/j.worlddev.2015.11.021.
15. Meinke, Holger, Nelson, Rohan, Kokic, Philip, Stone, Roger, Selvaraju, Ramasamy and Baethgen, Walter (2006) "Actionable climate knowledge – from analysis to synthesis," Climate Research, 33, pp. 101-110. www.int-res.com/articles/cr_oa/c033p101.pdf
16. Ulrich, Werner and Reynolds, Martin (2010) "Critical systems heuristics," in Systems Approaches to Managing Change: A Practical Guide, M. Reynolds and S. Holwell (eds.), Springer-Verlag, London, UK, pp. 243-292. Link to the chapter http://oro.open.ac.uk/21299/1/systems-approaches.

PII

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Experiences from a Development Project in Kenya – Baselines for Future Climate Information Systems

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Abstract. This paper explains our efforts in regards of hybrid climate services. As one part of our research efforts and exploration in Africa, we have worked with the Marigat District in Baringo County, Kenya, where we first intended to help the farmers to replace the invasive Prosopis juliflora deep-root species by another deep-root species easier to keep under control. Data was collected through questionnaires with open-ended and closed-ended questions to find a baseline of community challenges and technology use. The lessons learned in the project inspired us to analyze the data by using the lens of Heeks' [3] design theories. The main outcome of this study is a hybrid evaluation and its discussion with future implications for future climate services.

Keywords: Climate information systems · Agriculture · Developing countries

1 Introduction

During the recent decades, climate has started to change and so its variability as well. Hence the variety of climate impacts affecting everyday life especially in developing countries has changed and led to a growing need for hybrid and locally pertinent climate services. In line with this we started from the design research framework [1] as well as critical systems heuristics [11] and proceeded with local partners in a participatory way to imagine and co-create climate services for end-users in Kenya. In this article we focus on understanding the baseline situation and related technology usage for crucial farming and other decisions with using the method of Heeks [2] as one of our lens and tool, as well as with future needs for improved climate information systems in mind.

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Another kick-off to our start came from the design-thinking paradigm [3, 4]. We encountered *empathy* as its first stage of the inspiration space. According to Brown [3] the objective of the empathy stage is to experience a problem or an opportunity, which sets the relevant participants in motion. We joined a pre-negotiated program and adapted our sub-project, described in this paper, to its larger objectives without loosing our freedom to study problems and opportunities, which were pertinent for this project as well as its information systems, and included also the evaluation of our sub-project. Our preliminary data collection started by studying available local climate services and related general baselines in Marigat District, Kenya, with recommendations for actionable climate knowledge [5] in mind.

In the following sections we briefly describe the situations at the time of our field trip to Eldoret and Marigat District, Kenya. Then we cover the processing of parts of the interview material and introduce next the method, by which we evaluate the silvicultural information systems and the baseline data [2]. Thereafter we show pertinent results of the interviews as well as our evaluations of the baseline data and associated forestry information systems. In the context of the discussion and conclusions we mention the stalemate we encountered in Eldoret and Marigat District. The lessons learned inspired us to further apply and extend the evaluation method of Heeks [2] in the context of developing appropriate hybrid grass-root mobile climate services for local farmers in Kenya. Our suggestions include extending observations by Heeks [2] with suggestions that are based on co-creation and participatory design [3, 4]. Finally to conclude we share our inspirations with the readers.

2 The Project and Related Consortium

In the context of the umbrella project on "Building further capacity in Kenya: Strengthening practical & ICT aspects towards multidisciplinary and community-engaged forestry education" (SFEK) we established a joint project "Holistic grass-root mobile climate services" (HGMCS) with the School of Forestry of the University of Eldoret, Kenya (SF/UOE) and Marigat Research Sub Centre of Kenyan Forest Research Institute (MRSC/KEFRI) as our local hosts, the School of Forestry of the University of Eastern Finland (SF/UEF) and the School of Computing of the University of Eastern Finland (SC/UEF). The Centre for International Mobility, Helsinki, Finland (CIMO) funded SFEK.

Based on the declaration of the Kenyan minister of agriculture *Prosopis juliflora* to be a noxious weed [6] we agreed unanimously with the local colleagues to focus on attempts to replace the invasive *Prosopis juliflora* deep-root species by another deep-root species, which could be kept easier under control in Marigat District, which is located 100 km east-northeast of Eldoret on the opposite side of the Rift Valley. From this point we started our preparations to keep an MSc (Forestry) course on "Forest Management in a Varying and Changing Climate (FMVCC)" with the deep-root species problem in mind. FMVCC took place under mission 2 of SFEK - "Improvement of forest education curricula at MSc and PhD levels".

As noted, *Prosopis juliflora* is a recent invasive deep-root species in Lake Baringo area and has been discussed by [7]. By considering both its positive and negative effects to the local environment, people have preferred it to be controlled or eradicated [7]. It became clear that actions to eradicate *Prosopis juliflora* species and to replace it by another less invasive deep-root species were needed.

3 Crucial Need for Climate Information

Climate change and changes in climate variability are among the most serious problems of the world today. Climate change may cause a number of uncontrolled sequences of fatal harms, and as is well known by recent reports by IPCC[1] it directly threatens the future existence of humankind. The negative effects of climate change are already being experienced globally, particularly in the Global South, mainly by the most vulnerable groups of people, and the situation is getting worse as time passes. Therefore, urgent actions are needed in order to adapt to changing climate conditions. Our observations confirm that climate change and the changes in its variability are pertinent factors in this semi-arid region, too, and it has become clear that local people, typically smallholder farmers and nomads need appropriately tailored climate services.

A number of new climate service projects are underway in Tanzania, Kenya, and Uganda, to name a few examples. A number of projects are still in their developmental stages. However, some evidence of successes have been reported for example by [8]. In their research in Kenya, it was shown that farmers, who received climate information were better in crop management and got higher yields, as compared to farmers in a control group [8]. Thus, while many projects are still in their beginning stages, and many mobile services for agriculture have failed or disappeared, evidence of benefits from new technologies is also starting to emerge, which is encouraging and gives motivation for future efforts.

4 Data and Methods

4.1 Research Questions

Based on our objectives to develop future hybrid climate services, our preliminary data collection was set to understand the available local climate information systems and practices to gain general baselines of the context in Marigat District, Kenya. In regards of understanding the baseline situation, our research questions were set as follows.

(1) What are the current baselines for crucial information needs, current strengths, infrastructure, skillsets, climate information, and mobile usage patterns in Marigat District, Kenya?
(2) How can the baselines for current information and development processes for climate and weather information systems be evaluated from the viewpoint of Heeks' [2] design-reality theories?

[1] http://www.ipcc.ch.

4.2 Data Collection Protocol and Informants

The data collection protocol was designed to explore the strengths and gaps in baseline and behavior items that are pertinent to hybrid climate services. During data collection, we encouraged the local farmers and nomads to adopt a participatory and co-creative attitude. In order to collect data about the general baselines, a questionnaire was developed. The questionnaire contained both quantitative items with scales such as "good", "fair", "poor", as well as open-ended questions. The questionnaire contained six themes, which were: *community life*, *personal skills and expectations*, *local climate impacts and demands for pertinent climate services*, *ICT and its role in the daily life*, *livestock related items* as well as *first motivation for nomadism and collaboration to develop relevant local climate services* and finally *trust on other community members*.

The data was collected from the Marigat district in Kenya, from two communities: the Tugen-community and the Njemps-community. In addition to data collection, the visits included a two-week intensive course on climate services in Eldoret. In regards of numbers of respondents, there were a total of 27 respondents (10 females, 17 males). 15 respondents were from Tugen, and 12 respondents were from Njemps.

4.3 Data Analysis

First, the questionnaire data was analyzed in the following way. In regards of closed-ended questions, the number of responses per each item were calculated, and modes (Mo) were counted. In regards of open-ended questions, the related qualitative responses were coded so that each item or category was first collected, and then the total number of mentions of that specific issue was calculated. Per each item reported in the results, it is clearly stated if the item was an open-ended or a closed-ended question. This analysis is presented in Sects. 5.1–5.5.

Second, this baseline data was analyzed and evaluated from the viewpoint of the framework presented by Heeks [2], which is introduced in Sect. 4.4. The results of this evaluation are presented in Sects. 5.6–5.12. The analysis of results proceeds following the Heeks' [2] model, dimension by dimension, i.e. information, technology, processes, objectives and values, staffing and skills, management systems and structures and other resources.

4.4 The Evaluation Method of Heeks [3]

In order to evaluate forestry information systems of our interview sites in Marigat District Kenya, we applied the method of Heeks [2]. In our explorations we focused on the existing design-actuality gaps by recognizing as elements of design:

- components from the designer's own context and
- conceived assumptions about the situation of the end-user.

Our evaluations followed Heeks [2]. We applied his dimensions of relevance:

- information (data store, data flows, etc.),
- technology (both hardware and software),
- processes (the activities of end-users and others),

- objectives and values (the key dimension, through which factors such as culture and politics are manifested),
- staffing and skills (both the quantitative and qualitative aspects of competencies),
- management systems and structures, and
- other resources (particularly time and money).

With pertinent parts of the conducted surveys and interviews as well as related discussions as input we evaluated these seven dimensions separately for the design, represented by the designer, and the actuality, represented by the end-users, by rating on the scale low – medium – high and by taking into account the discussion and ideas of [2]. We considered also the relevant findings from related work [2, 6, 8–11].

5 Results

5.1 Community Life

In regards of *quality of life*, on a scale of “Good”, “Fair”, “Poor”, and “Can’t assess”, the following responses were given by interviewees. A total of 7 interviewees (4 males, 3 females) considered their life to be “Good”, 11 interviewees considered their life to be “Fair” (7 males, 4 females), 6 interviewees considered their life to be “Poor.” One interviewee responded with the “Can’t assess” option. Thus, the mode (Mo) was “Fair”.

The interviewees’ perceptions in regards of the *prominent main needs* were investigated by using an open-ended question *“At present, what do you think are the main needs/requirements/demands of the community?”* From the answers, the following main needs were found. The most often mentioned *prominent main need* was *access to clean water* (n = 18), followed by *education for children* (n = 11) and *tree plantation (n = 3).* In addition*, medical services, good roads, electricity,* and *irrigation and seeds* were each mentioned for one or two times in the data. Caretaking of handicapped or the lack of it was found also to be an issue.

The informants’ perceptions in regards of the *main strengths in their communities* were investigated by using an open-ended question. The data shows that among the mentioned strengths, *farming* (n = 17) was the most often mentioned, followed by *keeping livestock* (n = 15). The following strengths of the community were mentioned once or twice in the data: *charcoal burning, beekeeping, locally available resources, teamworking skills, fruit business* and *poultry rearing*. The community members were rather unanimous in regards of the main strengths.

In regards of the informants’ perceptions as to the *weaknesses in the communities*, this was also investigated by using an open-ended question. The results show that the most often mentioned weaknesses were *lack of water* (n = 4) and *preparedness against drought* (n = 4). In addition, the following issues were mentioned once, twice or three times: *preparedness against floods, poor poverty reduction, infrastructure, education level, business skills, communication skills, access to markets, knowledge of people and leadership, lack of food, medicine, information, means of transportation, grass, electricity, technology, land possible to cultivate, skills, resources and livestock,* *financial constraints, reliance on sole traditional knowledge, exposure on cattle rustling, illiteracy, people afraid, slow change, alcoholism and laziness.* Thus, the informants' perceptions to the weaknesses differed quite much with each other, and the answers seemed not to be too unanimous.

5.2 Infrastructure

In regards of *infrastructure items,* the questionnaire asked the informants to classify the following items: *roads, means of transportation, health centers, housing,* and *support for nomadism* on a scale of "*excellent", "good", "acceptable",* and "*poor".* In regards of *roads,* eight respondents (n = 8) considered the roads to be "acceptable", while nineteen (n = 19) considered the roads to be "poor". No-one considered the roads to be either "excellent" or "good". In regards of *means of transportation,* three (n = 3) respondents chose "excellent", six (n = 6) "good", four (n = 4) "acceptable", and fourteen (n = 14) "poor". Thus, in regards of roads and means of transportation, the modes (Mo) to both two questions were "poor."

In regards of *health centers,* the responses were as follows: *"excellent" (n = 2), "good" (n = 0), "acceptable" (n = 10), "poor" (n = 15).* In regards of *housing*, the responses were as follows: *"excellent" (n = 0), "good" (n = 2), "acceptable" (n = 7), "poor" (n = 15).* In regards of *support for nomadism,* the respondents gave the following answers. No-one considered this issue to be "excellent", three (n = 3) considered it to be "good", four (n = 4) considered it "acceptable", and twenty (n = 20) considered it to be "poor." Hence, in regards of all three questions in regards of health centers, housing, and support for nomadism, the modes (Mo) for the questions were "poor."

In regards of the interviewees' *willingness to settle down,* this was queried with a scale of "yes", "no", "conditionally yes" or "conditionally no." Of all the respondents, eleven (n = 11) answered yes, and no-one answered "no". Seven (n = 7) answered "conditionally yes", and five (n = 5) answered "conditionally no." For those who selected "conditionally yes", an open-ended question was presented. The answers to that question were: *improved services to access water, grass, more land and trees around the village.* Other aspects mentioned included *harsh conditions, willingness to settle down,* and *demarcation of land.* In regards of suggested changes to the community, in the open-ended answers, the most suggestions centered around *land demarcation (n = 6), access to clean water (n = 7), quality education for children (n = 8),* and *tree planting (n = 3).*

5.3 Personal Skills and Expectations

In regards of *skills that the interviewees would like to learn in order to improve their livelihood*, this was queried with an open-ended question. 21 out of 27 interviewees said that they wanted to learn new skills. The answers indicated the following. Improved farming skills were mentioned five times (n = 4), bookkeeping skills were mentioned three times (n = 3), driving was mentioned four times (n = 4), ICT skills was mentioned once (n = 1). Quite much other things were mentioned, too. These included: *skills in building irrigation canals, saloon hairdressing, cooking skills,* *charcoal burning skills, learning to sell, drip irrigation, buying and selling livestock, improving education level, masonry, animal breeding,* and *food planning.*

In regards of *expectations for the future*, the answers emphasized *electricity and water, improved infrastructure,* and *self-reliance.* In regards of past and present climate hazards the interviewees listed the following: *droughts (n = 18), floods (n = 13), diseases (n = 7), people displacement because of floods (n = 4).* In addition, 'hunger and poverty' was mentioned several times.

In regards of *suggestions to improve actions of local authorities,* this was asked with an open-ended question. The suggestions included *fast responses to needs (n = 3), improved collaboration (n = 4), help in tree planting (n = 3), early warning system (n = 3), basic climate education (n = 3),* and *improved education (n = 1).* Other suggestions were (each were mentioned once or twice): *access to clean water, change of river course, move livestock to grassland, getting subsidies, improved infrastructure, plant grass, access to health centers, access to medicine, assistance in selling livestock, assistance in farming, rebuilding houses, materials for new houses, increased government help,* and *donations and food.* Point of note is that responses to this question were spread on a wide scale, and no single issue was mentioned more than four times.

5.4 Local Climate Impacts and Demands for Pertinent Climate Services

In regards of *current access to climate and weather information,* the following was observed. For the questionnaire item "current access to climate and weather information", the interviewees responded *yes* for six times (n = 6) and *no* for twenty-one (n = 21) times. In regards of *devices used to access climate and weather information,* radio was mentioned seven (n = 7) times, television once (n = 1), and indigenous knowledge fourteen (n = 14) times. In regards of the *main need for climate and weather information,* the following items were mentioned: *information from mobile, radio and community meeting (barasa)* (n = 14), *rain information (n = 7).* In regards of the *willingness of the interviewees' to settle down in case that weather and climate information needs would be met,* the responses were *yes (n = 26),* and *no (n = 0).*

5.5 Mobile Technologies

In regards of *owned ICT technologies,* the following was found. Twenty-six (n = 26) persons owned mobiles, twenty-four (n = 24) a radio, eleven (n = 11) a television, and four (n = 4) a personal computer. The most often used ICT technologies were found to be mobiles (n = 24), followed by radio (n = 4), television (n = 1), and personal computer (n = 0). In regards of *usage patterns of mobiles,* the following was found. *Making and receiving voice calls (*n = 26*), sending and receiving short messages* (n = 21*), taking photographs (*n = 13*), accessing the internet (*n = 11*), sending and receiving money (n = 7),* and *listening to music (*n = 1*).* All but one of the interviewees were of the opinion that ICT supported nomadism.

In regards of *communication patterns,* the following issues were mentioned: *communication on proper pastures (n = 11), communication about access to drinking water (n = 6), communication on need for help (n = 6), communication on security* *issues (n = 7), communication with veterinarian (n = 5).* In addition, the following single issues were mentioned: *informing on animal conditions, business and marketing issues, cattle rustling danger, livestock auction dates,* and *livestock new breeds.*

In regards of *willingness to receive improved climate information*, the following was found. The responses to category "yes" were (n = 24), and to category no (n = 3). In regards of suggestions on how improved climate information would help in the future, the answers included the following: preparing land in advance (n = 7), preparations against hazards (n = 3), warnings for impending drought (n = 1), and possibility to preserve food (n = 1). In regards of the biggest risks for keeping livestock, the following were mentioned: *diseases (n = 11), cattle rustling (n = 9), droughts (n = 20), prosopis juliflora pads (n = 2), lack of water (n = 5).* In regards of benefits of improved climate information to livestock production, the following were suggested: *proper timing for selling and buying livestock (n = 15).* In addition, one interviewee pointed out the possibility for better timing in preparing tree planting. All interviewees indicated improved climate information would be beneficial to agricultural activities in the community.

In regards of *trust on other members of the community,* an almost unanimous trust was found. There were 23 of those who trusted everyone, and three (n = 3) of those who trusted only a part of other members.

5.6 Heeks' Design Reality Gap: Information

In the context of assessing the quality of community life, as noted in Sect. 5.1, the mode (Mo) of answers was "Fair". One qualitative comment in the data also read "*people are more informed.*" However, weaknesses in other responses in regards of lack of information, illiteracy, poor communication skills and poor knowledge, it was found that the informants were eager to utilize climate and weather information and related ICT solutions. The willingness to search for information was growing.

One important observation in regards of information was that in regards of some questions, such as *strengths, main needs,* and *infrastructure,* the respondents were quite unanimous in their responses. However, in regards of some other questions, such as *weaknesses, skills that the interviewees would like to learn in order to improve their livelihood,* and *suggestions to improve actions of local authorities,* the answers were not unanimous, but almost all participants had their individual views as to the most relevant issues. Thus, community members share quite strong common views into some important questions, while not to some others. For example, in regards of important skills for the future, almost each member had their own ideas.

In regards of climate information, the current access was assessed as "No" by most (n = 21) of the interviewees, while "Yes" was selected considerably less (n = 6). In regards of *willingness to receive improved climate information,* "Yes" was selected (n = 24) times, while "No" was chosen (n = 3) times. This indicates that in regards of current weather and climate information, there is a design-reality-gap [2]. In regards of weather and climate information, the respondents were unanimous. In regards of information flow between officials and community people, there were some hints that the information flow was not optimal.

5.7 Heeks' Design Reality Gap: Technology

While current access to ordinary mobiles was found to be good, access to other technologies came up mostly as needs or lacks, as seen in Sects. 5.3 and 5.5. There were signs of growing interest in terms of willingness to learn ICT skills. However, the current technology-usage patterns were found to be basic, and modern technology usage was at a very modest level. It must be noted that evidence of climate information systems with evidence of benefits to small scale farmers does not yet exist. Therefore, it is not a matter of *access* or *skills*, but a matter of future co-creation. In regards of future technologies for climate information, this project is at the inspiration stage with empathy as one of its primary tools, where problems and opportunities are first being experienced [3], before it becomes possible to build and test prototypes and later to implement fully operational technologies. The preliminary results indicate that future breakthroughs in technology will most likely happen through co-creation at the grass-root level.

5.8 Heeks' Design Reality Gap: Processes

One of the hard processes in our original and agreed plan was the replacement of *Prosopis juliflora* with another deep-root species. According to [7], the eradication of *Prosopis juliflora* from its originally planted area in Baringo County would had cost some one million euros, which the local communities would not have been able to afford. Both this action and to get the expansion of *Prosopis juliflora* under control would have required financial support and specific policies from the authorities.

On one of our first visits to Eldoret and Marigat, we found that in line with the findings by [7, 9, 10], the majority of people in Marigat argued that life would be better without the *Prosopis juliflora* species. For a long time prior to our visit there was no policy guiding the management of the plant but in effect from the end of 2008, when the minister for agriculture declared *Prosopis juliflora* as a noxious weed [6].

With this background in mind it was interesting to see both from our interviews and our surveys that in early 2015 almost nobody told any more of eradication of *Prosopis juliflora* in any of the questionnaires or other related talks. Instead, the local soft processes had been improvised to utilize it in handcrafts and also as raw material for a tuned power station. From our point of view a fast change of process had occurred, which was in complete conflict as to what had been agreed. Therefore, we conclude that lack of trust and commitment in agreed processes constituted a design-reality-gap.

5.9 Heeks' Design Reality Gap: Objectives and Values

We came with the hybrid objectives of our hard process and with values, expectations, and biases rooted in all of the local cultures where the authors of this paper originate from. Hence the soft objectives of local people were not always understood. This convinced us about the need for participatory co-creation in technology projects. We found self-reliance as one important wish for the future. Motivation to nomadism was based both on financial gains by selling livestock and on tending a flock while searching for water and pasture. Trust on community members was almost unanimous and different from some other cultures. On the other hand, while trust was unanimous in regards of the objectives of some issues, such as the most important skills for the future, each community member had their own views. On other issues, such as important needs, the groups views were unanimous. In addition to trust between members, other important attributes in groups were the tolerance for differing viewpoints, and social-psychological issues of leadership.

5.10 Heeks' Design Reality Gap: Staffing and Skills

Based on our interviews of community weaknesses, lack of skills and poor leadership were mentioned. On the other hand, bookkeeping appeared as a skill some community members wanted to learn (n = 3). However, as seen in Sect. 5.3, a number of other skills were mentioned too, including driving, hairdressing, cooking, charcoal burning, selling, masonry, breeding, food planning.

5.11 Heeks' Design Reality Gap: Management Systems and Structures

The interviewees asked us to list current inadequacies in the community baselines. However, management systems and structures were issues that our data did not deal in a great depth.

5.12 Heeks' Design Reality Gap: Other Resources

In other resources we came up with education, poverty, hunger and financial constraints. The interviewees emphasized the need of education for children, even though it was mentioned also as a strength. The mentioned weaknesses included poverty reduction and financial constraints. Impacts of past and present climate hazards having affected livelihood had caused hunger and poverty. Local important responses included the demand for basic climate education and improved education. A general lack of almost all possible resources was permanent, which was in conflict to the answers to general ratings of *quality of life*, which participants assessed as "Fair" (Sect. 5.1). It calls into question the reliability of answers to the question and possibly the tendency to give socially acceptable answers to questionnaires by outsiders. This observation contributes as one sort of design-reality-gap when future technologies or other interventions are planned.

6 Discussion and Conclusions

From this project we were left with some successes, some failures, and lessons learned. In regards of *Prosopis juliflora,* the problem still remains unresolved. It is obvious that our original hard process needed to be revised to become softer and to allow for improvisations. On the other hand, in line with the design-thinking paradigm [3, 4], we were able to experience local challenges, problems, and opportunities and collect reliable baseline data about the pertinent issues. This helped in building trust and connections in order to continue with possible future activities and initiatives. In discussing our results, we turn now to the specific research questions.

Research question 1 asked *"What are the current baselines for crucial information needs, current strengths, infrastructure, skillsets, climate information, and mobile usage patterns in Marigat District, Kenya?"* Our results showed the following.

First, the baseline data revealed a number of crucial needs in regards of equipment, access to resources, to medical care and to clean water, needs for educational resources, and demands for a variety of skill development opportunities. In regards of technology usage, the current usage patterns were mostly non-agriculture and non-climate related. The need for improved climate and farming information and services became clear, and this was one of the issues, where the locals were unanimous. In regards of some issues, the participants were unanimous. However, in regards of some other issues, such as the most important skills for the future, their opinions in regards of the most important lines of action differed quite much.

Our recommendations included the need to focus on areas where the collected information showed largest diversity and to think carefully, which parts of the data are crucial. As changes in current strengths, infrastructure and skillsets can occur even in a short time, follow-up studies are needed for these items. The awareness and access of climate information demanded strengthening in order to enhance the use and the learning of climate knowledge [5]. The use of mobile technology seemed to be wide and the leading way for communication. This provides a platform for future climate services. In regards of designing those services, co-creation and participatory design are recommended. In one way or the other, a number of stakeholders, who may not otherwise communicate very well with each other, need to be included in the design processes. Building commitment and trust is a crucial factor here. Projects that start with good intentions end too often when commitments and priorities change.

Research question 2 asked *"How can the baselines for current information and development processes for climate and weather information systems be evaluated from the viewpoint of Heeks' [2] design-reality theories?"* Our results show the following.

Our answers show that the dimensions of information, technology, processes, staffing and skills as well as management systems and structures are closely related to the operational aspects of climate and weather services. In addition, these dimensions overlap with the objectives and values as well as some other resources when we build hybrid climate services. For us, it was crucial to update our understanding with the interviews in regards of the local current baseline. First, we could see that a part of the responses were reasonable coherent, whereas some others were quite diverse. We may ask, how we could achieve a reasonable consensus. Should we encourage people for co-creative cooperation and take first steps to absorb, not just climate information, but to process it to climate knowledge in their minds.

Second, we face the challenge to narrow the design-reality gaps in terms of Heek's [2] model. Beside climate knowledge, this is another life-long exercise. Third, we see improvisation (Heeks [2]) as a vital tool for narrowing design-reality gaps. Fourth, with the ever-hectic changes in our environment we need agility in our responses. Hence, we would like to see agility to be extracted as an explicit new dimension from other resources in Heek's [2] model. Last but not least, we would recommend that evaluation would become an inseparable part of any development project.

References

1. Hevner, A.R., March, S.T., Park, J., Ram, S.: Design science in information systems research. MIS Q. **28**(1), 75–105 (2004)
2. Heeks, R.: Information systems and developing countries: failure, success, and local improvisations. Inf. Soc. **18**(2), 101–112 (2002)
3. Brown, T.: Change by Design: How Design Thinking Transforms Organizations and Inspires Innovation. Harper Collins, New York (2009)
4. Both, T.: Design project scoping guide. Hasso Plattner Institute of Design at Stanford, Stanford University, Palo Alto, California, USA (2016). https://dschool.stanford.edu/resources/design-project-guide-1
5. Meinke, H., Nelson, R., Kokic, P., Stone, R., Selvaraju, R., Baethgen, W.: Actionable climate knowledge – from analysis to synthesis. Clim. Res. **33**, 101–110 (2006). http://www.int-res.com/articles/cr_oa/c033p101.pdf
6. GoK [Government of Kenya]: The Kenya Gazette of 9th January 2009, vol. CXI, no. 2 (2009)
7. Maundu, P., Kibet, S., Morimoto, Y., Imbumi, M., Adeka, R.: Impact of Prosopis juliflora on Kenya's semi-arid and arid ecosystems and local livelihoods. Biodiversity **10**(2–3), 33–50 (2009). https://doi.org/10.1080/14888386.2009.9712842
8. Rao, K., Hansen, J., Njiru, E., Githungo, W., Oyoo, A.: Impacts of seasonal climate communication strategies on farm management and livelihoods in Wote, Kenya. In: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)/CCAFS Working Paper no 137 (2015)
9. Kipchirchir, K.O., Ngugi, K.R., Wahome, R.G.: Use of dry land tree species (Prosopis juliflora) seed pods as supplement feed for goats in the arid and semi arid lands of Kenya. Environ. Res. J. **5**(2), 66–73 (2011)
10. Mwangi, E., Swallow, B.: Prosopis juliflora invasion and rural livelihoods in the Lake Baringo area, Kenya. Conserv. Soc. **6**(2), 130–140 (2008)
11. Ulrich, W., Reynolds, M.: Critical systems heuristics. In: Reynolds, M., Holwell, S. (eds.) Systems Approaches to Managing Change: A Practical Guide, pp. 243–292. Springer, London (2010). https://doi.org/10.1007/978-1-84882-809-4_6. http://oro.open.ac.uk/21299/1/systems-approaches

PIII

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Community Climate Services for Small-Scale Farmers in Tanzania

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Abstract: Climate variability affects small scale farming in the Global South, with serious worldwide implications. Unreliable information has been found as one factor that contributes negatively to farming success. The issue of unreliable information has become ever more pressing with climate change. In the future, technology can contribute positively to farming success, if implemented well. In this paper, we present our results from initial data collection: the System Action Design Research Framework (SADR) and Epistemic Implementation Delphi Panel (EIM) models, and present first prototypes for a mobile holistic climate service, to be piloted in Morogoro region, Tanzania. Our results show high importance in inclusive and participatory approaches in project implementation, which aligns well with observations from related research.

Keywords: m-Agriculture, small scale farming, mobile technology.

1. Introduction

Climate variability is one of the most complex problems the world faces. It especially affects the most vulnerable people in the Global South. The changing climate has an extreme impact on small scale farmers. Small scale farming is an important way of generating income and employment for a large number of people. Together small-scale farmers produce an incredible 70% of the world's food [1]. Smallholder farmers often live in conditions of poverty, marginalisation and reliance on natural resources [2]. It is common that farming practices are passed on from generation to the next. However, this indigenous knowledge has become partly invalid under current conditions [2]. Farmers commonly lack the knowledge to prepare for and deal with the impacts of changing conditions [3,4,5]. Climate knowledge [7] is one key element in the whole food production chain. Responses to climate change need to encompass several levels, including crop and farm-level adaptations, national-level agriculture and supporting policies and investments, and regional and global policies and investments. Thus, it is important to develop methods to increase farmers' climate knowledge and increase their adaptability to new and changing conditions.

The aim of this project is to design and develop climate information solutions for small scale farmers and other interest groups such as government officials and decision makers to adapt to the effects of climate change in food production. The planning and implementation relies on our Systems Action Design Research (SADR) model, which is an extension of Hevner's [6] Design Science Research framework as well as Epistemic Implementation Delphi (EID) model. The basis for these models was gathered by surveying local readiness for developing holistic climate services, in separate initiatives conducted in Mozambique and Kenya, which included surveys, discussions, data collection, and workshops with local collaborators.

The emphasis of this project is in co-designing a community climate service. The shared climate knowledge, which is based on climate and weather data, aims to provide knowledge about new farming techniques, best practices and adaptation measures to local farmers. The new information services may help farmers to make better informed decisions in regards of choosing crops and seeds, selecting growing methods, and deciding sowing and harvesting times. The to-be-developed technology artefact can also include additional features, such as insurance against drought, market platform for selling extra harvest, and even a funding possibility to allow farmers to invest into new growing techniques.

The service will be implemented as a technology artefact that will be designed in a participatory way, following co-design principles, so to match the information demand of the local farmers and involve them in the entire development process. It will also be built by taking into account the local changing climate patterns and will emphasize the need to utilize climate-smart agricultural practices. The application development will also have a strong emphasis on financial sustainability, which will guarantee the continuity of the service after the project has ended, as recommended by [4,8,9].

2. Background

2.1 Learnings from the Previous m-Agriculture Initiatives

Based on the previous research done on m-Agriculture applications, few key points can be raised up, which have affect to the success and acceptability of the m-Agriculture applications in developing markets. Firstly, application development should be based on bottom-up model and be “tailor made”, in order to truly fit into the local conditions [9,4]. More effort should be made into understanding the potential end users and their needs, since the lack of such understanding has been named as one of the biggest challenges in developing applications and sustainable business models. For instance, it is still rare to see m-Agriculture developers working together with the intended end-users, in order to really understand their living conditions and daily challenges [10]. Information, which is provided through these applications, should be timely, and relevant [4]. Applications should also provide services and information on a wide range of matters; such as soils, seeds, weather and various financial services (for instance, insurances, microfinance and savings) [11].

Most importantly, applications should be designed to be user-friendly, which is presumed to result in better user acceptance, and finally to empower farmers to be more successful and knowledgeable in their farming activities [5]. Also, importance of connections and co-operation with local organisations, such as research institutes and NGO´s cannot be undervalued [12,10].

2.2 Participatory Design

In the past, mainstream rural development efforts have focused on technical innovations delivered to farmers in a top-down model [14]. However, many studies have found that such interventions, often conducted by formal research institutions, do not necessarily provide farmers with more secure access to new technologies or improve their livelihoods [13,14,15]. In particular, agricultural interventions in Africa have failed to provide useful outputs to poor small-scale producers [16,17]. One possible reason for this failure of diffusion of technologies through formal institutions is that the technologies are in some cases not developed based on farmers’ needs or constraints. Thus, too many newly introduced technologies have been inappropriate for poor farmers in marginal, rain-fed areas [18,14].

Participatory research is a “collaborative process of research, education, and action that is explicitly oriented towards social transformation” [19]. Participatory approaches to design and research are now widely accepted because they are focused not only on improving farming practices but focus also on empowerment. They recognize the importance of all stakeholders in the generation and dissemination of knowledge, contrary to approaches where the needs and preferences of the main beneficiaries are ignored [20].

In technology projects, it is crucial to understand local sociocultural practices, decision making processes, and role hierarchies [21,22,23,24,25]. Soft skills play an important role in building trust, building protocols of communication, and co-designing with local communities. The need for participatory design (PD), action research (AR), and design research (DR) to complement software development process models, such as Agile development is often emphasized [21,22,23,24,25].

In general, it has become well agreed that technology projects need to be geared with research in order to understand what to implement, how to implement, and for evaluating impact. At least the four broad stages suggested for constructive ICT4D projects need to be addressed: 1) how to analyse a context, 2) how to represent the resources of a context as inputs for a computational artifact, 3) how to design and build an artifact, and 4) how to evaluate the artefact [26]. A common guideline in inclusive innovation and participatory design is that the ownership of projects should be local: local African technology solutions are designed for local African challenges [27].

3. Previous work

3.1 Surveying Local Readiness

As the first step, we explored the local readiness and demands to develop holistic grass-root mobile climate services for local farmers in Chokwe Region, Gaza Province, Mozambique in 2011-2012 and in Marigat Region, Baringo County, Kenya in 2014-2015. At the former location, our objective was to clarify the existing baseline for sustainable development work, whereas in Kenya we focused on climate services to help replacement actions of aggressively spreading deep root tree species by optional deep root tree species. At the end workshop of our project in Chokwe Region, the local farmers presented the idea of developing local holistic grass root mobile climate services.

Our latter assignment in Kenya was part of a larger bilateral international mobility program between Kenya and Finland. At the beginning, the task was to replace one originally locally planted deep root species, Prosopis juliflora, to prevent farther desertification in semi-arid areas, like Marigat Region. However, this tree spreads aggressively and deteriorates pastures. Hence, local partners and community members nodded at first that the replacement of Prosopis juliflora was an idea to be sustained. We proceeded with the idea to develop appropriate augmentary mobile climate services to local farmers in two selected communities.

We were planning to make the general interviews and a part of the expert interviews; however, our time ran out and the project ended. Even if the two projects did not lead to the best possible outcomes, the grass root interviews indicated unanimous motivation and demand to develop holistic mobile climate services for farming. It has given to us the impetus to consider the fundaments of a feasible holistic climate service concept.

3.2 System Action Design Research Framework (SADR)

Our prior experiments led us to develop the modified DSR framework, adapted from Hevner [6], which is presented in Figure 1, and explained below.

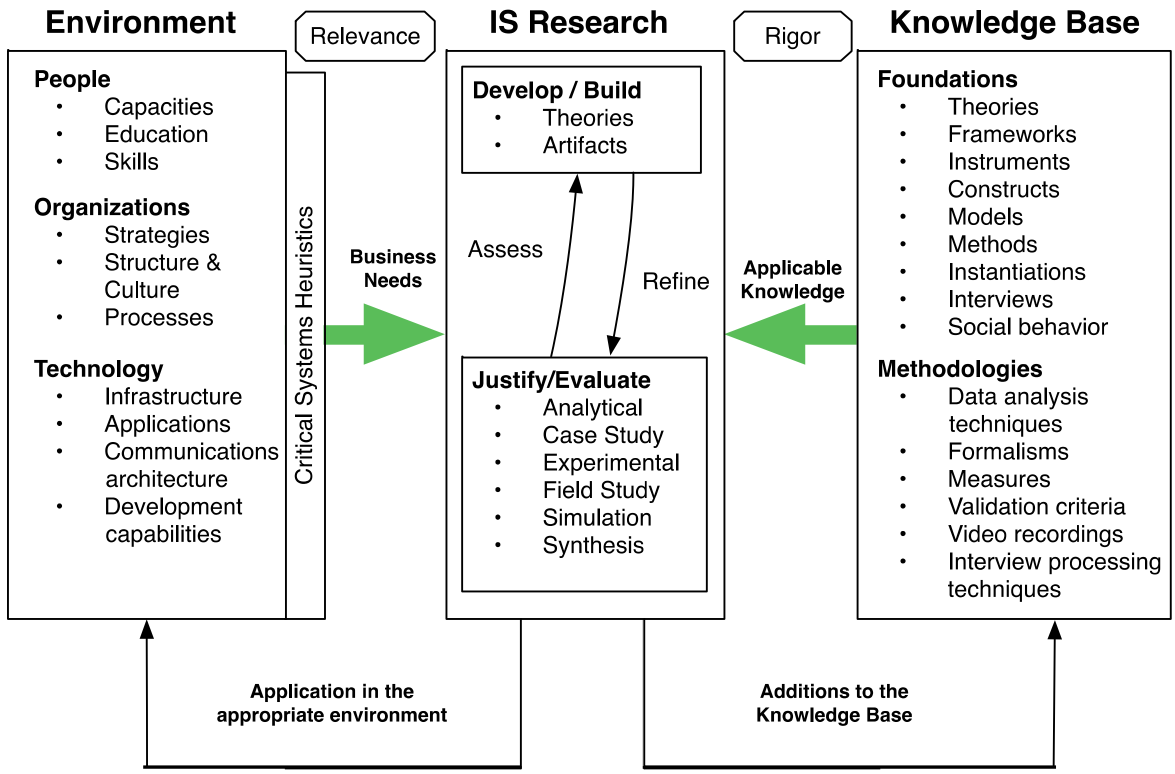

Figure 1: Systems Action Design Research (SADR) Framework as a modified Design Science Research (DSR) Framework of Hevner [6].

First, we start with the *environment* and in it with people (see Figure 1). In our coming prototype project, we have three groups of people: the local farmers of the communities (LCG), the various kinds of local experts extending from the community to the national level (LNG), and the supervisors from the foreign development aid party (SFG).

Regarding roles with reference to the General Theory of Consistency (GTC) of Kuusi [28, pages 247-255] we divide LCG people in every community for the field into two groups: non-learning beings and learning beings. Here not-learning beings typically trust on the use of traditional tacit knowledge whereas learning beings are willing to learn and use advised modern methods and practices. In addition, we expect to find from LCG, LNG and SFG experts in various invariances (climate, cultivation etc.) as well as human and social behaviour, from LNG and SFG experts in decision-making and from all three groups experienced synthesizers. The business needs/demands will be elaborated thoroughly in discussions and interviews guided by the twelve questions set of the Critical Systems Heuristics (CSH) [29, page 244].

Second, in regards of *knowledge base* (see Figure 1), with the HGMCSs and holistic views in mind, we need to take into account pertinent aspects of human and social behavior. Hence, we need in the knowledge base knowledge of social behavior, methods to make, video-record and process interviews [30,31]. Here an essential part of the collected data consists of compiled and video-recorded interviews.

Third, in regards of *IS Research and the Design Cycle* (see Figure 1), we have added to the Justify/ Evaluate Box syntheses, because in our framework development considerations we need also to make syntheses of their pertinent characteristics. As an outcome of our framework considerations we ended up to develop a new Systems Action Design Research (SADR) Framework with the Epistemic Implementation Delphi (EID) as its entry artifact. SADR together with EID allow for concurrent interactions of several systems. This is pertinent to our HGMCSs.

3.3 *Epistemic Implementation Delphi Model (EID)*

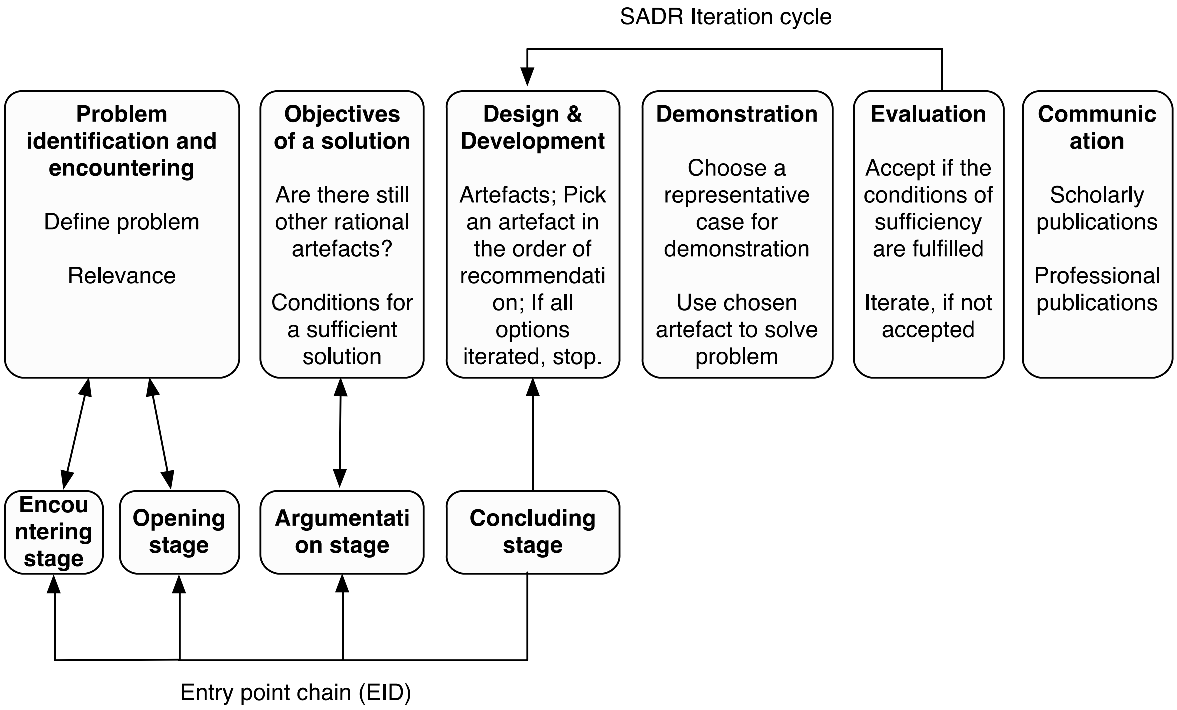

Figure 2: Allocating the stages of SADR on the EID chain (adapted from [32])

We understood that our HGMCSs comprise several concurrently interacting systems, such as temperature, precipitation, soil moisture, and farming (sowing, fertilization, follow-up of growth, harvesting). This led us first to discuss SADR in terms of its stages and the needed EID artifact along the ideas presented by Extended Action Design Research (EADR) Framework [32] In Figure 2, we present the stages of SADR on the continuum of the trans-disciplinary EID artifact.

The stages of SADR resemble the stages of EADR. In the first stage of SADR we have modified its heading to read “Problem identification and encountering” and listed as the items: define problem and relevance. In the case of developing countries encountering means that the primary idea of the project should come up from the local grass-root discussions and preferably from local farmers. More generally the primary idea of the project should be presented by end-users. The inclusion of end-users as experts of their own conditions is complementary if not contradictory to conventional development projects where the motivation to set up a project is based on demands that are usually explicated by external experts.

Before we present EID artefact of SADR at the lower row of Figure 2, it is important to recognize that the epistemic base of EID is GTC [28, pages 247-255]. At the first stage, “Encountering stage” of EID, we encounter the local farmers and experts of local national institutes. We make the general interviews and surveys, after which we negotiate the expert and management teams that include also qualified members from the end-user communities. Under the second stage the established EID expert team looks for possible rational action artifacts during the opening stage and leaves them all available for the process. In case of considerable uncertainties, like in the development of HGMCSs, the EID expert team together with the SADR completion team recommends the conditions of a sufficient solution in terms of both utility and fitness. The final decision on these conditions is made by the SADR completion team.

In the argumentation stage the EID, expert and management teams discuss thoroughly the suggested rational action artifacts. As an outcome of the discussions, SADR gets the list of accepted rational action lines with the recommended order of preference of implementation. In the concluding stage of EID, the management team implements the recommended rational action artifacts within SADR iteration cycle.

The completion team of SADR together with the expert and management teams of EID evaluates the implemented artifact to check, whether this artifact meets the utility and fitness criteria of sufficiency. If so, then the concluding stage of EID is accomplished and SADR proceeds to the communication stage. In case the outcome of the implemented artifact is not sufficient, the completion team of SADR returns the process back to the design and development stage to pick up the artifact option next on the recommendation list for implementation. This iteration is executed in as many loops as needed to find a sufficient outcome or all available artifacts being scrutinized. Only in case we have achieved a sufficient solution SADR completes the communication stage with appropriate scholarly and professional publications.

4. Project Implementation

In this section we introduce plans for project implementation. The implementation follows the EID Chain -model (see Figure 2 in Section 3.3), and SADR, which together provide an impressive arsenal of methods. The project is currently iterating between the problem *identification and encountering* -stage, and the *objectives of a solution* -stage. This means that the project researchers are currently ideating and investigating multiple possibilities for innovations (e.g. [33,34]), gaining more understanding about the situation [35], and looking at other alternative approaches for ideas and inspiration [36]. Current ideas for gaining relevant data include using soil moisture measurements and weather services from meteorological institutions. Initial ideas for building a protocol of communicating decision-making information to local farmers include co-designing [37] decision-tree -based icons [36]. More understanding is expected to evolve from field experiments, starting from qualitative data collection and prototyping to be conducted in April 2018.

4.1 Context: Tanzania

In Tanzania, small scale farming is the main form of crop production, and employment in agriculture is being increasingly challenged by the effects of the climate change [35]. On the other hand, Tanzania has an estimated 19 million mobile internet users [38], and mobile use in Tanzania is among the cheapest in Africa [39]. However, a meaningful technology innovation could also be applicable in other places, where smallholder agriculture is the norm, and which have an adequate digital infrastructure, including 3G/4G/Wi-Fi- coverage and availability of smartphones. Examples of such countries are Kenya, Uganda and Rwanda. There are only few active climate services that make effective use of smartphones. Typically such services are based on IVR or SMS technology [40] and therefore their usability and functionality is limited by technical restrictions.

4.2 Encountering and Opening

The first field visit will take place in the beginning of this April, in a village of Tambuu, close to the city of Morogoro, Tanzania. This two-weeks period will consist of two parts. Firstly, qualitative data will be collected. The qualitative data collection will help in defining the problem and its relevance from the local farmers' perspective. This will follow the SADR-ideology, which shows that the primary idea of a project should come from local grass-root discussions. Secondly, a first prototyping experiment will be conducted. This means that local farmers will be introduced to smartphones, preinstalled with an initial prototype, in order to introduce the participants to the technology and familiarize them with the idea of co-developing a climate service. A total of six smartphones will be used. The participants will be divided to six groups, with three participants each, to generate initial ideas about how weather-, and decision information can be presented. Several days will be reserved for symbol design, in regards of how to represent floods, winds, and other weather events. In regards of SADR (Figure 1), this phase falls under the category of field study in *IS Research*, uses video recordings, interview processing techniques from the *Knowledge Base*, and builds the relevance of the to-be-designed service by building understanding about the *Environment*, which, in this case, is Tambuu village.

4.3 Design and Development

The first field visit is followed by qualitative data analysis, analysis of the results and experiences gained from field, and technology design and development efforts. This includes strengthening co-operation with meteorological and agricultural institutions to improve the weather data and other needed measurement techniques and data flows, such as soil moisture sensors, and improving access to weather data servers. In addition, this phase involves improving the protocol of presenting relevant data for effective decision making to farmers, including design of contextually meaningful icons.

This phase also includes planning of testing periods. It is possible that smartphones will be given to local villages for periods of time for accessing weather forecasts, and other relevant agriculture information, and for providing assistance in decision making. SADR and EID also allow the use of a video diary technique similar to what was done in the Sauti ya Wakulima -project (http://sautiyawakulima.net).

4.4 Evaluation

The SADR and EID are rich in available methods for each phase of the project. If the project's previous stages succeed as expected, and the co-creation activities result in a meaningful and usable technology artefact, the next phase is to evaluate the artefact in practice. After extensive usability tests are complete and there is general agreement that the artefact is accepted by the local community and is beneficial to farming activities, it becomes possible to administer an experimental research setup, where a population of farmers are divided to groups who use the artefact in their farming activities (learning beings), and those who use traditional means in their farming activities (non-learning beings). Variables to be measured in such experimental research setting would include costs of farming inputs, amount of working hours, and most importantly, the farm yield. The preliminary plan is to begin evaluation at the end of 2018, but the schedule depends on the success of previous stages in project implementation.

5. Discussion and Conclusions

We recommend using the participatory co-design methods, which we assume to be helpful together with a multi-disciplinary viewpoint. Also, it is importance to steer the design and development processes with rigorous research methodology, including qualitative and quantitative methods. Using a standard software development process model would probably not work well. Besides our initial connections to local universities, we are open to form new partnerships to other African research institutes and universities. We see that topics of agriculture, ICT (especially co-design process with users, application development) and business model research would be suitable areas of cooperation.

Based on several years of interviews, panels, teacher exchanges, and discussions with diverse stakeholders in various African agricultural contexts, we have derived a model for co-designing a community climate service that would support small scale farmers to cope with the changing climate. The approach combines a design science based research approach to an extended version of Delphi panel. To allow for co-design with limited resources, the model divides the design process into two main parts: (1) building an open mock-up for the service based on the data collected from the local stakeholders, and (2) tuning (and possibly re-designing) the open mock up and implementing its functional prototype within the real user communities as a close and intense co-design loop. The open mock-up as the result of phase 1 comes with questions that need to be elaborated with local users in phase 2. We expect that the introduced model would lead to satisfactory climate services and other applications that would not mimic the use of technology in the Global North but provide solutions that would revolutionize their application areas. In the era of ever worsening and unpredictable effects of climate change, addressing climate change must be number one priority. Technology can play a big part here, if implemented well.

References

[1] Wolfenson, K. D. (2013). Coping with the food and agriculture challenge: smallholders' agenda. Preparations and outcomes of the 2012 United Nations Conference on Sustainable Development (Rio+20) by the Food and Agriculture Organization of the United Nations.

[2] Misaki, E., Apiola, M., Gaiani, S. (2016) Technology for Small Scale Farmers in Tanzania: A Design Science Research Approach. The Electronic Journal of Information Systems in Developing Countries, 74(4), 1-15.

[3] African Youth Foundation (AYF) and Centre for Agricultural and Rural Cooperation (CTA). (2014). Youth Sustaining family farming through ICTs.

[4] CTA, 2014. ICTs for Agriculture - Making it happen.

[5] Danes, M. H. G. I., Jellema, A., Janssen, S. J. C. and Janssen, H. (2014). Mobiles for Agricultural Development - Exploring trends, challenges and policy options for the Dutch government. Available at: http://edepot.wur.nl/297683

[6] Hevner, A. R., March, S. T., Park, J., and Ram, S. (2004) Design Science in Information Systems Research. MIS Quarterly 28: 75-105.

[7] Meinke, H., Nelson, R., Kokic, P., Stone, R., Sevalraju, R. and Baethgen, W. (2006). Actionable climate knowledge: from analysis to synthesis. Climate Research, 33, 101-110 (open access article).

[8] Crandall, A. and Kieti, J., 2013. Startup Business Models and Challenges for East African mAgriculture Innovations

[9] OXFAM, 2013. Incorporating the use of ICTs into Oxfam's markets-based livelihoods programmes: A guidance paper1, s.l.: s.n.

[10] Omwansa, T., Crandall, A. and Waema, T., 2013. The Gab between Mobile Application Developers and Poor Consumers: Lessons from Kenya

[11] Namisiko, P. and Aballo, M., 2013. Current Status of e-Agriculture and Global Trends: A Survey Conducted in TransNzoia County, Kenya

[12] Awuor, F., Kimeli, K., Rabah, K. and Rambim, B., 2013. ICT Solution Architecture for Agriculture

[13] Van de Fliert, E., and Braun, A.R. (2002): Conceptualizing integrative, farmer participatory research for sustainable agriculture: From opportunities to impact. Agriculture and Human Values 19, 25-38. http://dx.doi.org/10.1023/A:1015081030682

[14] Waters-Bayer, A., van Veldhuizen, L., Wettasinha, C. and Wongtschowski, M. (2004): Developing partnerships to promote local innovation. The Journal of Agricultural Education and Extension 10, 143-150. http://dx.doi. org/10.1080/13892240485300211.

[15] Hoffmann, V., Probst, K. and Christinck, A. (2007): Farmers and researchers: How can collaborative advantages be created in participatory research and technology development? Agriculture and Human Values 24, 355-368. http://dx.doi.org/10.1007/ s10460-007-9072-2.

[16] Sumberg, J. and Reece, D. (2004): Agricultural research through a 'new product development' lens. Experimental Agriculture 40, 295-314. http://dx.doi.org/10.1017/S0014479704002030.

[17] Breisinger, C., Diao, X., Thurlow, J. and Hassan, R.M.A. (2011): Potential impacts of a green revolution in Africa - the case of Ghana. Journal of International Development 23, 82-102. http://dx.doi.org/10.1002/jid.1641

[18] Hall, A. and Nahdy, S. (1999): New methods and old institutions: The "systems context" of farmer participatory research in national agricultural research systems. The case of Uganda. Network Paper No. 93. London: Agricultural Research and Extension Network.

[19] Kindon, S, Pain, R & Kesby, M 2007, 'Connecting people, participation and place' in eds. S. Kindon, R. Pain & M Kesby, Participatory Action Research Approaches and Methods: connection people, participation and place, Routledge, New York, pp. 1-5.

[20] Ajeigbe, HA & Dashiell, K 2010, Participatory research extension approach: N2 Africa extension method, International Institute of Tropical Agriculture (IITA), Ibadan.

[21] Blake, E. (2010) Software Engineering in Developing Communities. Proceedings of the 2010 ICSE Workshop on Cooperative and Human Aspects of Software Engineering (CHASE '10), pp. 1-4.

[22] Winschiers-Theophilusa, H., Bidwellb, N., Blakec, E. (2012) Altering participation through interactions and reflections in design. CoDesign, Vol 8, no 2-3, 163-182.
[23] Zewge, A., Dittrich, Y., Bekele, R. (2014) Software designing methodology for ICT4D domain. in Proceedings of the 13th Participatory Design Conference (PDC). Pages 237-241.
[24] Peters, A., Winschiers-Theophilus, H., Awori, K., Bidwell, N., Blake, E., Kumar, A., Chuvuno-Kuria, S. (2014). Collaborating with communities in Africa: a Hitchhikers Guide. in CHI '14 Extended Abstracts on Human Factors in Computing Systems, pp. 1969-1974.
[25] Doerflinger, J., Dearden, A. (2013). Evolving a Software Development Methodology for Commercial ICTD Projects. Information Technologies & International Development, 9(3): pp. 43-60.
[26] Sutinen, E., & Tedre, M. (2010). ICT4D: A computer science perspective. Volume 6060 of the series Lecture Notes in Computer Science (Algorithms and Applications),. Springer Berlin Heidelberg. pp. 221-231.
[27] Gomera, W. G., Oreku, G. S., Apiola, M., Suhonen, J. (2017) Mobile Training in Micro Business: Design Science Research for Frugal Innovation. In Cornish, D.R. (Ed), Proceedings of the 2017 IEEE Science Technology & Innovation for Africa Conference (AFRICON2017) - Advancing Technology for Humanity, IEEE, pp. 501-506.
[28] Kuusi, O. (1999) Expertise in the Future Use of Generic Technologies – Epistemic and Methodological Considerations Concerning Delphi Studies. VATT-Research Reports, 59, VATT Institute for Economic Research, Helsinki, Finland. Open access at www.vatt.fi/en/publications/latestPublications/publication/Publication_1345_id/221
[29] Ulrich, W. and Reynolds, M. (2010) Critical systems heuristics. In: Reynolds, M. and Holwell, S. (eds) Systems Approaches to Managing Change: A Practical Guide. (eds.) Springer, London, UK, pp. 243-292. Link to the chapter http://oro.open.ac.uk/21299/1/systems approaches.
[30] Afitska, O. (2009) Review of Transana 2.30. Language Documentation & Conservation 3: 226-235. (See also https://www.transana.com)
[31] Silver, C. and Lewins, A. (2014) Using Software in Qualitative Research: A Step-by-Step Guide (2nd edition). Sage Publications, London, UK.
[32] Mullarkey, M. T. and Hevner, A. R. (2015) Entering Action Design Research. In: Donnellan, B., nnnn (eds.) Desrist 2015. LNCS, vol. 9073. Springer, Heidelberg, Germany, pp. 121-134. doi
[33] Dinesh, D., Campbell, B., Bonilla-Findji, O., Richards, M. (eds). (2017) 10 best bet innovations for adaptation in agriculture: A supplement to the UNFCCC NAP Technical Guidelines. CCAFS Working Paper no. 215. Wageningen, The Netherlands: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Available online at: www.ccafs.cgiar.org
[34] Pretty, J., Toulmin C, Williams S. (2011) Sustainable intensification in African agriculture.
[35] Government of Tanzania. (2014) Tanzania Agriculture Climate Resilience Plan, 2014–2019
[36] Vitos M, Altenbuchner J, Stevens M, Conquest G, Lewis J, Haklay M. (2017) Supporting Collaboration with Non-Literate Forest Communities in the Congo-Basin. The 20th ACM Conference on Computer-Supported Cooperative Work and Social Computing
[37] Sander E. B.-N. and Stappers P. J. (2008) Co-Creating and the New Landscapes of Design.
[38] Tanzanian Communication . (2017) Quarterly communications statistics report - October- December 207
[39] ResearchICTAfrica.org. (2016) OTT - threat or opportunity for African Telcos?
[40] Tall, A., Hansen, J., Jay, A., Campbell, B., Kinyangi, J., Aggarwal, P. B., and Zougmoré, R. (2014) Scaling up climate services for farmers: Mission Possible Learning from good practice in Africa and South Asia. CCAFS Report No. 13

PIV

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Experiences from Tanzania – Interview Experiment in Co-designing Future Local Climate Services

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***Abstract*— Climate change has global consequences, and is already being experienced, mainly by the most vulnerable groups of people in the Global South. Face-to-face on-site interviews by two groups with an interpreter showed that farming activities in Tambuu Village, Morogoro Region, Tanzania are being complicated by additional uncertainties in weather patterns, climate change and changes in climate variability. To design future hybrid mobile climate services, we explored local information demands and current mobile usage patterns. The qualitative interview content analysis pinpointed a number of basic information demands, like seasonal climate outlooks and warnings for droughts or floods. The interviews revealed three interesting outliers. First, exceptionally large growing areas of the farm meant in practice need for information to support the maintenance for mechanized farming tools. Second, with a single exception, farmers showed a reluctant pattern to use services of agricultural extension officers. As third outlier, we found – among predominantly used ordinary button- the rising use of smartphones for farming activities. Our abductive analysis of the last outlier in Tambuu indicated the demand to take preparatory steps to design and develop integrated future hybrid climate services together with local farmers.**

Keywords—climate change, climate services, small-scale farming, abduction, information systems.

I. Introduction

The negative effects of climate change and changes in climate variability impact already globally, but particularly the most vulnerable groups, such as the small-scale farmers in the Global South (e.g. [1,6,9,17]). In this context we must not forget that small-scale farming produces 70% of the world's food, and generates income and employment for at least 200 million organized smallholder farmers [8, pp 10]. At the same time, the smallholder farmers of these groups live often in conditions of poverty as well as marginalization and their life relies directly on available natural resources as well as the working capacity of the family [12]. It is common that in farming communities in the Global South, farming practices are based on indigenous knowledge, which is passed on from generation to generation. However, in the context of climate services under the changing climate, changes in climate variability, and uncertainties in them, indigenous knowledge and traditional 30-year local or areal average values, the Climate Normals, lead to biases caused by the past. Hence they have lost their usefulness as reliable anchors [5, pp. 119-128], [12].

In this article, we present our design science research project, whose ultimate goal is - as inspired by Mullarkey and Hevner [15,16] –to design and develop a systems action design research (SADR) model which could help local farmers in developing their appropriate path towards informed decision making and sustainable development

We have started our bottom-up approach by collecting stories and by analyzing them [2,3,4]. We selected Tambuu village, Morogoro Region, Tanzania for our third mission, because Tambuu has a relatively good mobile phone connectivity as well as a history of successful participatory projects, established between Tambuu and Tanganyika Christian Refugee Service (TCRS).

We implemented the local face-to-face interviews in Tambuu in collaboration between University of Turku, Finland, Sokoine University of Agriculture (SUA), Morogoro, Tanzania, and College of Business Education (CBE), Dar es Salaam, Tanzania, and TCRS.

The paper is organized as follows. In section 2 we introduce the background and the previously conducted work in the field. In Section 3 we present research questions and methods as well as the methodologies and outcomes of data collection and processing . In Section 4 we provide the results and in Section 5 we discuss the findings. In section 6 we give the conclusions.

II. Background And Previous Work

A. *Climate services*

From the point of view of information producers (e.g. meteorological agencies) climate services have been defined as bodies, which provide climate information to those in demand of it (e.g. farmers), in order to help them to make viable and appropriate decisions. To improve the value of information, climate information is often combined with expert advices [20].

In our research, we are focusing on the agriculture sector. Hence suitable experts, like those working in the field of agriculture as researchers, experienced local farmers, extension officers or other experts, are those who provide the needed tailored information.

Generally we need four types of experts in: 1. invariances, 2. human and social behavior, 3. decision-making and 4. syntheses. The expert team members should be open to the problems of end-users, i.e. farmers. Non-academic experts on indigenous knowledge should also be included, because such type of knowledge is essential in farming practices and cannot be ignored.

Limiting issues to provide successful climate services can be manifold. Information flow between information providers and end users is often too slow [22]. Weather forecasts prepared by meteorological agencies may, in some cases, pass through various parties, like regional experts, experts on end-use and district councils. Processes like this lack the needed agility. Automating processes with information technology would bring enormous improvements to information services.

B. Previous work

Our earlier attempts to design and implement hybrid grass-root mobile climate services for local farmers took place in Chokwe District, Mozambique in 2010-2012 and in Eldoret and Marigat area, Kenya in 2013-2015. Their implementations and outcomes were described by Helminen et al [3,4].

The lessons learned from the two above mentioned projects gave us valuable insights for the planning of our Tambuu project from its very beginning without pre-specified objectives, with which we would have had to agree in advance. In addition we could also avoid a lack of unanimous commitment.

In our previous work we surveyed information needs and mobile usage patterns in Chamwino, Tanzania, in a collaborative project between College of Business Education (CBE), Dar es Salaam, Tanzania, and University of Eastern Finland (UEF), Joensuu. Finland [11,12]. In addition, our previous work surveyed mobile solutions for agriculture in Kenya [16].

III. Data, Research Questions and Methodology

A. Data on Tambuu Village

Tambuu village is located in Lundi Ward, Matombo Division, Morogoro Rural District, of Morogoro Region. According to the village chairman report, Tambuu village has a total population of 2,684, of which 1,434 are men and 1,250 women. Morogoro Region had a total population 2,218,492 in 2013, with a total land area of 70,624 km^2. Morogoro Region is bordered to the north by Tanga Region, to the east by Coastal and Lindi Regions, to the west by Dodoma and Iringa Regions and to the south by Ruvuma Region.

Tambuu village community is engaged in micro-economic activities, specifically in farming business. The farming practices focus on crop production; maize, rice, cassava, banana, sesame (Swahili word "Ufuta"), potato, peas, pepper, cloves and oranges, among others. Tambuu and other villages in Matombo Division feed residents of Morogoro and some parts of Dar es Salaam Region to a large extent. Heavy trucks carry tons of farm products, and distribute to cities as well as municipalities every day.

In the case of our research it was essential to determine the priorities of the Tambuu community and the potential concerns that it faced. This could be achieved by asking farmers about their daily practices (collecting qualitative data), their satisfaction with current agricultural or technological services, and their particular demands for future services. In agriculture, it is common that farmers face a number of risks and uncertainties, including variations in weather and yields, swings in prices, variations in government policies, uncertain trends in global markets, and other factors that can cause major changes in the farm's operation and income of the farm. Now, in addition to these "typical" challenges, climate change is causing new uncertainties, which further complicates the life of farmers. The farmers' viewpoint to their information needs is crucial in order to build and plan future information services.

B. Research questions

The research questions were set as follows.

- RQ1: *What are acute needs for sustainable development and action in Tambuu community?*

For designing future mobile technology use, it is important to understand the current mobile usage patterns of a user group. This includes the ownership of ordinary phones, and smartphones, their usage patterns, related challenges, and other important issues. Therefore, the second research question of this study was set as follows.

- RQ2: *What are the current mobile usage patterns of farmers and demands to improve them in terms of boosting the local cooperation in Tambuu community?*

After gaining an understanding about acute needs of Tambuu community, it is essential to build drafts and prototypes of future technology services, which address the technology and information demands. In addition it is basic that the farmers are involved throughout the design process. Ideas and prototypes about how to address acute technology and information demands of the Tambuu community were generated.

C. Methods

1) Qualitative content analysis of the interviews

Thirteen semi-structured interviews (albeit it with little deviation from the proposed interview schedules) were conducted in the Tambuu region of Tanzania on 10, 12, and 17 April with help from local interpreters, who not only translated questions and answers, but also clarified ambiguities and difficulties in understanding some of the questions. The interviews were voice-recorded and transcribed by a native Swahili speaker into 13 individual text documents. The transcribed interviews were imported into Atlas.ti™ (a qualitative computer-assisted data analysis software) and analyzed by means of the thematic content analysis method.

The interviews were first skimmed before further familiarization through in-depth reading and re-reading. All documents were subsequently coded using inductive coding. The researcher responsible for the qualitative analysis, while very familiar with African culture (having lived and worked in Africa for over 30 years), was not present during the interviews and therefore opted to work without a priori codes in an exploratory fashion. No new codes surfaced after the fourth interview and no new information emerged after coding the sixth interview. Upon realizing data saturation while coding the seventh interview, the researcher synthesized the data into broader patterns of meaning that included: (a) weather and climate; (b) technology; and (c) indicators. Reviewing the themes alongside the data, refined the codes into a further four themes, namely: (a) knowledge and information; (b) farming business; (c) farming interferences; and (d) urgencies and wishes. Although data saturation was reached at interview seven, the researcher continued coding all 13 interviews to construct a representative summary of the code grounding and form a definitive comprehension of the seven themes

2) Abduction

In terms of logic, deduction and induction are the two main paths to make inferences by reasoning also in the context of artefacts. Here deduction refers to an inference by reasoning, which leads from generals to particulars. This takes place typically when we start our inferences from data or also a given application, which will be localized. In the opposite case of our inference by reasoning, leading from particulars to generals or from observations to theory we refer to induction, typical in theoretical reasoning.

Both deductive and inductive reasoning strive at a singular truth, whereas in reality phenomena include various uncertainties so that we face wicked problems. Then abductive approaches, where we aim to find possible satisfactory solutions, offer an interesting possibility to be explored. Lee et al [7] have considered this from the point of view of theorizing in design science research.

Recently abduction (e.g. Peirce [19, pp. 7.202-219, 1901]), which gives means to understand the role of theorization and the interplay between theories and observations in methodology, has prompted new interpretations on Peircean abduction and emphasized abductive strategies in the context of dynamic aspects of abduction as one method and methodology as science of methods in general [18]. When we use rational heuristics as our method to find satisfactory artefacts, Paavola [18] pointed out that abduction allows us to understand that research methodology combines rational heuristics and various spontaneous elements, which in our case are qualitative outliers in the interviews.

Out of the seven abductive strategies presented by Paavola [18] we applied the following two. First, *searching somehow anomalous, surprising, or disturbing phenomena and observations (abductive strategy 1)* and, second, *searching for "patterns" and connections that fit together to make a reasonable unity (abductive strategy 6).*

3) Interview questions

After drafting and discussing we jointly agreed on questions to be discussed during the two face-to-face interview visits to Tambuu village on 10 and 12 April 2018. After the first visit we made minor clarifications to the questions. The questions asked by the interviewer are shown in Figure 1.

For the in situ interviews the local TCRS employee had selected thirteen Tambuu interviewees with reasonable representativeness in mind. The third visit took place on 17 April. We devoted it for drafting appropriate weather icons and to give an idea of this creative process to the farmers. Then we surveyed various facilities, like fish ponds and tomato plantations. Finally we visited the local preliminary school with a field of fruit plantations. Right after having collected the interviews we looked over them and discussed our impressions with the interviewers.

1) What crops do you grow, in how big area?
2) Tell us about your normal day in the farm; How is it during
   pre-growing,
   planting,
   growing (tilling, weeding),
   harvest and
   post-harvest
3) What are your requirements during each phase in terms of information, tools and inputs?
4) Draw us your yearly crop calendar
5) How do you select
   What crops to grow?
   When to put the seeds to ground?
   When to harvest?
   Where to sell?
6) Where do you currently get your agricultural information? Radio, tv, friend/ relatives, extension, newspapers, etc.
7) Have you a phone?, a smartphone?
8) Do you use it to get agriculture related information, if yes, what kind of information and from where?
9) Do you see that phones could help you to get relevant information?
10) How to currently predict weather or access the weather forecast?
11) Would you be interested to watch videos about agricultural practices?
12) In which topics would you mostly be interested to get information by using phones?
   weather
   crops
   livestock
   improved growing practices (conservation agriculture/climate smart agriculture, agroforestry)
   water harvesting techniques
   market prices
13) What other things would help you in your farming?
   (access to seeds, pesticides, fertilizers, irrigation,
   better roads)

Figure 1. Interview questions

In the interviews we focused also on clear qualitative deviations from the main stream as well as on the reactions of farmers to our suggestions of co-creative development of hybrid grass-root mobile climate services (HGMCSs) and related training.

IV. Results

A. Qualitative Content Analysis

After coding and analyzing all 13 interviews with farmers from the Tambuu region in Tanzania, 24 codes emerged and were grouped into seven themes: (a) Agricultural indicators; (b) Electronic technology; (c) Farming as a business; (d) Farming interferences; (e) Knowledge and information; (f) Urgencies and wishes; and (g) Weather and climate. The themes were not surprising as they were born from a relatively structured interview schedule with explicit information gathering goals. The evidence that shed a brighter light on the Tambuu circumstances however, was the grounding (how often a code occurred) of the individual codes. Figure 2 provides a list of the codes and their respective themes in terms of code group and grounding.

Since a fairly rigid interview schedule was used, almost all questions were asked from all respondents. It therefore stood to reason that the more grounded a code, the more elaborate the answer was and as such, could be assumed to carry more weight in terms of importance to the farmers. The codes with the highest grounding (above the 75th percentile) were technology availability (52), information access (52), technology usage (47), production cause-and-effect (39) and resources available for farming (36). Technology availability and technology usage referred to electronic technologies that Tambuu famers had access to (including electricity, radios, televisions, solar power, telephones and other) and how they were currently utilizing these technologies, be it (among others) for lighting, information gathering or communication. Information access covered aspects related to the source and type of information and how the Tambuu farmers retrieved these. The primary mode of finding information came via radio and the most sought after topics revolved around how to farm better. The two major codes belonging to the farming as a business theme, were indicators of: (a) how well the Tambuu farmers understood the immediate impact of their environment and decision-making on their farming success (production cause and effect); and (b) their means to conduct effective agricultural practices (resource available for farming).

Collectively, the two codes (activities outside own farm and daily routines) belonging to the farming interferences had low grounding—5 and 10 respectively. Since only a few comments were made of these, we could surmise that activities not directly related to their farming were not hindering their success and that there were other factors at play in this regard. Other codes with low grounding included harvesting indicator (8), technology usefulness (8), point of sale (8) and understanding of climate (5). These low groundings all had fairly superficial explanations, given here in order of the list: (a) harvesting was not as critical in the light of the climate outlook, but rather an outcome of preparing and sowing by following weather forecasts; (b) Tambuu farmers had severely diminished electronic technology exposure, so it was difficult for them to express their perception of the usefulness of such devices; (c) the question of where the farmers sold their products did not require more than stating the fact—the question was never explored deeper; and (d) while the farmers understood that weather affects their farming, they did not distinguish between weather forecasts useful to guide daily actions and climate outlooks to help to plan the coming growing season—hence the point of this study.

B. *Outlier aspects in interviews*

We found altogether three outliers in the interviews. First, feedbacks to question 1 indicated that single farmers had already widened the cultivation area of their farms in order to improve their baseline against worsening impacts of climate change and changes in climate variability as well as for resilience in their crop yield production and food safety.

The second outlier in the context of question 6 was the finding that the farmers almost unanimously ignored the services of the Agricultural Extension Officers (AEO). One farmer was reluctant to use these services by claiming that AEOs disturb the practices in the midst of the busiest cultivation phase.

Question 7 revealed the third outlier as we could recognize that two farmers out of thirteen farmers owned a smart mobile or touch phone, while the rest of the farmers owned an ordinary button phone. We could detect a starting interest to purchase and utilize versatile smartphones. Notwithstanding this, it turned out that so far the owners of the smartphones had quite limited skills to use them.

Code	Code Group	Grounding
Harvesting indicator	Agricultural indicators	8
Land preparation indicator	Agricultural indicators	23
Planting indicator	Agricultural indicators	29
Weeding indicator	Agricultural indicators	10
	Agricultural indicators	**70**
Smartphone readiness	Electronic technology	29
Technology availability	Electronic technology	52
Technology usage	Electronic technology	47
Technology usefulness	Electronic technology	8
	Electronic technology	**136**
Cultivation - cause and effect	Farming as a business	10
Current farming practices	Farming as a business	26
Point of sale	Farming as a business	8
Production - cause and effect	Farming as a business	39
Resources available for farming	Farming as a business	36
	Farming as a business	**119**
Activities outside own farm	Farming interferences	5
Daily routines	Farming interferences	10
	Farming interferences	**15**
Decision making	Knowledge and information	31
Information access	Knowledge and information	52
Record keeping	Knowledge and information	16
	Knowledge and information	**99**
Desired knowledge and information	Urgencies and wishes	37
Towards improved farming	Urgencies and wishes	31
	Urgencies and wishes	**68**
Understanding of climate	Weather and climate	5
Weather prediction current practices	Weather and climate	29
Weather prediction requirements	Weather and climate	10
Reliance on weather	Weather and climate	10
	Weather and climate	**54**

Figure 2. List of grounded codes, code group/theme and grounding

V. DISCUSSION

A. *Research question one (RQ1)*

The Tambuu region had a diverse set of farmers who grew a wide range of crops, ranging from citrus fruits and bananas to cereals and root vegetables. However, the primary crops in the area were maize, rice and cassava. The farming community made almost exclusively (except minor transportation) use of manual farming tools ("*I can't cultivate more, because I am using physical strength*"; "*We have no modern hoes, maybe just modern pangas*")—automation was not mentioned in any interview. The land size of the interviewees varied from 0.5 acres to 3 acres per crop, with each farmer growing multiple crop types throughout the season.

The first outlier is an important signal to the local agrotechnology to develop and produce affordable mechanized tools appropriate for small-scale farms. This possible development might impose also new requirements for the tailored weather, climate and agricultural information as well as to keep land-use management sustainable.

Land preparation, sowing, weeding and harvesting followed traditional schedules, which were passed on generationally ("*In September we start to prepare the lands*"; "*the trends, which our parents used, were the same we use now*"; "*I know in a certain month, then we start cultivating*"), regardless of weather patterns. Moreover, Tambuu farmers tended to react to visual climate clues ("*when we see rain clouds*"; "*after rain falls, we start planting*"; How do you know that it's time to do farming? "*We understand it based on our surroundings… the weather conditions*"), rather than to predictions ("*weather forecasts are not considered*"; Do you consider weather forecast information? "*Not really… sometimes the forecasts may not be accurate*"; Do you normally use the phone to check about weather forecast? "*No*"). This might be attributed to farmers not understanding the meaning of climate nor the impacts climate has on their farming success. It could also be more likely that they did not have enough information about climate (given their highly diminished access to information technology – probably because they have no electricity – it is very likely) and as such, they were not concerned with it. Hence, the notable praxis was to prepare land and plant again as soon as a crop failure is imminent or perceived as unavoidable—regardless of the time of year ("*In case we miss the February harvest ... we start then to prepare and sow the land again during the same month*").

This last point marked that the Tambuu farmers were certainly losing money (plant seeds for nothing, unnecessary wear and tear on equipment, etc.) and that what they had on their plates was compromised ("*we have already consumed the crop we cultivated in October*"; "*we do farming so as to get food*") by unawareness of climate outlooks. There is certainly the case here that with reliable climate outlooks and improved climate knowledge [11] many of these costs and the threat of livelihood could be avoided as it would allow the farmers to plan their crop types (e.g. if they particularly knew that the rain season was due, and they could focus their energy on rice cultivation) and time their sowing periods more effectively.

The second outlier, the ignorance of the current services of the AEOs should encourage the authorities to reconsider the role of AEOs towards helping the farmers to understand the benefits of proper use of tailored weather forecasts in their daily practices and of tailored climate outlooks for planning their coming growing season activities. Here the AEOs could focus their efforts in the planning of the growing season as well as on education and encouragement for participatory co-creative activities.

From the telecommunication point of view, many farmers relied on radio for information about farming and weather. There might be several reasons for this, but the most severe one could be the lack of electricity in many farmer homes—radio works well with batteries. This might raise the question, if these farmers have no access to electricity at home, how will they charge a smartphone? One respondent indicated that they would be purchasing solar panels. This might be a solution for phone charging as well.

Apart from the lack of electricity, farmers in this region had seemingly little exposure to mobile phones ("*those with smartphone are almost one percent of the population*" this quote was provided by a TCRS representative), most not owning one and many having only seen them being used ("*I have seen one, which was brought to me by my brothers*"; Have you ever used a smartphone? "*Not yet*") without an opportunity to handle and operate one by themselves. Given this limited mobile technology exposure, we dared to state that their desire for a mobile phone was not a strong one, even more so, a mobile phone to follow weather predictions. This became especially clear through their ambivalent attitude toward weather predictions.

In terms of outlier three, the few owned smartphones and their poor utilization by owners highlight that the challenge is to educate the Tambuu farmers to use smartphones as well as to establish the needed improved telecommunication network. These lacks challenge both the AEOs and the telecommunication authorities into action. It is a major task, but worth in terms of sustainable development as well as food security.

Although their attitude might result from not currently having weather predictions available at farms, they wanted far more fertilizers, better seeds and further information on best farming practices (What kind of an improvement do you think you need? "*Having modern farming, including fertilizers*"; "*she would like to have improved seeds, fertilizers as well as knowledge on good agricultural practices*"; "*Also to get better seeds is a great challenge*"; "*they should provide me with fertilizers and seeds*"; "*I would like to be trained on the best practices of seed planting and how to do the farming and if the farming needs fertilizer or not*").

B. Research question two (RQ2)

As pointed out already in the context of outlier three we think that before unleashing a mobile phone roll-out to this community, they would be better served by an education (or information) drive about climate and how it impacts their farming. Augmenting this with regular weather forecasts and climate outlooks on the media mode they are most familiar with, namely radio, would most likely have a far deeper impact. Not only would weather forecasts and climate outlooks possibly instill more informed farming practices, but would also act as more effective than just subliminal prompt toward conscious thought and peer discussion about weather forecasts and climate outlooks. The aim of such an intervention should be to shift the Tambuu farming community paradigm from *planting-in-the-hope-of-favorable-weather* to *how-should-we-plant-based-on-weather-forecasts-and-climate-outlooks*. Only once such a shift is achieved, will the Tambuu farming community start to see the value of ubiquitous weather and climate prediction in their pockets. This is not to say that a mobile phone intervention for weather and climate forecasting would not be beneficial, but rather that such an intervention will have bide its time and would require to be aware of several caveats to be addressed.

Revisiting the point of limited mobile phone exposure, it is apparent that an education drive would not immediately be able to delve into the business of weather-pattern farming. Many of the Tambuu farmers would have to first be taught about using and owning a mobile phone. This would have to, in some cases, include elementary actions such as engaging with a touch screen—it would take some time before the notion of an "app" can be presented. Although this may appear to be a drawn out process, the benefits would be more far-reaching than farming. Such an intervention would empower the farmers with the means of immediate communication. It should also be added that several of the farmers understood, even if the conviction came from others, that owning a smartphone could be beneficial ("*A phone can be of help to you, especially according to those who own a smartphone*"; "*most people say it is useful*"). One should however, not overlook the peripheral requirements that would accompany a mobile phone intervention in Tambuu. Beside infrastructure and mobile coverage, the most obvious necessity would be service and support points. Without such amenities, there exists a great risk that with the first incidence of inoperability, the mobile phone will be placed out of mind, or sold to the highest bidder.

Whatever the intervention, one must keep in mind that the first priority for this Tambuu farming community is survival ("*It depends on the harvest. If there is a surplus, then I can sell*"; "*My guideline is based on the need of food, for instance, if I plant maize, my children are able to get food in three months' time*"; *"If you plant maize, you can get food for many of us*") and that until now, they have done so. Any intervention aimed at changing their current practices, would likely be perceived as jumping into an unknown at the risk of not having food on the table. Whatever intervention we convey onto the Tambuu farmers, will have to undergo a lengthy trust-building.

VI. Conclusions

In Tambuu and more generally in developing countries, the impacts of climate change and especially changes in climate variability are already being experienced as uncertain weather patterns, which seriously complicate the life of small-scale farmers. How to provide farmers with accurate predictions to assist them in decision making of farming is a crucial problem. However, smartphone ownership is rapidly increasing in developing countries, and smartphones provide an excellent platform to run future climate service applications that may assist small-scale farmers in their daily practices. Here we remind that the technical question is not just about having smartphones but also about a sufficient operative base station network for smartphones and proper skills to utilize them.

Our abductive analysis of the outliers in the context of acute information needs of Tambuu farmers and of their mobile use patterns inspired us to suggest to start the planning of a co-creative and participatory prototype task to build a sound smartphone based HGMCS system integrated with a resilient and agile network of AEOs with pertinent encouraging skills.

The implementation of the stages is typically iterative, and in each stage, a set of relevant research and engineering methods are used. These methods include all available quantitative and qualitative research methods, and may even include methods of agile software development and use case engineering (e.g. [21]).

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References

[1] Chang'a, Ladislaus B., Kijazi, A., Luhunga, P., Ng'ongolo, H. and Mtongor, H. (2017) "Spatial and Temporal Analysis of Rainfall and Temperature Extreme Indices in Tanzania," *Atmospheric and Climate Sciences*, (7: 4).

[2] Helminen, Jaakko, Myllynpää, Ville, Apiola, Mikko, Dayoub, Moammar, Westerlund, Tomi and Sutinen, Erkki (2018) "Community Climate Services for Small-Scale Farmers in Tanzania." in *Proceedings of 2018 IST-Africa Week Conference (IST-Africa)*, IEEE 2018.

[3] Helminen, Jaakko, Leão, António José, Myllynpää, Ville, Gaiani, Silvia, Apiola, Mikko, and Sutinen, Erkki (2019a) "Towards a Design Research Model for Climate Services: Experiences from a Development Project in Mozambique," to be published in proceedings of ICT4DA2019 Conference, Bahir Dar, Ethiopia.

[4] Helminen, Jaakko, Bekuta Kirongo, Balozi, Gaiani, Silvia, Apiola, Mikko, Ezra Misaki, and Sutinen, Erkki (2019b) "Experiences from Development Project in Kenya – Baselines for Future Climate Information Systems," In: Nielsen P., Kimaro H. (eds) *Information and Communication Technologies for Development. Strengthening Southern-Driven Cooperation as a Catalyst for ICT4D*. ICT4D 2019. IFIP Advances in Information and Communication Technology, vol 551. Springer, Cham.

[5] Kahneman, Daniel (2011) "Thinking, fast and slow," Farrar, Straus and Giroux, New York, USA

[6] Komba, Coretha and Muchapondwa, Edwin (2015) "Adaptation to Climate Change by Smallholder Farmers in Tanzania," Environment for Development Discussion Paper Series.

[7] Lee, J.S., Pries-Jeje, J., & Baskerville, R. (2011). Theorizing in design science research. In 6th International Conference on Design Science Research in Information Systems and Technology (DESRIST), Milwaukee, USA

[8] Maass Wolfenson, Karla D. (2013) "Coping with the food and agriculture challenge: smallholders' agenda," In Preparations and outcomes of the 2012 United Nations Conference on Sustainable Development (Rio+20). Food and Agriculture Organization of the United Nations.

[9] Magehema, Alfred O., Chang'a, Ladislaus B. and Mkoma, Stelyus L. (2014) "Implication of rainfall variability on maize production in Morogoro, Tanzania," International Journal of Environmental Sciences, (4: 5).

[10] Meinke, H., Nelson, R., Kokic, P., Stone, R., Selvaraju, R., and Baethgen, W. (2006) "Actionable climate knowledge – from analysis to synthesis," Climate Research, 33, pp. 101-110. Open access at www.int-res.com/articles/cr_oa/c033p101.pdf.

[11] Misaki, Ezra, Apiola, Mikko and Gaiani, Silvia (2015) "Technology for Agriculture: Information Channels for Decision Making in Chamwino, Tanzania," In *Proceedings 21st ICE/IEEE International Technology Management Conference*. Belfast, Northern Ireland.

[12] Misaki, Ezra, Apiola, Mikko and Gaiani, Silvia (2016) "Technology for Small-Scale Farmers in Tanzania: A Design Science Approach," *Electronic Journal of Information Systems in Developing Countries*, (74:4), pp.1–15.

[13] Misaki, Ezra, Apiola, Mikko, Gaiani, Silvia and Tedre, Matti (2018) "Challenges facing Sub-Saharan Small-scale Farmers in Accessing Farming Information through Mobile Phones: A Systematic Literature Review," *Electronic Journal of Information Systems in Developing Countries*. Vol 84(4).

[14] Mullarkey, Matthew T. and Hevner, Alan R. (2015): Entering Action Design Research, DESRIST 2015: New Horizons in Design Science: Broadening the Research Agenda, LNCS, 9073, Springer International Publishing, pp. 121-134.

[15] Mullarkey, Matthew T. and Hevner, Alan R. (2018): An elaborated action design research process model, European Journal of Information Systems, DOI: 10.1080/0960085X.2018.1451811

[16] Myllynpää, Ville (2016) "Mobile applications, solution for sustainable agriculture? – Study of mAgriculture services in Kenya," Master's thesis. Lappeenranta University of Technology, http://www.doria.fi/handle/10024/120305

[17] Paavola, Jouni (2008) "Livelihoods, vulnerability and adaptation to climate change in Morogoro, Tanzania," Environmental Science & Policy, (11: 7), pp. 642 – 654.

[18] Paavola, Sami (2014) "From Steps and Phases to Dynamically Evolving Abduction," A paper presented at the Charles S. Peirce International Centennial Congress 2014. Invigorating Philosophy for the 21st Century. Lowell, USA, 16-19 July 2014. The Commens Working Papers, Preprints, Research Reports & Scientific Communications, Edited by Mats Bergman, Sami Paavola & João Queiroz.

[19] Peirce, Charles S. [CP (volume.paragraph, year)] (1931-1958). Collected Papers of Charles Sanders Peirce, vols. 1-6, Hartshorne, C. and Weiss, P., (eds.), vols. 7-8, Burks, A. W., (ed.). Harvard University Press, Cambridge, Mass, USA

[20] Tall, Arame (2013) "What Do We Mean by Climate Services?" https://public.wmo.int/en/bulletin/what-do-we-mean-climate-services WMO Bulletin (Special Issue) 62 (2013).

[21] Tiwari, Saurabh and Gupta, Atul (2015) "A systematic literature review of use case specifications research," Information and Software Technology, 67, pp. 128 – 158. https://doi.org/10.1016/j.infsof.2015.06.004

[22] Yanda, Pius Z., West, Jennifer Joy and Daly, Meaghan E. (2015) "Institutional Analysis for Climate Services Development and Delivery in Tanzania. CICERO (Center for International Climate Research) Report 02.

PV

Helminen, J. and Sutinen, E. 2017. ’Design Science Research for Holistic Climate Services’. In: Maedche, A., vom Brocke, J., Hevner, A. (eds.) *Designing the Digital Transformation: DESRIST 2017 Research in Progress Proceedings of the 12th International Conference on Design Science Research in Information Systems and Technology*. Karlsruhe, Germany 30 May – 1 Jun. Karslruhe: Karlsruher Institut für Technologie (KIT). pp. 83-91.

Design Science Research for Holistic Climate Services

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Abstract. The innovated fitness-utility Systems Design Research (SDR) model is generalized from the Extended Action Design Research (EADR) model and discussed in terms of the Design Science Research (DSR) framework. In the context of SDR as well as the recent Paris Agreement, the 2030 Agenda for Sustainable Development and the Agenda for Humanity the challenges of holistic climate services are discussed. As an application of the trans-disciplinary SDR holistic grass-root mobile climate services are developed for local farmers in communities of an African developing country.

Keywords: Design science research · Fitness-utility model · Trans-disciplinary systems · Holistic climate services

1 Introduction

In the discussed research in progress we are concerned with obvious demands for designing holistic grass-root mobile climate services (HGMCSs) to empower local farmers in communities of an African developing country to cope with the changing climate. The services are critical because traditional tacit knowledge no more works. The task includes increased awareness of climate impacts and the improvement of our trans-disciplinary baselines to meet them. In concert with the recent Paris Agreement (PA) [1], Transforming our world: the 2030 Agenda for Sustainable Development (ASD) [2], Agenda for Humanity (AH) [3] and Natural Disasters and Climate Change: Managing Risks & Crises Differently (NDCC) [4] our effort is to get a holistic view included in climate services and our prototype HGMCSs landed for active use and further participatory development by local farmers. The subjective demand, not only the objective need for HGMCSs became apparent during our several pilot studies since 2011 in different grass-roots level contexts in Africa.

The four references [1-4] mentioned above give an overall view of the current situation of the global leadership in climate change issues. Formerly UN Framework Convention on Climate Change (UNFCCC) with its Conferences of Parties (COPs) kept the leading role in climate change issues by global agreements on climate change, like the Kyoto Protocol of 1997 and PA.

Recently the UN General Assembly has released as its resolution the ASD. This agenda includes nineteen Goals of Sustainable Development with Goal 13 “Take urgent action to combat climate change and its impacts”. ASD presents the social, economic, and environmental dimensions as the three dimensions of the sustainable development.

ASD integrates them, climate included, fully in a coherent, holistic, comprehensive and balanced way.

The Secretary-General of UN released AH in the World Humanitarian Summit (WHS) in 2016 in Istanbul. In addition WHS released also NDCC, in which the Core Commitment 1 repeated the urgency of ASD Goal 13.

As a consequence of the actions mentioned above UN has taken the global leadership in integrating the issues of climate change and its impacts into ASD and AH.

Regarding the climate change and its impacts PA gives to us recommendations how we can contribute to limit and to stop the human-induced climate change to a bearable extent. In changes of climate impacts we focus on two changes in climate, on changes in extreme values and on changes in climate variability. These are the aspects, which impact most directly the baselines of the societies.

One crucial question to accomplish sustainable development is to achieve a climate with stable mean values and stable variability. For design science SDR with its artifacts offers one possibility to contribute to the development of sustainable holistic climate services.

As the needed Design Science Research (DSR) [5] tool we present and discuss the setup, the stages and the objectives of the Systems Design Research (SDR) fitness-utility model, which is a generalization of the Extended Action Design Research (EADR) model by Mullarkey and Hevner [6]. In the same context, we introduce the Epistemic Implementation Delphi (EID) model with its stages as the design artifact of SDR. Finally, we outline some prospects of SDR and conclude our presentation.

2 Systems Design Research

We develop SDR to study several concurrently interacting systems. In fig. 1 we present the stages of our Systems Design Research (SDR) fitness-utility model on the continuum of the entry point chain of our trans-disciplinary Epistemic Implementation Delphi (EID) model.

The stages of SDR resemble the stages of EADR. However, in the first left-hand box we have replaced motivation by encountering, which in the case of developing countries means that the primary idea of the project should come up from the local grassroot discussions and preferably from local farmers. More generally the primary idea of the project should be presented by the end-users. The inclusion of end-users as experts of their own condition is complementary if not contradictory to conventional development projects where the motivation to set up a project is based on needs that are usually explicated by external experts.

Concurrently during the encountering, we search competent members to SDR completion team primarily from the local community and from local pertinent expert institutes. The role of outside supervisor parties, like representatives of foreign development aid should be relatively strong at the beginning of the project and decrease during the participatory working phase.

It is important to recognize that the epistemic base of EID is the General Theory of Consistency (GTC) [7]. According to GTC the local population participating to the project experiment on grass-root level is divided into two groups: not-learning beings, who trust on the use of traditional tacit knowledge, and learning beings, who are willing to learn and use advised modern methods.

In the second box from the left the chosen EID expert team looks for possible rational artifacts during the opening stage and leaves them all available for the process. In case of considerable uncertainties, like in the development of HGMCSs, EID expert team together with SDR completion team determines the criteria of a sufficient solution in terms of both utility and fitness.

At the design and development stage of SDR the expert team of EID elaborates further the action lines as rational artifacts. This takes place at the opening and especially the argumentation stage of EID. It is important that the elaborated artifacts as different versions of the developed climate services are kept separate from each other. The outcome of the design and development stage of SDR is one artifact recommended by EID expert team to be implemented in the demonstration stage by EID management team.

The completion team of SDR together with the expert and management teams of EID evaluates the implemented artifact to check, whether this artifact meets the utility and fitness criteria of sufficiency. If so, then the concluding stage of EID is accomplished and SDR proceeds to the communication stage. In case the outcome of the implemented artifact is not sufficient, the completion team of SDR returns the process back to the design and development stage to pick up the artifact option next on the recommendation list for implementation. This iteration is executed in as many loops as needed to find a sufficient outcome or all available artifacts being scrutinized. Thereafter SDR completes the communication stage with appropriate scholarly and professional publications.

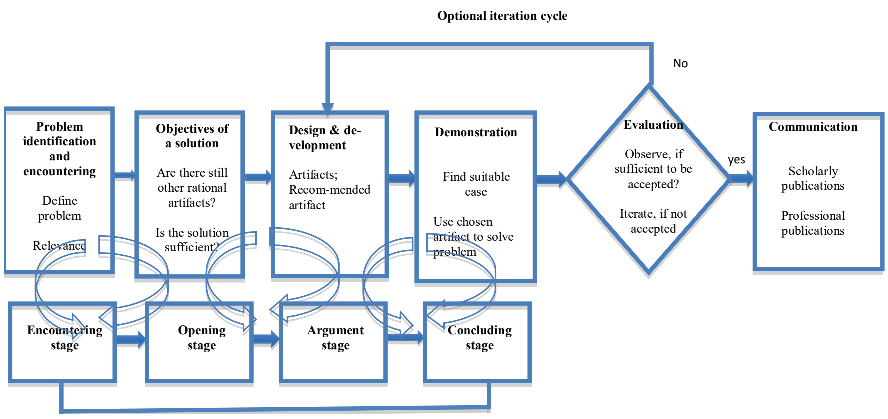

Fig. 1. Allocating the stages of SDR on the research entry point chain of EID (adapted from [6]).

3 Design Science Research

Next, we discuss SDR in terms of DSR framework [5] depicted in fig. 2. Where appropriate we focus our discussion on our particular application of SDR in the development of HGMCSs for local farmers in communities of an African developing country.

Environment. We start with the environment and in it with people. In our coming prototype project, we have three groups of people: the local farmers of the communities (LCG), the various kinds of local experts extending from the community to the national level (LNG), and the supervisors from the foreign development aid party (SFG).

Ideally the first encountering should take place by a meeting of LNG and SFG, when a letter of intent has been sent or preliminary discussions of intention on a joint SDR project have taken place. The expertise of LNG should include scientific experts on relevant invariances and experts on local social aspects and human behavior, decision makers with the authority to allocate needed local resources as well as funding, and synthesizers with the overall vision to become supervisors. Compared with LNG, the composition of SFG should rather be experts on decision-making issues and have the needed backup in funding issues. The outcome of this meeting should be a draft of the project agreement, the mutual written understanding of the joint objectives and commitments, and the written consent of the right to archive and use the compiled video-recorded interviews as well as other collected data.

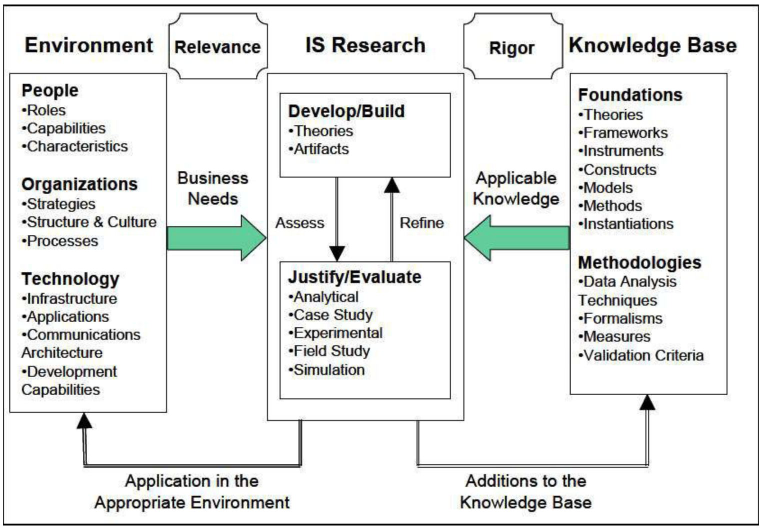

Fig. 2. Design Science Research Framework [5].

Early prior to the expected rain season LCG not-learning and learning groups of the participating communities should together make overall crop cultivation plans, where every community decides the cultivated crop species, the tilling method, and the possibly used fertilizer, pesticide or plant disease control agent. During this planning, the local farmers consult the needed national expert institutes, like the national institute of agricultural research as well as the national meteorological and hydrological institute, in order to get advice on proper crop selection, expected precipitation, risk for draughts, floods, pests, and plant diseases for the coming rain season. Co-designing the services need to be closely tied to the planning activities.

After the overall cultivation plans are ready the local decision-makers plan the allocation of the needed separate experiment parcels for the not-learning and the learning farmers on a fair basis including also the access to eventual irrigation. The crop yields of the parcels are compared under the assumption that both groups have equal access to the information disseminated by HGMCSs. As our approach is holistic we cannot limit our scope just to develop technically appropriate trans-disciplinary climate services and compare their effects. In developing countries, we have several other factors affecting significantly the crop yield, like the use of quality seeds, fertilizers, pesticides, plant disease control agents as well as of modern tilling methods. The local experts need to consider, which of these factors need to be included explicitly in our field experiments in the form of additional parcels so that we can convincingly demonstrate the sufficient success of the developed HGMCSs.

All human-driven activities presented above tie the people, pertinent organizations and technologies to joint business needs, which are elaborated further under the develop/build and justify/evaluate phases of the trans-disciplinary DSR. The objective of these efforts is to develop beneficial local HGMCSs and to take place under SDR steered EID actions.

Knowledge Base. We introduced SDR combined with EID as a fitness-utility model [8]. It is our contribution to the knowledge base.

Regarding the fitness of our model we assess it in terms of the fitness definition #2 [8]. With HGMCSs and holistic views in mind we need to take into account pertinent aspects of human and social behavior. Here an essential part of the collected data consists of compiled and video-recorded interviews, including especially those from the co-design process. As guidance for the interviews we use the set of twelve questions of the Critical Systems Heuristics (CSH) [9], which in our application concern boundary judgments of particular HGMCSs. The consideration of boundary judgments and the possible extension of the boundaries of our design space stand both for an opportunity and a necessity in the development of HGMCSs. All in all, this makes our fitness considerations an exciting and demanding challenge where experience and resilience are needed.

In the context of our design artifact EID the utility has to cover two aspects, the metric utility for measurable quantities, like crop yield, and the epistemic utility for assessed qualities, like motivation. To build the metric utility function is a straightforward objective matter, whereas the epistemic utility is a different issue and involves subjective evaluations. As a first trial, we form an epistemic utility function by dichotomizing the observations on a one step scale from zero to five as follows: 0 = cannot be assessed, 1= very poor, 2 = moderately poor, 3 = medium, 4 = moderately good, and 5 = very good. One more sophisticated way to assess the epistemic utility would process the original transcribed video-recorded interviews by applying the Computer Aided

Qualitative Data Analysis Service (CAQDAS) [10] with the Transana qualitative analysis software for text, audio and video data [11] to help us to explore the design space and to find new aspects in it.

The nine first questions of CSH apply to those, who use and develop HGMCSs and are involved in the process. The first three questions are on motivation, the next three on control and questions seven to nine on knowledge. The last three questions concern those affected by the process, like neighboring communities, and are on legitimacy. The interviewer presents the questions both in the form "ought to be" and "is/are", the former pointing to the future and the latter to the presence. According to Ulrich and Reynolds [9] it is easier to start the interview with the "ought to be" questions, which allow the interviewee to respond by future wishes. Thereafter the "is/are" questions on the present situation become easier for the interviewee to answer. For newcomer CSH interviewers Ulrich and Reynolds [9] have recommended an order to present the questions. However, the questions are independent and can be presented in the order an experienced interviewer finds appropriate for a particular interview. As Ulrich [12] pointed out the quest for competence in CSH is a life-long learning process.

With the observed changes of climate and climate variability we recognized that our representative climate records were short. Therefore, our current climate records include considerable uncertainties in the epistemic meaning of the word. Then reliable risk estimates by statistical methods are not possible to make. In addition, in developing countries data records of other pertinent disciplines, like agriculture, are at their best sporadic and inhomogeneous. All in all, classical statistical methods cannot be applied. In concert with this we include CSH into our fitness-utility model. In addition, we will take into account advances in heuristics [13].

IS Research and the Design Cycle. With reference to the first framework Systems Design Research we discuss here only the box on justify/evaluate.

After having accomplished and submitted our article on the theory and artifacts of SDR, EID and CSH we implement a field experiment in some representative communities of an African developing country in Ethiopia or in Kenya as a prototype case study of our fitness-utility model. We start this by building our preliminary plan for the first encountering meeting, which we hope to take in the African host country in summer 2017.

At the first encountering meeting, we need to establish the core network of the joint project and ascertain our mutual engagement to it. In addition, the needed prior capacity building of local focal persons and students as well as practical arrangements for the whole period of the project need to be discussed, agreed and delegated in a truly participatory manner. Already from the beginning we need a convincing local commitment to the project and the development of HGMCSs so that by the end of the project its ownership is in active and firm local hands for further development. This means also that we have to ensure that our joint undertaking has the local funding for the needed operative expenses and sustainable development. We, the representatives of the foreign development aid funding, make clear our role as kicking off the development of HGMCSs to support local sustainable development in terms of improved crop cultivation and food security.

One crucial issue throughout our project is communication. Not to underestimate the role of the publications smooth, open and pertinent communication is a fundamental part of our project. In local practice this means that HGMCSs information must be disseminated also in forms, which illiterate community members can understand and make use of. However, our emphasis on co-designing the services means that every participant is involved even in the agile prototype design process, which requires learning communication within the highly heterogeneous co-design team.

After the survey of the existing IT networks the needed supplements are designed and established prior to the field experiments.

The local languages pose another interesting challenge. First of all, we need a sufficient number of interpreters (local language – English – local language), like local students, for CSH guided interviews and also to transcribe these interviews both in local language and in translated English. This is important for the reason that the correspondence between the answer in local language and its English translation is never one-to-one as the evolution of any language takes into account the local culture and habits, which are partly baked into the used expressions. These features are of importance in the context of epistemic assessments to extend our design space. The quest for common understanding is not limited to human languages, but will also cover more artificial languages, for the co-design team to control the technology.

One important item to be discussed at the first encountering meeting is the evaluation of our fitness-utility model and the project in terms of HGMCSs. This evaluation covers three aspects, namely the holistic, the metric and the epistemic evaluations. They all focus on the benefit, feasibility, validity, relevancy, and fitness of the model and the project.

The metric evaluation is based on variables with measurable quantities, like crop yield, cost of tilling, cost of fertilizers etc. With their values, we can determine the profit gained by the experiment parcel under consideration. The obtained profit numbers give one view on the considered evaluation qualities and especially on the benefits, which are of fundamental importance under conditions of poverty or nearby poverty. However, we need to keep in mind that the profit numbers alone give a limited scope of the synthesized view in the holistic context.

The epistemic evaluations of qualities like motive, truthlikeness, trust and willingness to participatory cooperation give us wider understanding to form the synthesized view on the sufficiency of the developed HGMCSs. Here we should keep ourselves to conclusions based on the primary projecting results as the dichotomized data is at least partly prone to subjective judgments and to possible biases associated with heuristics.

As pointed out by Gill and Hevner [8] in the context of a fitness-utility model the assessment of its fitness is a demanding task. Here we have at least three opportunities, by which we can have an influence on improved fitness of our model. The first option is the communication box of SDR. At least we could focus some of the publications in both categories to fitness related items so that the readers could become convinced of the benefits of our holistic model. The second option lies in the environment column of the DSR framework in various organizations of at least regional coverage. In the African context, we could proceed on this path up to the African Union. The third option is the needed landing of the recent global agreements and agendas [1-4] down to the grass-root level as well as the associated need for synthesized views and messages. All in all, by doing our own job well we can let the publicity work for the fitness of our model.

4 Future Prospects of SDR

The impetus to innovate SDR was in our case the need to develop HGMCSs and to demonstrate the feasibility of our idea. Even if we still are in the midst of the task we are with our earlier experience already confident that we can reach sufficient outcomes. In addition, we can see that SDR itself is not bound to our particular application and can be explored in many other trans-disciplinary contexts.

Meinke [14] and most probably quite a few other scientists have presented the idea that during the present century it is time to emphasize the need of synthesizing approaches beside the earlier well established analytical research line. SDR can be seen as one response to this recent suggestion. The challenging part of SDR lies in the initial data of its design artifact EID. First the divide of the experiment population to not-learning and learning beings is by no means a straightforward task and needs careful considerations. Also, GTC sameness assumptions especially on the not-learning being group limits the step from the initial state to the final state. In many cases this limits the predictability, and the data for every prediction step has to be initialized. In addition, the theoretical feasibility of SDR framework remains to be analyzed. In our view SDR opens up to DSR the opportunity to become a major player on the synthesis research line.

Along our development of HGMCSs we hope that SDR can gain wider fitness and contribute significantly to the alleviation of poverty and hunger in developing countries. It should be recognized that SDR framework does not limit the possible climate service applications to the grass-root level. The reasons why we focused our attempts on the grass-root level in a developing country were our earlier experiences in this field, the expected feasibility of the attempt as a prototype project, and the urgent local need for help. However, the field is wide open for challenging undertakings and could lead to a snowball effect both in the fitness of SDR and an extended landing of pertinent global agreements and agendas [1-4]. We hope that SDR through our prototype experiment can convince the decision-makers to enhance the guidance of DSR also in climate-related issues.

5 Conclusions

With the SDR framework accomplished our progressing research has entered now the implementation of its prototype HGMCSs experiment in communities of an African developing country. By the outcomes we expect to demonstrate the feasibility, the validity and the relevancy of SDR as a fitness-utility model. We look forward to enhance its fitness with appropriate publications and contacts to relevant decision-makers.

We hope also that the outcomes of SDR prototype HGMCSs experiment encourage DSR community to seize on the need to develop tools suitable for designing trans-disciplinary interacting systems and to consider this as a challenging opportunity.

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References

1. UNFCCC, "Paris agreement," 2015. [Online]. Available: https://unfccc.int/files/meetings/paris_nov_2015/application/pdf/paris_agreement_english_.pdf. [Accessed 27 02 2017].
2. UN, "Transforming our world: the 2030 Agenda for Sustainable Development. Resolution adapted by the General assembly on 25 September 2015 (A/RES/70/1)," 2015. [Online]. Available: www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E. [Accessed 27 02 2017].
3. UN Office for the Coordination of Humanitarian Affairs , "Agenda for Humanity," 2016. [Online]. Available: http://www.agendaforhumanity.org/summit.. [Accessed 27 02 2017]
4. UN Office for the Coordination of Humanitarian Affairs, "Natural Disasters and Climate Change: Managing Risks & Crises Differently," 2016. High-Level Leaders' Roundtable #5, Core Responsibility Four of the Agenda for Humanity. [Online]. Available: https://www.worldhumanitariansummit.org/summit/roundtables
5. A. Hevner, S. March, J. Park and S. Ram, "Design Science in Information Systems Research," MIS Quarterly, vol. 28, pp. 75-105, 2004.
6. M. T. Mullarkey and A. R. Hevner, "Entering Action Design Research," in DESRIST 2015, Heidelberg, Germany, 2015, doi:10.1007/978-3-3198-18718-3_8.
7. O. Kuusi, "Expertise in the Future Use of Generic Technologies – Epistemic and Methodological Considerations Concerning Delphi Studies," 1999. [Online]. Available: www.vatt.fi/en/publications/latestPublications/publication/Publication_1345_id/221. [Accessed 27 02 2017].
8. G. T. Gill and A. R. Hevner, "A Fitness-Utility Model for Design Science Research," in DESRIST 2011, Heidelberg, Germany, 2011, doi:10.1007/978-3-642-20633-7_17.
9. W. Ulrich and M. Reynolds, "Critical Systems Heuristics," in Systems Approaches to Managing Change: a Practical Guide, M. Reynolds and S. Holwell, Eds., London, Springer, 2010, pp. 243-292.
10. C. Silver and A. Lewins, Using Software in Qualitative Research: a Step-by-Step Guide, 2nd Edition ed., London: Sage Publications, 2014.
11. O. Afitska, "Review of Transana 2.30. Language Documentation & Conservation 3: 226-235," 2009. [Online]. Available: https://www.transana.com. [Accessed 27 02 2017] uri: http://hdl.handle.net/10125/4441.
12. W. Ulrich, "The Quest for Competence in Systemic Research and Practice," Systems Research and Behavioral Science, vol. 18, pp. 3-28, 2001, doi:10.1002/sres.366.
13. D. Kahnemann, Thinking, Fast and Slow, New York: Farrar, Straus and Giroux, 2011.
14. H. Meinke, Personal communication, 2007

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