Promising practices for dealing with complexity in research for development

Are there aspects of complexity that are characteristic for research for development projects? Our study shows what are these aspects, how they affect research and what practices seem to be promising for dealing with the increasing levels of complexity.

Carmenza Robledo Abad, Sabin Bieri, René Eschen, Sandra Fuerst, Johanna Jacobi, Elizabeth Jiménez, Aymara Llanque Zonta, Meleesa Naughton, Urs Schaffner, Mirko S. Winkler, Manuel Flury

Promising practices for dealing with complexity in research for development
GAIA 32/1 (2023): 115–124

Abstract
The need to deal with complexity is getting increasingly attention in research for development projects implemented through transboundary research partnerships between organisations from the Global North and the Global South. However, less is known about aspects beyond the systems under study that still affect complexity in the research project. We conducted an experience capitalization of five transboundary research partnerships undertaking research in 14 countries in the Global South. We found that the combination of multiple contexts, the cultural and disciplinary diversity of the transboundary research partnerships, and the set of rules and proceedings from the funding mechanism affect the levels of complexity. We further identified that a transdisciplinary approach and several related practices, like intercultural communication or integrative partnerships, are promising ways of dealing with complexity. Current structures in research for development need to improve in order to fully use the potential of transdisciplinarity for sustainability transformation.

Keywords
complex adaptive system, experience capitalization, Global North, Global South, transboundary research partnership, transdisciplinarity

There is growing recognition that scientific frameworks applied in single disciplines do not capture the complexity of global challenges (Klein et al. 2022, Preiser and Woermann 2019). Emergence, or the behaviour of a system that cannot be reduced to the sum of the behaviours of its individual parts, is a characteristic of complexity (Holland 2014, Ladyman et al. 2013, Preiser 2019). Properties enabling emergence include self-organisation, multilevel organisation, adaptive interaction, and sensitivity to changes in initial conditions (Turner and Baker 2019, Andersson and Törnberg 2018). They result in more frequent occurrences of rare events than predicted by a normal distribution (Mitchell 2012, Holland 2014). Emergence shows evolved contingency and downward causation. These are bottom-up and top-down influences and relationships between levels within a system which make complex systems hard to model and to predict (Mitchell 2012).

Complexity science evolved as a response to a reductionist scientific approach aimed at universality, determinism, simplicity, and unification, that operated under the assumptions of repetition and linear causality for clarifying all processes and outcomes (Batterman 2001, Mitchell 2012). Recognising emergence, in contrast, required a pluralist approach to understanding causality and multidimensional phenomena (Wolf-Branigin 2013, Mitchell 2012). This has been a multidisciplinary journey with contributions from different fields including, but not restricted to, chaos theory, mathematics, quantum physics, adaptation, biol- >

Dr. rer. nat. Carmenza Robledo Abad | ETH Zurich | Transdisciplinarity Lab – USYS TdLab | Zurich | CH | carmenza.robledo@usys.ethz.ch

Prof. Dr. Sabin Bieri | University of Bern | Centre for Development and Environment | Bern | CH | sabin.bieri@unibe.ch

Dr. René Eschen | Centre for Agriculture and Bioscience International (CABI) | Delémont | CH | r.eschen@cabi.org

Sandra Fuerst, MSc | SKAT Foundation | St. Gallen | CH | sandra.fuerst@skat.ch

Prof. Dr. Johanna Jacobi | ETH Zurich | Department of Environmental Systems Science | Institute of Agricultural Sciences | Zurich | CH | johanna.jacobi@usys.ethz.ch

Prof. Dr. Elizabeth Jiménez | Universidad Mayor de San Andrés | La Paz | BO | ejimenez@cides.edu.bo

Dr. Aymara Llanque Zonta | Leuphana University Lüneburg | Lüneburg | DE | aymara.llanque_zonta@leuphana.de

Meleesa Naughton, MSc, MA | SKAT Foundation | St. Gallen | CH | meleesa.naughton@skat-foundation.ch

Prof. Dr. Urs Schaffner | Centre for Agriculture and Bioscience International (CABI) | Delémont | Switzerland | u.schaffner@cabi.org

Prof. Dr. Mirko S. Winkler (DTM&H) | Swiss Tropical and Public Health Institute | Basel | CH *and* University of Basel | Basel | CH | mirko.winkler@swisstph.ch

Dr. Manuel Flury | Bern | CH

https://doi.org/10.14512/gaia.32.1.8
Received February 18, 2023; revised version accepted March 15, 2023 (double-blind peer review).

ogy, ecology, or the concept of spontaneous order from social science (Biggs et al. 2021, Wells 2012).

Complexity-aware research is considered necessary for ensuring that research contributes to the *2030 Agenda for Sustainable Development (2030 Agenda)*, agreed upon at the United Nations in 2015 as a global pathway for development (Gentili 2021, Norberg and Cumming 2008). First, global issues articulated in the *2030 Agenda* are embedded within dynamic, unpredictable, and multidimensional (complex) systems shaped by interconnected human and non-human agents through multiple relationships (Larson 2018, Goodier and Apgar 2018). Second, international cooperation practitioners understand the need to be complexity-aware because otherwise key aspects of cooperation initiatives are hidden, proposals based on simplistic assumptions create perverse incentives and cause considerable harm, and transformative opportunities remain underused (ODI 2013, 2011).

However, conducting research activities on complex adaptive systems while aspiring for transformation is also challenging (Ramalingam et al. 2008, Root et al. 2015). First, competencies needed for tackling complex problems are spread across disciplines and stakeholders at different scales. Second, due to the inherent uncertainty and unpredictability of complex adaptive systems (Preiser 2019), interventions need flexibility to adapt to or use emergence. Third, addressing complex problems can involve conflicting goals and divergent, but equally plausible, interpretations depending on the disciplines or stakeholders involved (ODI 2011, Ramalingam et al. 2014).

Several approaches have been developed to promote complexity awareness in research for sustainable development (R4D) (Belcher and Palenberg 2018, Thornton et al. 2017). However, the uptake of such approaches is still low. The assumption of linear cause-effect relationships, the lack of evidence behind the assumptions of the impact pathways, and a reduced prior understanding of feedback loops are still common in R4D (Larson 2018, Thornton et al. 2017).

Funding mechanisms from the Global North increasingly promote transboundary research partnerships[1] as a means to implement R4D activities in the context of international cooperation (KFPE 2014, Kotze and Dymitrow 2022, Masselli et al. 2004). Transdisciplinarity – understood as research approach characterised by being rooted in real-world problems; recognising the need to address complexity in research; taking into account different perspectives; linking abstract (academic/scientific) and case-specific knowledge; and being aimed at producing knowledge, norms, technologies or practices that promote sustainable development (Miller et al. 2014, Pohl and Hadorn 2008) – has been portrayed as a useful approach for conducting research on complex adaptive systems (Pohl et al. 2021) because transdisciplinary research can have a transformative character by promoting changes in society or social norms (Pennington et al. 2013, Wuelser et al. 2011). This was exemplified in an recent in-depth analysis of over 40 transboundary research partnerships in R4D (Jacobi et al. 2020).

Less is known about the aspects of R4D in transboundary research partnerships that are beyond the systems under study, yet still affect the level of complexity of the research. To explore this knowledge gap, our study addressed three research questions: 1. Are there distinctive aspects of transboundary research partnerships that are beyond the complex adaptive systems under study and affect complexity in R4D? 2. What are their effects on the levels of complexity in R4D by transboundary research partnerships? 3. What are some promising practices to address these effects on the levels of complexity in R4D conducted by transboundary research partnerships?

Method

Experience capitalization is a method of reviewing experiences – positive or negative –, to co-produce knowledge that emerges from practice (experience) and can be used for future activities (Bächler et al. 2005). It includes four steps: reflexion of own experiences, dialogue with peers about similarities and differences in the reflexion step, analysis of preliminary results from the dialogue and validation of these results. The process is conducted by an external facilitator and each step is documented by a third party (CTA 2019).

We conducted an *experience capitalization* with five R4D projects implemented by transboundary research partnerships funded by the *Swiss Programme for Research on Global Issues on Development* (box 1). Four projects lasted for six years (two phases of three years each), while one project lasted only three years. All

BOX 1: The five learning cases included in this research

Feminisation, agricultural transition and rural employment (FATE)
Bolivia, Laos, Nepal, and Rwanda
www.fate.unibe.ch

Towards Food Sustainability: Reshaping the coexistence of different food systems in South America and Africa (FoodSAF)
Kenya, Bolivia, Brazil, Colombia, Zambia, and Ghana
www.cde.unibe.ch/research/projects/towards_food_sustainability/index_eng.html

Health impact assessment for engaging natural resource extraction projects in sustainable development in producer regions (HIA4SD)
Burkina Fasso, Ghana, Mozambique, and Tanzania
https://hia4sd.net

Surveillance and response to zoonotic diseases in Maya communities in Guatemala: A case for One Health (OneHealth)
Guatemala
https://data.snf.ch/grants/grant/160919

Woody invasive alien species in East Africa: Assessing and mitigating their negative impact on ecosystem services and rural livelihood (Woody Weeds)
Ethiopia, Kenya, and Tanzania
http://woodyweeds.org

1 For the purpose of this article, transboundary research partnerships and transboundary research collaborations are considered interchangeable terms.

RESEARCH QUESTIONS

1. Are there distinctive aspects of TRPs that are beyond the complex adaptive systems under study and affect complexity in R4D?
2. What are their effects on the levels of complexity in R4D by TRPs?
3. What are some promising practices to address these effects on the levels of complexity in R4D conducted by TRPs?

STEP	REFLEXION	DIALOGUE	ANALYSIS	VALIDATION
	■ What type of complexity-related phenomena did the project partners experience during the project and where does that come from? ■ How did the projects deal with complexity in regard to the project design, the research methodology, the team and research management, the practice-policy interface and the relationship with the programme management and funders?	about commonalities identified by clustering the data from the reflexion sessions	text analysis for identifying promising practices (done by facilitators and documentarists only)	for validating results of the previous steps
DATA GATHERING	■ 15 focus group discussions ■ 4 semi-structured interviews	3 participative workshops		1 participative workshop
PARTICIPANTS	■ members of each TRP (academic, non-academic) ■ facilitators, documentarists	■ members of TRPs (academic, non-academic) ■ facilitators, documentarists		■ leaders and senior researchers from each TRP ■ facilitators, documentarists

RESULTS

FIGURE 1: *Experience capitalization* in the five learning cases. TRP = transboundary research partnership. R4D = research for development.

projects (hereinafter referred to as "learning cases") looked at complex adaptive systems, while each of the cases related to a particular specific topic (e.g. food security, invasive species, feminisation of value chains). This allowed a certain level of comparability while including different political and cultural contexts, and complex adaptive systems in our sample (see online supplementary material [SM] *FATE*[2] for explanations of the learning cases). The study took place towards the end of the research projects.

The method of *experience capitalization* allowed us to use both the scientific knowledge of the researchers about the complex adaptive systems under research in each project, and their experiential knowledge (Gardien 2017) in how they dealt with changes in levels of complexity linked to aspects beyond the complex adaptive systems under study. The method is appropriate for this study for several reasons. First, it allows the generation of meaning from a large set of information which is not necessarily uniform or standardised (Spector et al. 2014). Second, *experience capitalization* is used for making sense of experiences that show retrospective coherence (i. e., the behaviour by which cause and effect chains are only coherent in retrospect; Kurtz and Snowden 2003). Third, it allows inductive learning (Michalski 1983) through a participatory process that facilitates the identification of promising practices and tools.

The transboundary research partnerships in the sample had not been asked for an explicit definition of complexity before obtaining research funding. Thus, at the beginning of our research, we considered the possibility of different understandings of complexity. As such, only an inductive method, using systematic observation, reflexion, and discussion, can be considered as an appropriate means of answering our three research questions.

We undertook a total of 15 focus group discussions and four semi-structured interviews to discuss the research questions with academic and non-academic members of the five transboundary research partnerships. The data were documented via recordings and notes by the researchers. The notes were validated by the interviewees or participants in the focus group discussions. Preliminary results about the aspects of transboundary research partnerships that are beyond the CAS under study and affect the levels of complexity were identified by clustering the data (figure 1). We conducted three workshops with a core group from each learning case (SM: *FATE, FoodSAF, HIA4SD, OneHealth, Woody Weeds*)[2] to validate the preliminary findings. A text analysis of the notes and recordings of all data allowed us to identify promising practices and tools (SM Text analysis *CapEx*)[2]. These results were validated in a final workshop with representatives of all learning cases.

Results

This section is structured along the research questions presented at the end of the introduction. >

2 Supplementary material available at *https://doi.org/10.14512/gaia.32.1.8.suppl*.

Aspects beyond the system under research that affect complexity

All research projects looked at complex adaptive system in geographically delimited social-ecological systems (Biggs et al. 2021, Glaser et al. 2008, Preiser et al. 2018). In four of the five projects, the research sites were distributed in more than one country (project sites), therefore in more than one social-ecological system embedded in different geographical, cultural, and sociopolitical contexts, with specific sets of values, as well as formal and informal agreements and customs that regulate and explain the relationships between social groups and their geographical context. This *multiplicity of contexts* provided different lenses to the research questions and methods, and increased complexity while enriching the research process.

Each transboundary research partnership in this study included academic and non-academic partners, as well as researchers with different disciplinary and cultural backgrounds (e.g., language, religion, or customs). Although the researchers recognised the importance of this *cultural diversity,* they reported that it also increased the level of complexity of the project.

A third distinctive aspect increasing the level of complexity of R4D are the *rules and proceedings from the North-South funding mechanism*. This set of regulations established the roles and responsibilities of the partners in the Global North and the partners in the Global South prior to the research design, including budgetary regulations as well as that the leading organisation and the lead researcher were obligatorily located in Switzerland (SM *Characterization of the system boundaries of the complex adaptive systems in the learning cases*)[2].

Effects on complexity levels

Related to multiple contexts and cultural diversity

Although all learning cases made progress in *increasing systems knowledge on social-ecological systems,* transformation knowledge (Kueffer et al. 2019) was not achieved to the same extent at the time of our study. However, some researchers reported initial contributions towards sustainability transformation in specific sites.

Learning cases used *universalised concepts,* in other words, concepts already established in the northern dominated scientific community. However, academic and non-academic partners in the Global South often perceived these concepts as delinked from the perspectives or value systems prevailing in the project areas, as exemplified in the opinion of a local stakeholder:

> *Quinoa producers have their own interests and objectives that might not be directly related to the research project's objective. In addition, farming timeline is not necessarily the same as for academics.* SM *FATE*[2]

This created the need to contextualise universalised concepts by accommodating local views and context-related feedback loops, modifying the original concepts, and reducing the level of generalisation to fit the local context, while keeping conceptual coherence. The participants found this a challenge.

All transboundary research partnerships faced challenges linked to *interdisciplinary backgrounds*. A significant number of partners in all transboundary research partnerships had previously worked in interdisciplinary partnerships. Yet, while interdisciplinary teams offer more entry points for each research question, researchers had to deal with multiple disciplinary theories, jargons, and divergent methodological requirements (e.g., qualitative vs. quantitative methods). Thus, interdisciplinarity required widening the disciplinary perspectives of the researchers, and increased the challenge of developing coherent methodological frameworks.

All learning cases showed *cultural diversity,* or the multiplicity of values, norms, or customs explaining the "way to understand and do things" within the transboundary research partnerships. The following statement illustrates the importance of cultural diversity even within one country:

> *Guatemala is a country with multiple ethnolinguistic groups, including several Maya groups, mestizos and "whites". Different cultures have different cosmologies, time-counting systems, epistemologies or approaches towards disease and healing. This diversity can be seen as a cultural richness. However, there are still ethnocentric attitudes at country and at region level, with a certain tendency to racism. This results in a subjacent cultural conflict between Mayas and other groups.* SM *One Health*[2]

Cultural diversity can affect the perception of legitimacy of partners, representativeness, the relevance and appropriateness of research questions, and the chance to influence transformative pathways. It also explains uneven levels of acceptance to some sources of knowledge and to scientific insights. In our sample, some cultural aspects converged (e.g., the importance of traditional knowledge), while others diverged across the multiple actors involved (e.g., the roles and responsibilities within members of the transboundary research partnerships). These convergences and divergences were not clear when the projects started, and intercultural diversity had to be addressed during the design and implementation of research methods and in the management of the transboundary research partnerships.

Researchers reported that the *political situation and infrastructure available at the sites* varied across and within countries and sites, and affected the level of complexity and emergent phenomena. For instance, the degree of closeness between the research teams and the government varied with government changes, thereby influencing the research activities, the uptake of results, and the overall outcome of the research. Furthermore, political stability and security was crucial for field activities, and the quality of available infrastructure (e.g., roads, internet, telephone, etc.) influenced most interactions as exemplified by following statement:

> *[...] safety issues like political unrest in the host country affected the field work and forced some researchers to abandon or re-orient part of their activities. This was managed without compromising on the project's outputs. Safety was addressed by informing local stakeholders about planned visits, which helped*

obtain timely information from local sources about emerging risks in order to take the necessary precautions.
SM *Woody Weeds*[2]

Related to the framework provided by the funding mechanism

Overall, the researchers recognised the importance of having access to a North-South funding mechanism that strengthens research on complex systems in the Global South. However, the request by the funding mechanism of having the leadership of the research projects located in an organisation of the Global North created a structural imbalance in the power arrangement.

All learning cases reported tensions between *different priorities and expectations not being fully aligned* with programme funders[3], researchers, and key stakeholders in the research areas. This resulted, for instance, in levels of *aspiration for measurable and up-scalable transformation* that were not fully aligned between the partners in the transboundary research partnerships and the two funding agencies. This generated tension between the requirements from the scientific community (e.g., scientific publications) and the achievement of development outcomes.

Diverse and sometimes contradictory *administrative procedures* from the funding agencies, the organisations in the transboundary research partnerships, and the organisations involved in the learning cases created tension as well. Facing this challenge demanded more resources than expected, including the time of senior researchers and administrative staff:

Rigidity (from the donors) regarding budgeting guidance was challenging. We hadn't contingency funding to address emerging opportunities or challenges. This could be solved only using the coordinator's own budget. However, using emerging phenomena is key, for instance, when influencing policy.
SM *Woody Weeds*[2]

The effects above are intertwined and critical for the implementation, outputs, and outcomes of the learning cases, and the perception of equity and hegemony in R4D.

Practices for dealing with increasing levels of complexity in research for development

During implementation, only a small number of researchers per learning case were in contact with all sites and partners involved in the given transboundary research partnership, and only a very small number of persons had an overview of the strategies used for dealing with the challenges. Table 1 (p. 120 f.) characterizes the six identified *promising practices* that can be used for dealing with the effects on complexity: inter- and transdisciplinary research, communication strategy, building integrative and stable partnerships, team building, transformative pilot actions and adaptive project management.

Two generic tools were considered as well as promising for dealing with effects on complexity that are distinctive in R4D: the *Guide for Transboundary Research Partnerships "Towards equitable and effective collaboration"* (KFPE 2014) and the *Toolbox Dialogue Initiative (TDI*[4]; Eigenbrode et al. 2007).

Discussion

We identified three aspects that affected the complexity of the R4D projects caused by aspects beyond the complex adaptive system under study: 1. a combination of multiple contexts, 2. the cultural and disciplinary diversity within the transboundary research partnerships, and 3. the set of rules and proceedings from the funding mechanism. We further identified practices that can be implemented by the research teams to deal with increasing levels of complexity. We structure this discussion through two lenses, first the practices used by the transboundary research partnerships in R4D (table 1), and second the institutional setup.

Practices used

Transdisciplinarity (table 1) was identified as a useful approach to navigate increasing complexity in R4D. Although not all projects in our sample were designed as transdisciplinary from the onset, transdisciplinary aspects were included, especially the increasing participation of non-academic actors during the implementation of the research activities as a means to increase impact. This finding is aligned with the postulate of transdisciplinary research having a transformative character (Pennington et al. 2013, Wuelser et al. 2011) and with the contribution of transdisciplinarity to use research knowledge in multiple development pathways (Jacobi et al. 2020). Other authors have identified the importance of cultural diversity, context, and the inclusion of local knowledge or participatory approaches for empowerment in transdisciplinary research (Hölsgens et al. 2023, Horcea-Milcu et al. 2022, Nikulina et al. 2019). The novelty of our study is that transdisciplinarity was not the starting point for the research, nor were most of the researchers trained in transdisciplinary methods, and transdisciplinarity was rather an "ad hoc" practice for dealing with increasing complexity in transboundary research partnerships. However, other authors have criticised a focus on the transdisciplinary approach in transboundary research partnerships because it can become "lofty", "unattainable", and can be "used in a tokenistic manner as a means to obtain funding" (Kotze and Dymitrow 2022, p. 12). This divergence in findings can be attributed to different understandings of transdisciplinarity among researchers in transboundary research partnerships. For example, the difference between "strong" and "weak" transdisciplinarity in R4D, as identified by Jacobi et al. (2020), or the different "ways to do transdisciplinarity research" depends on such aspects as the intention, the starting point, and the level of engagement with the theory and practice (Mitchell et al. 2015).

Strong partnerships, team building, and a strong communication strategy were all identified as promising practices for dealing with complexity in transboundary research partnerships >

3 The *Swiss Programme for Research on Global Issues for Development* funded all learning cases. It has two financing agencies: 1. a governmental international cooperation agency, and 2. a scientific research foundation funded with public money.
4 *http://tdi.msu.edu*

TABLE 1: Promising practices for dealing with increased complexity caused by aspects beyond the complex adaptive systems (CAS) under study in research for development (R4D). The statements in the third column are taken from the learning cases (LCs) reports[2], which include detailed information about the LCs insights.

PRACTICE	DESCRIPTION
inter- and trans-disciplinary research (ITD) ...	■ ... secures participation of academic and non-academic researchers in as many phases of the R4D project as possible to secure knowledge co-creation. ■ ... acknowledges and integrates non-scientific knowledge. ■ ... makes it possible to influence boundary partners and other stakeholders, because it includes the interests and needs of multiple actors. ■ ... provides participative decision-making mechanisms.
communication strategy ...	■ ... enables mutual understanding, dialogue, and trust and helps creating a "common enterprise". ■ ... that includes different levels: the project team, the boundary partners, and other stakeholders ■ ... that secures getting skills for clarifying content-related complexity features in a disciplinary and culturally diverse team. ■ ... includes concrete practices for addressing language barriers (e.g., involving a linguist). ■ ... based on sensitization and training within the research teams.
building integrative and stable partnerships ...	■ ... after careful selection of partners, considering partner's risks and previous experiences. ■ ... allow long-term collaboration based on shared interests (beyond the specific project). ■ ... based on collaboration agreements between partner organizations agreed before going into administrative matters, and the identification of potential differences in contracting procedures within the partnership. ■ ... provides incentives for supervision of students in the organizations in the Global South and in the Global North. ■ ... that strengthen the partner organizations in the Global South, as well as in the Global North. ■ ... uses long-term relationships with boundary partners beyond the project that can trigger development outcomes.
team building ...	■ ... including face to face team meetings and visits to the project sites. ■ ... that provides disciplinary and interdisciplinary training, including on social skills (intercultural communication, conflict reduction and management, etc.). ■ ... ensuring team members from the Global North and from the Global South share responsibilities (e.g., creating tandems for data gathering and analysis or co-leading activities). ■ ... allows clarifying potential enrolment conflicts for students from the beginning. ■ ... including people with ample context-related experience in the teams. ■ ... considering emotional competences of the staff when selecting the team (e.g., mindfulness, openness to other values and customs) besides content-related skills. ■ ... after securing enough time availability for senior staff in the project budget.
transformative pilot actions ...	■ ... based on the scientific findings, and adapted to priorities and values of local stakeholders. ■ ... able to secure tangible transformation (even if small). ■ ... using synergies with other (ongoing) activities. ■ ... after clarifying potential benefits (or lack thereof) early, as well as when to expect these benefits. ■ ... should include the management of expectations from local stakeholders. ■ ... establish the link between pilot activities and policy influence from the onset.
adaptive project management ...	■ ... because it allows reacting to unexpected events, being either challenges or opportunities. ■ ... allows flexibility in different contracting rules across countries. ■ ... includes certain budget flexibility. ■ ... based on shared responsibility and on a country strategy sensitive to cultural aspects and political tension for the different sites.

(table 1). The importance of communication has been highlighted by different scholars (Stone 2014, Klein 2014). Our research shows that communication comprises multiple levels, requires training and skills, and that a comprehensive communication strategy can help navigate both the complexity of the complex adaptive systems under research, as well as the increasing levels of complexity resulting from aspects beyond these systems. Similarly, the importance of building long-term partnerships and robust team relationships for dealing with increasing complexity in R4D is aligned with the lessons from other international programmes in R4D (CGIAR-IEA 2017).

At the time of our study, transformation knowledge was at a low level compared to the increment in system knowledge (table 1) (Kueffer et al. 2019). This result needs to be seen in perspective. A meta-analysis of over 47 transboundary research partnership evaluations concludes that it can take up to 15 years to achieve transformation (understood as reaching a sustainable scale and generating social and economic outcomes and impacts; CAS Sec-

PRACTICE	EXAMPLES OF STATEMENTS FROM THE LCS
inter- and trans-disciplinary research (ITD) ...	■ *Engaging with stakeholders early and sharing data that can be used to support advocacy work can have a transformative effect.* SM *FATE*[2] ■ *Using an innovative data integration approach, linking data collection at comparable scale units across socio-economic and environmental disciplines, enabled comparison using nested design, allowing the researchers to understand how they affect each other quantitatively.* SM *WoodyWeeds*[2]
communication strategy ...	■ *Research with mining companies: As most private mining companies regarded research as an "intrusive activity", touching sensitive issues such as finances and land rights, collaboration required strong negotiation and persuasion. Through a communication strategy focusing on [the] neutrality of research, the cross-country scope of the HIA4SD Project, and [the] confidentiality agreements, the project was able to build a basis for trustful collaboration.* SM *HIA4SD*[2] ■ *Communication awareness is key because when there are multiple languages within the project teams (academic and non-academic researchers, different countries, and different cultural backgrounds) the same words can have different meanings or there are no proper translations into local languages. Thus, the researchers need to improve their communication skills.* SM *FATE*[2]
building integrative and stable partnerships ...	■ *Building a "collective enterprise" was important for building and maintaining a common identity, for sharing key concepts and values, for doing joint fieldwork and collective action, and for managing difficulties throughout the project. For each of the core concepts a (strong) partner organisation was engaged.* SM *FoodSAF*[2] ■ *The project team estimates that the success of the project in policy influence is mostly due to long-term engagement and communications with policymakers (to build personal relationships and trust), and partly due to "luck" (being in the right place at the right time).* SM *WoodyWeeds*[2]
team building ...	■ *We spend time and resources creating an open-minded and engaged team and fostering a learning attitude, accepting to be challenged by other views even "if you are a well-recognised scientist".* SM *OneHealth*[2] ■ *Conducting field work in tandems of PhD students from different countries over a couple of weeks was beneficial, as PhD students supported each other's understanding. This facilitated cross-country experience sharing and enabled more efficient communication later on (e.g., when exchanging data or preparing joint publications).* SM *HIA4SD*[2]
transformative pilot actions ...	■ *Transformative pilot actions in the second phase responded to the priorities and initiatives of the communities; and researchers altered their role to become "agents of change".* SM *FoodSAF*[2] ■ *We used a two-phased research-communication/application approach: The first project phase focused on research, building the evidence-base and developing the assessment tool. The second phase focuses on communication and application, including prospects for improving regulations and carrying out health impact assessments (HIA) through policy dialogue and capacity building.* SM *HIA4SD*[2] (figure 2, p. 122).
adaptive project management ...	■ *In our project we allowed "backwards planning because it allowed [us] to design "modulators of change" after jointly identifying underlying assumptions and specific context conditions (reality check).* SM *OneHealth*[2] ■ *The flexibility of the Swiss coordinator and the experience of the country coordinators [were] critical factors for the success of the research project.* SM *WoodyWeeds*[2]

retariat 2021). Furthermore, our results show that pilot actions that respond to the research questions on complex adaptive systems, and are adapted to the realities, the needs, and the processes in specific contexts, might not be universalizable or fully scalable but are essential to achieve development outcomes, and thus transformation (table 1). This is aligned with the evaluation findings of several R4D programmes and highlights the need to consider longer timeframes when seeking to understand transformative development outcomes of R4D (CAS Secretariat 2021).

Institutional set-up

Our study also highlighted how the institutional set-up provided by the funding mechanism, and the institutional relationships between the partner organisations involved in R4D can increase the levels of complexity. This result is aligned with previous research (OECD GSF 2011, Ott 1972, Paulo 2014). However, the extent to which this affects the existing epistemological hegemony, or the strategies for dealing with complexity in R4D, is only starting to be analysed (Llanque Zonta et al. 2023, in this spe- >

FIGURE 2: Dialogue with women in Houndé, Burkina Faso in the *Health impact assessment for engaging natural resource extraction projects in sustainable development in producer regions (HIA4SD)* project.

cial issue). Eschen et al. (2021) also highlight the importance of having organisations in the Global South lead R4D programmes.

Conclusions

Embracing complexity in the research for sustainable development gives us the opportunity to overcome widespread oversimplification of complex adaptive systems with misleading conclusions and merely symptom fighting actions. This experience capitalization study enabled us to analyse how five North-South transboundary research partnerships and increasing complexity resulting from aspects distinctive to R4D in transboundary research partnerships.

We demonstrated that beyond addressing the complexity related to the research subject, R4D projects face multiple contexts, diverse partnerships, and the funding mechanisms, and that affect the level of complexity of these projects. We observed that inter- and transdisciplinary approaches, a communication strategy, team building, and adaptive management are helpful practices for dealing with increasing complexity in North-South transboundary research partnerships for sustainable development. We also observed that accommodating multiple visions and value systems in the research activities is challenging, but ensures that the research will more likely have an impact on the development process. Finally, the institutional set-up can provide both opportunities and limitations.

Although complexity with regard to the research subject (complex adaptive systems, such as the food system) is increasingly recognised in R4D programmes (Natera and Castellacci 2021, Wuelser et al. 2011), increases in the level of complexity due to aspects beyond the complex adaptive systems under study are not yet fully recognised during the design of R4D projects, or in the budgets of corresponding funding mechanisms. In order to enlarge transformative processes, future R4D programmes can consider strategies for securing the time, competences, and resources necessary for dealing with increasing levels of complexity in R4D undertaken by transboundary research partnerships. Equally important seems to improve the the institutional agreements to secure full participation of the partners in the Global South.

Acknowledgement: We would like to thank two anonymous reviewers for their helpful comments.
Funding: The *Swiss Programme for Research on Global Issues for Development (Swiss r4d)* funded all case studies and provided meaningful funding for the experience capitalization.
Competing interests: The authors declare no competing interests.
Author contribution: *CRA, MF:* involved with initial research design; *CRA, SB, SF, RE, JJ, MW, EJ, ALZ, US, MN, MF:* data collection and analysis; *CRA, RE, JJ, MW, EJ, ALZ, US, MF:* manuscript drafting; *JJ, MW, MF:* collaborating to the final manuscript; *MN:* language check; *CRA:* writing the final manuscript, corresponding author.

References

Andersson, C., P. Törnberg. 2018. Wickedness and the anatomy of complexity. *Futures* 95: 118–138. https://doi.org/10.1016/j.futures.2017.11.001.
Bächler, G. et al. 2005. *Experience capitalisation: A guide*. Bern, CH: Swiss Agency for Development and Cooperation.
Batterman, R. W. 2001. *The devil in the details: Asymptotic reasoning in explanation, reduction, and emergence*. Oxford, UK: Oxford University Press. https://doi.org/10.1093/0195146476.001.0001.
Belcher, B., M. Palenberg. 2018. Outcomes and impacts of development interventions: Toward conceptual clarity. *American Journal of Evaluation* 39/4: 478–495. https://doi.org/10.1177/1098214018765698.
Biggs, R. et al. 2021. What are social-ecological systems and social-ecological systems research? In: *The Routledge handbook of research methods for social-ecological systems*. Edited by R. Biggs. London: Routledge. 3–26. https://doi.org/10.4324/9781003021339-2.
CAS Secretariat (CGIAR Advisory Services Shared Secretariat). 2021. *Synthesis of learning from a decade of CGIAR research programs*. Rome: CAS Secretariat Evaluation Function. https://iaes.cgiar.org/sites/default/files/pdf/June21_2021%20Synthesis%20Report_Final%20updated%2002_2022.pdf (accessed February 11, 2023).
CGIAR-IEA (CGIAR Independent Evaluation Agreement). 2017. *Evaluation of partnerships in CGIAR. Rome: CGIAR-IEA*. https://iaes.cgiar.org/sites/default/files/pdf/IEA-Evaluation-of-partnerships_Summary_Report.pdf (accessed April 2, 2023).
CTA (Technical Centre for Agricultural and Rural Cooperation). 2019. *Experience capitalization from theory to practice: Trying out a new approach*. Experience Capitalization Series 11. Wageningen, NL: CTA.
Eigenbrode, S. D. et al. 2007. Employing philosophical dialogue in collaborative science. *BioScience* 57/1: 55–64. https://doi.org/10.1641/B570109.
Eschen, R., P. R. Mbaabu, B. S. Ramamonjisoa, C. Robledo Abad. 2021. Factors enhancing the level of utilisation of research knowledge on ecosystems. *PLoS ONE* 16/7: e0254752. https://doi.org/10.1371/journal.pone.0254752.
Gardien, È. 2017. What does experiential knowledge bring to research in human and social sciences? *Vie sociale* 20/4: 31–44. https://doi.org/10.3917/vsoc.174.0031.
Gentili, P. L. 2021. Why is complexity science valuable for reaching the goals of the UN 2030 Agenda? Rendiconti Lincei. *Scienze Fisiche e Naturali* 32/1: 117–134. https://doi.org/10.1007/s12210-020-00972-0.
Glaser, M., G. Krause, B. Ratter, M. Welp. 2008. Human/Nature interaction in the Anthropocene: Potential of social-ecological systems analysis. *GAIA* 17/1: 77–80. https://doi.org/10.14512/gaia.17.1.18.
Goodier, S., M. Apgar. 2018. *Opportunities for using complexity-aware approaches to Theory of Change*. Briefing Note 8. Brighton, UK: Institute of Development Studies. www.shareweb.ch/site/Poverty-Wellbeing/Documents/SDC-IDS%20BriefingNote%2008_Marina_Sarah_final.pdf (accessed April 2, 2023).

Guimarães, M., C. Fonseca, C. Gonzalez, T. Pinto-Correia. 2017. Reflecting on collaborative research into the sustainability of Mediterranean agriculture: A case study using a systematization of experiences approach. *Journal of Research Practice* 13/1: M1.

Holland, J. H. 2014. *Complexity: A very short introduction*. Oxford, UK: Oxford University Press. https://doi.org/10.1093/actrade/9780199662548.001.0001.

Hölsgens, R. et al. 2023. Transdisciplinary research along the logic of empowerment: Perspectives from four urban and regional transformation projects. *Sustainability* 15/5: 4599. https://doi.org/10.3390/su15054599.

Horcea-Milcu, A.-I., J. Leventon, D. J. Lang. 2022. Making transdisciplinarity happen: Phase 0, or before the beginning. *Environmental Science & Policy* 136r: 187–197. https://doi.org/10.1016/j.envsci.2022.05.019.

Howe, K. R. 2012. Mixed methods, triangulation, and causal explanation. *Journal of Mixed Methods Research* 6/2: 89–96. https://doi.org/10.1177/1558689812437187.

Jacobi, J. et al. 2020. Utilization of research knowledge in sustainable development pathways: Insights from a transdisciplinary research-for-development programme. *Environmental Science & Policy* 103: 21–29. https://doi.org/10.1016/j.envsci.2019.10.003.

Jacobi, J. et al. 2022. Transdisciplinary co-creation increases the utilization of knowledge from sustainable development research. *Environmental Science & Policy* 129: 107–115. https://doi.org/10.1016/j.envsci.2021.12.017.

KFPE (Commission for Research Partnerships with Developing Countries). 2014. *A guide for transdisciplinary research partnerships: 11 principles*. Bern, CH: KFPE.

Klein, J. T. 2014. Communication and collaboration in interdisciplinary research. In: *Enhancing communication and collaboration in interdisciplinary research*. Edited by M. O'Rourke, S. Crowley, S. Eigenbrode, J. Wulfhorst. Thousand Oaks, CA: Sage. 11–30. https://doi.org/10.4135/9781483352947.n2.

Klein, L., P. Buckle, N. Nguyen, R. Preiser, R. Ison. 2022. Growing a community of conversation and understanding: The 2023 agenda for the systems community. *Systems Research and Behavioral Science* 39/6: 1103–1107. https://doi.org/10.1002/sres.2919.

Kotze, S., M. Dymitrow. 2022. North-South research collaborations: An empirical evaluation against principles of transboundary research. *Development Policy Review* 40/2: e12555. https://doi.org/10.1111/dpr.12555.

Kueffer, C., F. Schneider, U. Wiesmann. 2019. Addressing sustainability challenges with a broader concept of systems, target, and transformation knowledge. *GAIA* 28/4: 386–388. https://doi.org/10.14512/gaia.28.4.12.

Kurtz, C. F., D. J. Snowden. 2003. The new dynamics of strategy: Sense-making in a complex and complicated world. *IBM Systems Journal* 42/3: 462–483. https://doi.org/10.1147/sj.423.0462.

Ladyman, J., J. Lambert, K. Wiesner. 2013. What is a complex system? *European Journal for Philosophy of Science* 3/1: 33–67. https://doi.org/10.1007/s13194-012-0056-8.

Larson, A. 2018. Evaluation amidst complexity: Eight evaluation questions to explain how complex adaptive systems affect program impact. *Evaluation* 24/3: 353–362. https://doi.org/10.1177/1356389018781357.

Llanque Zonta, A., J. Jacobi, S. Mukhovi, E. Birachi, P. von Groote, C. Robledo Abad. 2023. The role of transdisciplinarity in building a decolonial bridge between science, policy, and practice. *GAIA* 32/1: 107–114. https://doi.org/10.14512/gaia.32.1.7.

Masselli, D., J.-A. Lys, J. Schmid. 2004. *Improving impacts of research partnerships*. Bern, CH: Swiss Commission for Research Partnerships with Developing Countries (KFPE).

Michalski, R. S. 1983. A theory and methodology of inductive learning. *Artificial Intelligence* 20/2: 111–161. https://doi.org/10.1016/0004-3702(83)90016-4.

Miller, T. R. et al. 2014. The future of sustainability science: A solutions-oriented research agenda. *Sustainability Science* 9/2: 239–246. https://doi.org/10.1007/s11625-013-0224-6.

Mitchell, C., D. Cordell, D. Fam. 2015. Beginning at the end: The outcome spaces framework to guide purposive transdisciplinary research. *Futures* 65: 86–96. https://doi.org/10.1016/j.futures.2014.10.007.

Mitchell, S. D. 2012. *Unsimple truths: Science, complexity, and policy*. Chicago, MI: Chicago University Press.

Natera, J. M., F. Castellacci. 2021. Transformational complexity, systemic complexity and economic development. *Research Policy* 50/7: 104275. https://doi.org/10.1016/j.respol.2021.104275.

Nikulina, V., J. L. Lindal, H. Baumann, D. Simon, H. Ny. 2019. Lost in translation: A framework for analysing complexity of co-production settings in relation to epistemic communities, linguistic diversities and culture. *Futures* 113: 102442. https://doi.org/10.1016/j.futures.2019.102442.

Norberg, J., G. Cumming. 2008. *Complexity theory for a sustainable future*. New York: Columbia University Press.

ODI (Overseas Development Institute). 2011. *Taking responsibility for complexity: How implementation can achieve results in the face of complex problems*. Working Paper 330. London: ODI.

ODI. 2013. *A guide for planning and strategy development in the face of complexity*. Background Note. London: ODI. https://cdn.odi.org/media/documents/8287.pdf.

OECD GSF (Organisation for Economic Co-operation and Development Global Science Forum). 2011. *Opportunities, challenges and good practices in international research cooperation between developed and developing countries*. Paris: OECD. www.oecd.org/sti/inno/47737209.pdf (accessed April 2, 2023).

Ott, M. C. 1972. Mediation as a method of conflict resolution: Two cases. *International Organization* 26/4: 595–618. https://doi.org/10.1017/S0020818300003052.

Paulo, S. 2014. *International cooperation and development: A conceptual overview*. German Development Institute Discussion Paper 13. https://doi.org/10.2139/ssrn.2430206.

Pennington, D. D., G. L. Simpson, M. S. McConnell, J. M. Fair, R. J. Baker. 2013. Transdisciplinary research, transformative learning, and transformative science. *BioScience* 63/7: 564–573. https://doi.org/10.1525/bio.2013.63.7.9.

Pohl, C., G. Hirsch Hadorn. 2008. Methodological challenges of transdisciplinary research. *Natures Sciences Sociétés* 16/2: 111–121. https://doi.org/10.1051/nss:2008035

Pohl, C., J. T. Klein, S. Hoffmann, C. Mitchell, D. Fam. 2021. Conceptualising transdisciplinary integration as a multidimensional interactive process. *Environmental Science & Policy* 118: 18–26. https://doi.org/10.1016/j.envsci.2020.12.005.

Preiser, R. 2019. Identifying general trends and patterns in complex systems research: An Overview of theoretical and practical implications. *Systems Research and Behavioral Science* 36/5: 706–714. https://doi.org/10.1002/sres.2619.

Preiser, R., R. Biggs, A. De Vos, C. Folke. 2018. Social-ecological systems as complex adaptive systems: Organizing principles for advancing research methods and approaches. *Ecology and Society* 23/4: 46. https://doi.org/10.5751/ES-10558-230446.

Preiser, R., M. Woermann. 2019. Complexity, philosophy and ethics. In: *Global Challenges, Governance, and Complexity*. Edited by V. Galaz. Cheltenham, UK: Edward Elgar. 38–62. https://doi.org/10.4337/9781788115421.00012.

Ramalingam, B., H. Jones, T. Reba, J. Young. 2008. *Exploring the science of complexity: Ideas and implications for development and humanitarian efforts*. Working Paper 285. London: Overseas Development Institute.

Ramalingam, B., M. Laric, J. Primrose. 2014. *From best practices to best fit: Understanding and navigating wicked problems in international development*. Working Paper. London: Overseas Development Institute. http://www.wageningenportals.nl/sites/default/files/resource/9159.pdf.

Root, H., H. Jones, L. Wild. 2015. *Managing complexity and uncertainty in development policy and practice*. ODI Report. London: Overseas Development Institute.

Spector, P. E., S. G. Rogelberg, A. M. Ryan, N. Schmitt, S. Zedeck. 2014. Moving the pendulum back to the middle: Reflections on and introduction to the inductive research special issue of journal of business and psychology. *Journal of Business and Psychology* 29/4: 499–502. https://doi.org/10.1007/s10869-014-9372-7.

Stone, D. 2014. Beyond common ground: A transdisciplinary approach to interdisciplinary communication and collaboration. In: *Enhancing communication and collaboration in interdisciplinary research*. Edited by M. O'Rourke, S. Crowley, S. Eigenbrode, J. Wulfhorst. Thousand Oaks, CA: Sage. 82–102. https://doi.org/10.4135/9781483352947.n5.

>

Thornton, P. K. et al. 2017. Responding to global change: A theory of change approach to making agricultural research for development outcome-based. *Agricultural Systems* 152: 145–153. https://doi.org/10.1016/j.agsy.2017.01.005.

Turner, J. R., R. M. Baker. 2019. Complexity theory: An overview with potential applications for the social sciences. *Systems* 7/1: 4. https://doi.org/10.3390/systems7010004.

Wells, J. 2012. *Complexity and sustainability.* London: Routledge. https://doi.org/10.4324/9780203095676.

Wolf-Branigin, M. 2013. *Introduction: The history and theory of complexity. In: Using complexity theory for research and program evaluation.* New York: Oxford University Press. 1–31. https://doi.org/10.1093/acprof:oso/9780199829460.003.0001.

Wuelser, G., C. Pohl, G. Hirsch Hadorn. 2011. Structuring complexity for tailoring research contributions to sustainable development: A framework. *Sustainability Science* 7/1: 81–93. https://doi.org/10.1007/s11625-011-0143-3.

Carmenza Robledo Abad
1996 PhD in geography (University of Stuttgart, DE). Lead author in the *Fifth Assessment Report* of the Intergovernmental Panel on Climate Change (IPCC) (2014). 2017 to 2021 coordinator of the synthesis program, within the framework of the *Swiss Programme for Research and Global Issues for Development*. Currently senior scientist at Transdisciplinarity Lab (USYS TdLab), ETH Zurich, CH. Research interests: contribution of transdisciplinarity to sustainable transformation as well as climate change and natural resource management.

Sabin Bieri
Studies in social geography. 2007 PhD in geography and gender studies. Since 2020 director of the Centre for Development and Environment, University of Bern, CH. Research interests: agricultural transition and rural labour markets in a globalized world, the changing nature of work and gendered division of labour in a post-growth society, social and economic transformations to sustainability, *2030 Agenda* and pathways to sustainability.

René Eschen
2006 PhD in ecology (Fribourg, CH). Since 2011 research scientist at Centre for Agriculture and Bioscience International, CABI, Delémont, CH. Research interests: ecosystems management, risk analysis, invasion ecology.

Sandra Fuerst
MSc in geographical development research. Since 2018 development professional at Skat Foundation, St. Gallen, CH. Research interests: climate-resilient water and food systems, design and implementation of sustainable innovations for rural livelihoods at scale.

Johanna Jacobi
Studies in geography, biology and social anthropology. 2013 PhD (University of Bern, CH). 2014 to 2015 postdoctoral project at the University of California, Berkeley, US, on agroforestry. 2015 to 2021 research on food system resilience and sustainability in Latin America and Africa. Since 2021 assistant professor for Agroecological Transitions at ETH Zurich, CH. Research interests: agroecology as science, practice and social movement, and approaches from political ecology.

Elizabeth Jiménez
1995 MA in development and international studies, 2000 PhD in development economics (both from the University of Notre Dame, US). Since 2005 professor at CIDES-UMSA, the graduate centre for multidisciplinary studies of the Universidad Mayor de San Andres in La Paz, BO. Currently academic coordinator of the *Multidisciplinary PhD program on Development Sciences* at CIDES-UMSA. Research interests: rural transformations, climate change, labour issues, the commons and institutional economics.

Aymara Llanque Zonta
Studies in community social psychology. 2019 PhD in philosophy (Universidad Nacional Siglo XX, La Paz, BO). 2016 to 2020 researcher leading "transformative pilot actions" in Latin America and Africa in the frame of the *r4d* project *Towards Food Sustainability*. Ten years of experience in sustainable management of Amazonian forests, as a researcher and project manager. Currently fulltime lecturer at the Faculty of Sustainability, Leuphana University Lüneburg, DE. Research interests: transdisciplinary research on agroecological transitions and food systems, with emphasis on inclusiveness and equity.

Meleesa Naughton
2010 to 2011 MSc in water science, policy and management, 2016 MA in geomatics project management. Since 2017 water resources management professional at Skat Foundation, St. Gallen, CH. Research interests: rural and urban water supply and sanitation, and mapping and remote sensing for natural resources management.

Urs Schaffner
1994 PhD in ecology (University of Bern, CH). Since 2000 head of the Ecosystems Management section at the Centre for Agriculture and Bioscience International, Delémont, CH. Since 2008 affiliate assistant professor at the University of Idaho, US. Research interests: evolutionary ecology of invasive species, their environmental and socio-economic impacts and their sustainable management, particularly in grassland ecosystems.

Mirko S. Winkler
Studies in environmental sciences (2008 MSc). 2011 PhD and 2019 habilitation in epidemiology. Since 2018 head of Health Impact Assessment (HIA) Research Group at the Swiss Tropical and Public Health Institute, Basel, CH. Research interests: HIA of large infrastructure development projects in low- and middle-income countries, and urban public health.

Manuel Flury
PhD in geography (University of Bern, CH). Former collaborator of the Swiss Agency for Development and Cooperation (SDC), Bern, CH. Currently independent consultant in international cooperation. Area of expertise: working at the interface of research, policy and practice in international cooperation.