universitätbonn

Zentrum für Entwicklungsforschung
Center for Development Research
University of Bonn

Through the doors? Scope, types and goals of interdisciplinarity in selected projects at the Center for Development Research

Janina Kleeman, ZEF c

Hugo Rosa da Conceição, ZEF a

Muhammed Abdella Usman, ZEF b

November, 2012

Interdisciplinary Term Paper

ZEF Doctoral Studies Program

Table of Contents

Abstract **1**

Acknowledgement **1**

Acronyms and Abbreviations **2**

1. Introduction **3**

2. Approaches and definitions of multi-, inter- and transdisciplinarity **5**

3. How to analyse inter- and multidisciplinarity? The typology of Huutoniemi et al. (2010) **8**

4. Appling Huutoniemi´s framework: Interdisciplinarity in selected projects of ZEF **11**

4.1 Secondary Forests and Fallow Vegetation in the Agricultural Landscape of the Eastern Amazon Region (SHIFT-Capoeira) 12

4.2 Conservation and Use of the Wild Populations of Coffee Arabica in the Montane Rainforests of Ethiopia (CoCE) 14

4.3. Global Change and Hydrological cycle in the Volta Basin (GLOWA Volta) 18

5. Is Interdisciplinarity measurable? Discussion of ZEF´s projects and Huutoniemi´s framework **24**

5.1 Discussion of the interdisciplinary character of the selected projects 24

5.2 Limitations of Huutoniemi´s Approach 26

5.3 Limitations of the term paper 26

6. Conclusion **27**

References **29**

Abstract

Interdisciplinarity has become an increasingly aim of academic research in recent decades. The debate on the meaning of the term and on how to carry out interdisciplinary research has yielded a rich literature, but tools to identify interdisciplinarity in actual research activities are not well developed. This article builds upon the framework of Huutoniemi et al. (2010) to analyse the dimensions of interdisciplinarity in the GlOWA Volta, CoCE and SHIFT-Capoeira projects of the Center for Development Research. The paper identifies variable degrees of interdisciplinarity between the projects and along the projects' implementation and a general move towards interdisciplinarity in the Center activities.

Keywords: Epistemology, qualitative indicators, typology, interdisciplinary

Acknowledgement

We would like to thank everybody who gave fruitful input for this paper. Special thanks goes to our tutors Jan Börner, Henning Sommer and Till Stellmacher who kindly agreed to spend time on our topic and to give us useful comments. We also thank Daniel Callo-Concha for the preparatory meetings which were very helpful in organizing our thoughts and our colleagues, who greatly helped us during the preparatory meetings and whose suggestions provided invaluable insights.

Acronyms and Abbreviations

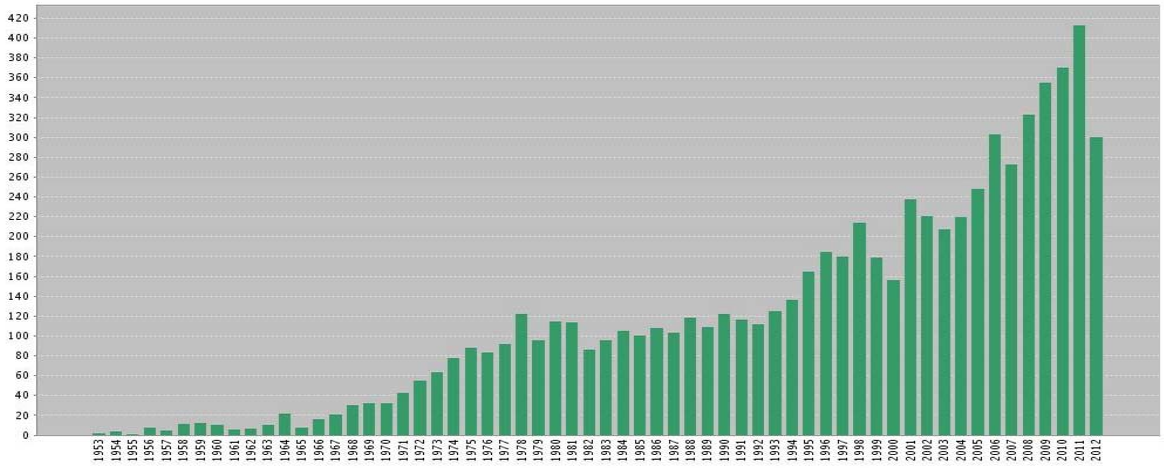
BMBF	German Ministry for Education and Research
CFIR	Committee on Facilitating Interdisciplinary Research
CoCE	Conservation and Use of the Wild Populations of Coffee Arabica in the Montane Rainforests of Ethiopia
CSF	Common Sampling Frame
DSS	Decision Support System
ECFF	Ethiopian Coffee Forest Forum
EIAR	Ethiopian Institute of Agricultural Research
GLOWA Volta	Global Change and Hydrological cycle in the Volta Basin
GVP	GLOWA Volta Project
IBC	Institute of Biodiversity Conservation
ID	Interdisciplinarity
IMK-IFU	Institute of Meteorology and Climate Research, Atmospheric Environmental Research
MD	Multidisciplinarity
OECD	Organisation for Economic Co-operation and Development
SHIFT Capoeira	Secondary Forests and Fallow Vegetation in the Agricultural Landscape of the Eastern Amazon Region
SP	Subproject
TD	Transdisciplinarity
ZEF	Center for Development Research

1. Introduction

Interdisciplinarity has been part of the academic and policy making discourse and practice for some decades now (Klein, 1990). The intention behind inter- and transdisciplinary research is often to improve the basic understanding of phenomena by means of an expanded viewpoint, to solve (complex and real-life) problems (Hirsch Hadorn et al., 2011), and critically reflect the work conducted by disciplines (Schön, 1983).

A quick search on an academic database[1] shows that the term was present in academic papers since at least the 1950s and that its usage has been steadily growing (see figure 1).

Figure 1: Search results for the term "interdisciplinary" in academic article titles between 1953 and 2012



Source: ISI Web of Knowledge, accessed on November 9th, 2012.

Despite its increasing popularity, there is no consensus on a definition of the term (Pohl et al., 2011). There is a general understanding that interdisciplinarity is related to the production of knowledge across the boundaries of traditional disciplines. More detailed and concrete definitions abound, but none of them is widely accepted by scholars and practitioners. As it will be discussed in more detail in section 2, the difficulties in reaching a consensus on the definition of the term stem from the fact that interdisciplinarity can take many shapes and include a wide array of interaction forms between scholars and

1 Figure 1 was generated though a search in the ISI Web of Knowledge, with the term "interdisciplinary" in the title field and a filter for "articles".

practitioners (Huutoniemi et al., 2009). One of the few broadly agreed upon distinctions is the one between multidisciplinarity, interdisciplinarity and transdisciplinarity (Klein, 1990), which will also be discussed in more detail in section 2.

Another issue that remains far from a consensus is the empirical analysis of research regarding interdisciplinary content. Criteria and procedures to identify and evaluate interdisciplinarity in actual research activities remain not widely accepted (Pohl et al., 2011; Haapasaari, 2012), despite the increased use of bibliometric studies (Rafols and Meyer, 2008) and a number of attempts at categorizations (Huutoniemi et al., 2010). The authors applied the typology of ID research proposed by Huutoniemi et al. (2010).

The Center for Development Research (ZEF) portrays itself as an interdisciplinary institute and makes efforts to ensure interdisciplinarity in its activities, to address complex and multi-causal issues of development. Since the start of its activities, in 1997, the Center has hosted a large number of projects, most of which with aims at producing interdisciplinary research. However, there has been to date no attempts to empirically analyze the wealth of information on interdisciplinary research produced by the ZEF. The latest report on ZEF activities, (Hemmer et al., 2010) discusses the extent to which interdisciplinarity is achieved in the Center. The report stated a predominance of discipline-specific publications at ZEF and recommended the improvement of interdisciplinary research (Hemmer et al. 2010, p.4). The weakness of the report is a missing framework through which interdisciplinarity can be identified.

For that reason, the authors of this paper believe that there is space for a more detailed analysis of interdisciplinary research practice at the ZEF. This paper aims at analyzing interdisciplinarity in selected ZEF projects based on a more concrete framework, with explicit, although still somewhat subjective, indicators and at discussing how characteristics[2] (successes, challenges, limitations, design, etc.) of the selected projects interact with their interdisciplinary scope, types and goals. It also aims at providing a contribution to ZEF's understanding and practice of interdisciplinarity in its research activities.

2 Characteristics as defined by the projects' documents and members themselves.

The paper is structured as follows: section 2 provides an overview of the key aspects of the current discussion on the concepts of interdisciplinarity, multidisciplinarity and transdisciplinarity. Section 3 presents the framework for the analysis of the three selected ZEF projects: SHIFT-Capoeira, CoCe and GLOWA Volta and briefly explain why it was chosen over other available approaches. In section 4, which is the core section of the paper, the analysis of the selected projects is carried out, according to the framework exposed on section 3. It also presents the criteria used for the selection of the projects. Section 5 provides a discussion of section 4's findings, focusing on the dimensions of interdisciplinarity identified in ZEF projects. It also presents the limitations of the conceptual framework and of the paper, as identified by the authors. The last section concludes the main aspects of the paper and provides suggestions on how the insights obtained could improve interdisciplinary research at ZEF.

2. Approaches and definitions of multi-, inter- and transdisciplinarity

In some interpretations, interdisciplinarity can be traced back to thinkers of past times, such as Aristotle, Kant and Da Vinci, whose ideas spread through a vast array of intellectual fields (Klein, 1990). Even closer to our own time, in the 19th century, some of the great scientists did not remain confined in a specific discipline. A good example is Charles Darwin. Widely known for his theory on the evolution of species, Darwin also published works in areas which today would be labelled as belonging to genetics, zoology, botanic, geology, archaeology and agronomy (Bryson, 2003).

The second half of the 19th century, however, witnessed a strong surge towards specialization of scientific knowledge. Many factors have been identified as relevant for the increase in specialization. Some authors identify internal aspects, such as the limitations in the cognitive capacities of researches to handle the increasing and cumulative amount scientific production, or the "crowding in an existing field" which "leads young scientists to develop a new specialty in an effort to secure rewarding employment" (Wray, 2005, p. 152). Other authors identify external factors, such as the industrial revolution, which demanded an increased amount of specialists, shifting the model of the scholar from the humanist or naturalist to the specialized professional researcher (Klein, 1990).

The increased specialization of science became even stronger throughout the 20th century and disciplinarity became dominant, despite some attempts to avoid the fragmentation of knowledge, well described by Klein (1990). From the 1960s, however, "interdisciplinarity has become a major topic in academic and policy oriented discourse on knowledge production and research funding" (Huutoniemi et al., 2010), due to a series of educational reforms promoting interdisciplinarity, which also stimulated the debate on the concept, and to the concern of international organizations, notably the OECD (Klein, 1990).

The main driving force towards the increased attention devoted to interdisciplinarity was the awareness that many problems faced by science are complex phenomena. The notion of *complexity*, according to Mollinga (2010, p. S-2) has a three-pronged meaning. *Ontological complexity* is related to the characteristics of complex and multidimensional phenomena, which have components and relationships behaving in a nonlinear and unpredictable manner. *Analytical complexity* means that complex phenomena cannot be properly studied by focusing solely on its individual parts and relations, as they cannot provide a comprehensive understanding of the phenomena. Interdisciplinary research would, thus, help solving problems that lay at the interfaces of disciplines (CFIR, 2005). Finally, *societal complexity* means that complex phenomena involve different groups of people with different and often conflicting interests. Other driving forces are the necessity for technological solutions to societal problems, which sometimes demand close collaboration between disciplines, and the creation of generative technologies, which stimulate increased connections between scholars and research processes (CFIR, 2005).

Due to the increased relevance of interdisciplinary research, there have been attempts to define and operationalize the term "interdisciplinarity", yielding a rich literature on the issue. This literature has developed a number of terminologies used to describe research that is done jointly by researchers from more than one discipline, but no consensual synthetic definition has been reached (CFIR, 2005; Petts et al., 2008). Despite this lack of consensus, distinctions between multidisciplinarity and interdisciplinarity and between interdisciplinarity and transdisciplinarity have been especially influential (Klein, 1990). The

very idea of having a strict definition has, however, also been put to question, as the terms are subject of a plurality of understandings (Huutoniemi et al., 2010; Pohl et al., 2011).

The first distinction to be explained is, therefore, between multidisciplinarity and interdisciplinarity. Multidisciplinarity is commonly understood as the type of research where investigators of different disciplines work on the same general problem, but focusing separately on different aspects of it, in a self-contained manner, reaching related but separate outputs. Their efforts are mutually supportive but additive, without cross-fertilization or synergies among disciplines or integrative theories and methods (Klein, 1990; Bruce et al., 2004; CFIR, 2005; Petts et al., 2008). It is important to notice that multidisciplinarity can yield beneficial results and should not be seen as failed interdisciplinarity (Petts et al., 2008). Interdisciplinarity, on the other hand, aims at integrating or even transcending disciplines (Huutoniemi et al., 2010), going beyond disciplinary understandings in response to stimuli from conjoined work, where scholars occupy spaces between disciplines (Petts et al., 2008). The final aim of interdisciplinarity is producing a "single, intellectually coherent entity" (Klein, 1990, p. 57) that integrates different fields of knowledge in "a holistic or systemic outcome" (Bruce et al., 2004, p. 459). It means, therefore, more than simply a group of researchers working together, maintaining their own disciplinary identities, but rather an effort to arrive at a synthesis of terminology, methods and/or theories, able to provide answers beyond the grasp of specific disciplines (CFIR, 2005).

Transdisciplinarity is another term related to interdisciplinarity but distinguished from it by some characteristics. While interdisciplinarity remains within the structure of academic institutions and parameters, transdisciplinarity takes into consideration the dimensions of knowledge produced by stakeholders and practitioners, emphasising the context-specificity of such knowledge and actively involving "different interest groups associated with a complex societal problem in the research process from the very beginning" (Mollinga, 2008, p.10).

3. How to analyse inter- and multidisciplinarity? The typology of Huutoniemi et al. (2010)

The openness of the conceptual debate resonates in the challenges of the empirical identification of interdisciplinarity in research activities (Pohl et al., 2011). Concretely identifying interdisciplinarity is seen by Huutoniemi et al. (2010) as the most glaring gap in the currently literature on the theme. Some researches try to bridge this gap by performing "bibliometric" studies of academic production. Such studies screen large samples of academic articles, making quantitative inferences based on the authors' academic affiliations, keywords and classification codes from different disciplines, the relation between papers' disciplinary categories and journals' disciplinary categories, and the relation between papers' disciplinary categories and the disciplinary categories of the references they cite (Bordons et al., 2005).

Bibliometric studies are interesting tools to provide rough maps of interdisciplinarity work in selected issue areas. However, they are not suitable for an analysis of the contents of interdisciplinary work and cannot capture the "multiple ways interdisciplinary interactions can be conceived and actualized" (Huutoniemi, 2010, p.80). Since the objective of this paper is a more specific discussion of the interdisciplinary interactions in selected ZEF projects, a qualitative analytical framework is necessary. For that reason, the paper will apply the framework provided by Huutoniemi et al. (2010) to analyse the interdisciplinary content of the selected ZEF projects.

The indicators of interdisciplinarity presented by Huutoniemi et al. (2010) are based on a literature review of existing indicators for interdisciplinarity research and on the development of new ones (Huutoniemi et al., 2010, p. 82). The framework uses the term "field"[3] instead of "discipline", to avoid intellectual and institutional connotations inherent to the term discipline and provides, therefore, the additive value that inter-, trans- and multidisciplinarity do not have to be further specified. Huutoniemi et al. (2010) focus on three dimensions: a) *what* is integrated (scope of interdisciplinarity), b) *how* it is integrated

[3] A "field" is a group of researchers with a shared set of questions or problems, focusing on a specific knowledge domain (Darden and Maull, 1977).

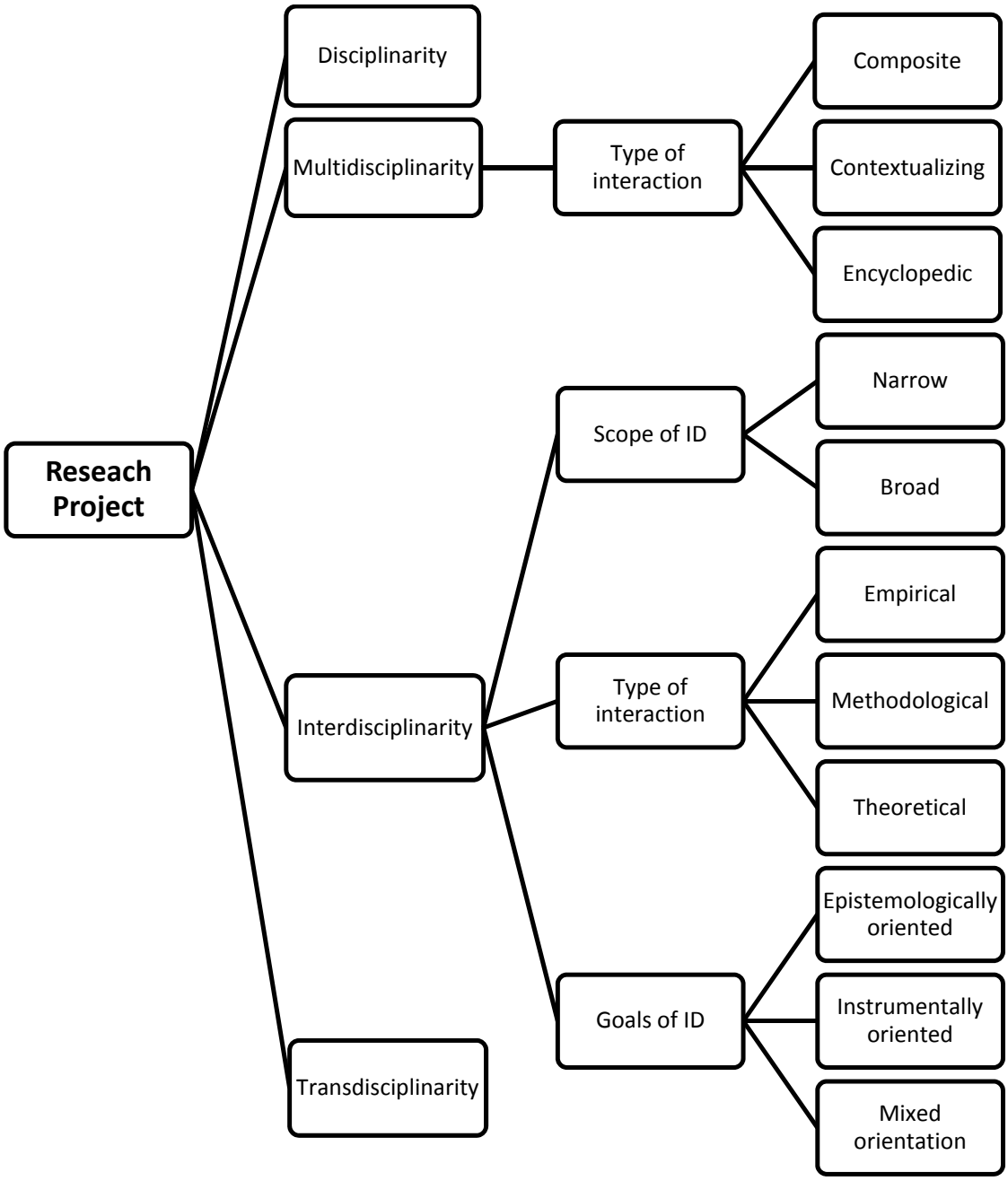
(type of interdisciplinary interaction) and c) *why* it is integrated (type of goal). Below, figure 2 illustrates the different categories.

The scope of interdisciplinarity relates to the conceptual distance between the members of a research project group, as defined by the field of research, for example biology. Researchers who work together in one field share the same structures of knowledge (theories, concepts, methodologies) and is, hence, not interdisciplinary. Researchers from conceptually closer backgrounds, such as biology and hydrology, are bound in a *narrow interdisciplinarity*. *Broad interdisciplinarity* occurs when researchers from distant fields, such as law and geology, work in the same research context. Broader disciplinarity tends to be more difficult to achieve due to larger differences in scientific paradigms, making consensus building more challenging.

The types of interdisciplinary interactions are subdivided by its epistemic components (e.g. theories, methodologies, empirical data exchange) and focuses on the distinction between multidisciplinarity (MD) and interdisciplinarity (ID). Transdisciplinarity (TD) is seen by Huutoniemi et al. (2010) as the operationalization of the interdisciplinarity concept and belongs to the instrumentally oriented interdisciplinarity, while this paper conceives transdisciplinarity as an extra component (see figure 2).

Encyclopedic multidisciplinarity occurs when there is no cognitive link between the disciplinary components of a research activity. *Contextualizing multidisciplinarity* is an interaction between the fields where knowledge from one field addresses the problem in another field. Interaction between the fields has, however, an informal character and scientific exchange beyond the problem setting is limited. *Composite multidisciplinarity* comes close to interdisciplinary components and is therefore difficult to identify. In composite multidisciplinarity, the knowledge of different fields is combined to create new knowledge. What makes the difference to interdisciplinarity is a rather “technical” than “dialogic” interaction between the fields. A technical interaction is reflected by providing scientific tools for another field without further linkages. Dialogic interaction, in turn, means a continuous exchange of knowledge, concepts, theories, methods and shared paradigms based on a constant process of communication, mutual understand and learning (Huutoniemi et al., 2010).

Figure 2: Modified sketch based on Huutoniemi et al. (2010)



Empirical interdisciplinarity focuses on the empirical data integrated in a joint manner, to reveal relations between phenomena, *methodological interdisciplinarity* looks at the different methodological approaches composed in a new way. Methods are not only taken from one discipline to be used in another innovative way, developed to fit into the interdisciplinary context. Related to methodological interdisciplinarity, the *theoretical*

interdisciplinarity merges concepts, models, and theories to develop new theoretical approaches.

The last dimension mentioned by Huutoniemi et al. (2010) is why interdisciplinarity is preferred instead of using disciplinary approaches - the type of goal. In *epistemologically oriented research* the different perspectives and methodologies should lead to a more comprehensive, overarching understanding on the object of research. For the second type of goal, *instrumentally oriented research*, interdisciplinarity is thought to be the key to solve social problems embedded in the complex environment of reality or to contribute to private industry and develop commercial products. Instrumentally oriented research is often related to goals outside the typical academic range. When a research project blends both goals, it is said to have a *mixed orientation*.

4. Appling Huutoniemi´s framework: Interdisciplinarity in selected projects of ZEF

The idea of analyzing projects conducted by ZEF and not issue areas or projects conducted in other institutions came up as it was clear that it would be much more feasible to acquire information on research activities by means beyond the simple analysis of project documents. Therefore, the authors performed informal interviews with former members of the projects that are still based in ZEF to gain additional insights into the projects and obtain information which would not have been mentioned in an official reports.

The criteria for selection were the leadership of ZEF in the research effort, previous knowledge of the authors about interdisciplinary or transdisciplinary elements in the projects and familiarity of the authors with the region and country where the projects were implemented.

4.1 Secondary Forests and Fallow Vegetation in the Agricultural Landscape of the Eastern Amazon Region (SHIFT-Capoeira)

The Secondary Forests and Fallow Vegetation in the Agricultural Landscape of the Eastern Amazon Region (SHIFT-Capoeira[4]) project was part of a broader research program from the German Ministry for Education and Research (BMBF), named Studies on Human Impact on Forests and Floodplains in the Tropics (which originates the acronym SHIFT). The broader program had four research areas in Brazil and the SHIFT-Capoeira project was located in the Northeastern part of the Amazon forest.

The SHIFT-Capoeira project aimed at developing alternatives to slash and burn agriculture by promoting the better use of secondary vegetation as a source of soil nutrients and organic matter, as well as maintaining or shortening the fallow period without shortening the productivity of the land (SHIFT, 1998). The project was divided in three phases: exploratory research (1991-1995), solution-oriented research (1995-1999) and implementation oriented research (1999-2003).

SHIFT- Capoeira Phase I

The main objective of the first phase was to provide a diagnostic of the physical and biological properties of fallow vegetation (biodiversity, biomass, regeneration) and systems (nutrient dynamics, soil properties). In this phase, the work was conducted mainly by vegetation and agricultural scientists. The planning phase did not have any conscious attempt to include ID or TD, which is understandable since the project started in 1991, at a time when ID was in much lower place in the academic agenda (Dr. Denich interview 11/13/2012, ZEF). In spite of that, it is possible to identify a connected background and objectives, even with a dispersed expertise and implementation. For that reason, the first phase can be placed in the contextualizing MD category, with a narrow scope, since the researchers came from close fields.

[4] Capoeira, in this context, is the name given in Brazil to low height secondary forest. This meaning is believed to precede the most known meaning of Capoeira as the traditional Brazilian dance/martial art. The project changed its name to "Tipitamba" in Brazil, but we'll keep the SHIFT-Capoeira name, as it is how the project is more commonly known at ZEF.

It is important to notice that during project implementation, the researchers notice the need to understand the behavior and motives of the farmers of the studied region. That required the work of social scientists. However, the work was not performed within the SHIFT-Capoeira project, but assigned to a completely different team of researchers working in different organizations with different Brazilian partners, in a separate project within the institutional umbrella of the SHIFT program.

SHIFT- Capoeira Phase II

The second phase was aimed at providing alternatives to the traditional slash and burn agricultural systems. The alternative under study was the use of a chopping and mulching treatment of fallow vegetation instead of burning to provide nutrients for the soil. The researchers knew that manually mulching the vegetation would be a very time consuming process, so they contacted agricultural engineers for the development of a tractor-driven chopper. The phase also added a new component to the project that dealt with the consequences of cattle ranching in the project region. The addition of new researchers in the context of the project was due to identified research and practice necessities, more than as a result of any previous planning. The addition of researchers from different fields broadened the scope of the project but the expertise was still dispersed, and it can still be placed in the contextualizing MD category. The second phase also witnessed the institutional move of the project's leadership to the ZEF.

SHIFT- Capoeira Phase III

The third phase was aimed at the field implementation of the results of the research. It performed tests on the chop and mulch technology and performed a financial analysis on how this technology would affect the farmers. The tests were done in actual farming lands and not in experimental testing sites, as the researchers believed the tests sites could be "contaminated" by residues of previous experiments, such as fertilizers in the soil. A team of economists worked within ZEF to perform the financial analysis, in what could be considered as a sub-project of the ZEF Capoeira. The project has also contacted a manufacturing company to scale up the production of the mechanic mulcher and hired local work to perform the projects field tasks.

The outcomes of the economists' team had empirical links to the work of the natural scientists, but no common methodologies or theories were jointly developed, as the groups tended to work quite separately. For that reason, the third phase was one of empirical ID, with a broad scope. The project also hinted some TD, as it involved non-academic partners. These partners, however, were more considered "hired labor" than project partners (Dr. Denich interview, 11/13/2012, ZEF).

Conclusion

The SHIFT-Capoeira project never had ID as an objective aim. The addition of researchers from different backgrounds came up as technical necessities of the project. The SHIFT-Capoeira's activities influenced the adoption of interdisciplinary activities in following ZEF projects. The project leader interviewed (Dr. Denich) affirmed that the addition of new disciplines was not part of a previously planned ID strategy, but came as a result of research necessities of the projects.

4.2 Conservation and Use of the Wild Populations of Coffee Arabica in the Montane Rainforests of Ethiopia (CoCE)

The research project was conducted in two phases in collaboration with: Institute of Biodiversity Conservation (IBC), Addis Ababa University, Ethiopian Institute of Agricultural Research (EIAR), GEO schützt den Regenwald e.V. and Amber Foundation. The entire duration of the project was from August 2002 – July 2009 and financed by BMBF and GEO schützt den Regenwald e.V. The first phase of the project was from August 2002 – July 2006 and its second phase was carried out from August 2006 – July 2009. The main objective of the project was to evaluate the diversity and economic value of the *Coffea arabica* in the montane rainforests of Ethiopia, based on the conservation of the natural forest and vice versa.

CoCE Phase I

The first phase of the CoCE project was subdivided into six subprojects and each team focused on their own works –these subprojects were structured along disciplinary basis. In the final report of the first phase, it was explicitly mentioned that the "investigation of wild

coffee populations in their comprehensive biodiversity context called for a multidisciplinary approach which considers natural sciences, economics and social sciences" (CoCE I, 2007, p.32). There was much effort at the beginning of the project to structure it in an interdisciplinary framework, but, it became more difficult to apply it at the ground due to various reasons[5].

The authors believed that the research project teams, which comprised different academic disciplines, could actually represent the same broad realm of scholarly works. There was also a considerable degree of relation among the subprojects by sharing findings and knowledge to inspire others and to show the progress of their works –for instance, regular workshops and symposiums to create a good platform in sharing and communicating ideas, especially during the first phase of the project. Though the general objective of all the subprojects were linked with a common research topic, the project was designed in separate work-packages, so that the disciplinary subprojects conduct their work rather separated from each other.

It could be argued that based on the Huutoniemi et al. (2010) framework, the first phase of the project could fit in the narrow ID category in terms of its scope. However, this was not the case, since each subprojects carried out their works separately using their own methodological frameworks –which were organized along disciplinary lines. In other words, different methodological approaches were not combined, and/or the subprojects did not share any common methodological frameworks. The subprojects from different fields were linked loosely by a general research topic which showed that the level of interaction among them was weak. This characterizes that the project was encyclopedic MD in its approach. Alternatively, when the goals of the project are analyzed, it was an instrumental oriented research. Hence, conserving the genetic of the wild coffee would solve the social problems which would result in developing commercial products that would also benefit the society at large.

[5] The ID approach was not successful due to the fact that it requires high transaction costs, longer time frame, and academic language problem between different disciplines. These entire problems could not be overcome within the give time frame work so that the whole package of the work was redesigned in a multidisciplinary framework (Dr. Denich interview, 11/13/2012, ZEF).

CoCE Phase II

The second phase of the research project (CoCE II) mainly focused on the implementation and communication of the results of CoCE I. Based on the first phase of the project, CoCE II was initially structured along disciplinary subprojects (SP) and stated a number of cross-cutting implementation targets in the project proposal SP 6.2 (CoCE II, 2010).

However, the CoCE II was challenging in finding an organizational structure and working procedures that helped integration of the research findings in the subprojects. It was not easy to bring the results of all the subprojects together in one umbrella that could potentially be further communicated and implemented effectively. To do so, two external research consultants were hired and, together with the whole project team, developed an approach to create the necessary integration, on the basis of either interdisciplinary or disciplinary research, in the related subprojects. The main task of theses consultants was to make sure that the research findings would not be lost and to bring the results together in a multi– and transdisciplinary framework, without neglecting the interdisciplinary and disciplinary demand in the subprojects. Moreover, "it was also an experiment on project level as new elements for integrative, inter-and transdisciplinary methodologies and techniques were tested and utilized" (CoCE II, 2010, p. 20). Integrating different types of empirical findings in order to further explain the dynamics and relationships between different disciplines developed the projects into empirical ID.

Communicating and externalizing the knowledge produced needed the participation of different interest groups and stakeholders for effective implementation. At the later stage of the project different interest groups were consulted and worked together to implement the research results. Therefore, the participation of some stakeholders in implementation stage of the research results displayed elements of a transdisciplinary research[6].

[6] The Final Report (2010) acknowledged that the implementation-orientation is more effective where there are tangible end user groups who have an interest in the project results and these target groups should be integrated in the projects work from the earliest point of time frame as early as possible. Because, Implementation-orientation requires integrative work from the very beginning and through all project phases, not just at the end of a project.

Since the findings and knowledge which were produced by the subprojects were communicated and externalized in a modularized way from one subproject to another, bypassing technical barriers. It implies that, to some extent, the project can fit in the composite MD category. As the report argued, integration of scientific results was not the final target, but the project used them for further research and model development on implementation, working with scientific results produced by the subprojects as well as by interdisciplinary working groups.

Analyzing the type of goals, or why ID came into play in the second phase, inclined the authors to categorize the project as one of mixed orientation ID. The argument is that the research project tried not only solving the social problems at large, but also worked to had a more profound scientific understanding of the area being investigated, which in turn aimed at more implementation-orientation in global change research.

Even though the project CoCE II was structured along disciplinary subprojects, the project proposal SP 6.2 stated a number of cross-cutting implementation targets by identifying eight implementation targets[7]. Based on this implementation target, the Ethiopian Coffee Forest Forum (ECFF) has been established, contributing to the sustainability of CoCE's research findings. The final report of CoCE II (2010) also suggested that this nongovernmental organization served as a bridge to disseminate and translate scientific results into actions.

Conclusion

The research project progressed and developed from a multidisciplinary to a transdisciplinary approach. Even though the idea of ID was conceived in the beginning of the research project, it was purely multidisciplinary in its approach. ID was not in practice in the ground at the first phase of the project. In the second phase, an interdisciplinary approach was still a challenge hence, "working in self-organizing interdisciplinary working groups was still too unfamiliar for most of the involved scientists - especially where team members are not located in the same building and not even the same country" (CoCE II, p.23). Moreover,

[7] Much emphasis was laid on the project progress towards the implementation targets the integration of inter –and transdisciplinary results. At this stage, this was assumed to be of greater interest for BMBF and other target groups (CoCE II, 2010).

the integrative work requires extra amounts of time and much attention for communication among the team members in working environments, daily work and during workshops and meetings. However, the integration of disciplines and individual work packages was successful especially where people work together at the same place and meet on regular basis.

4.3. Global Change and Hydrological cycle in the Volta Basin (GLOWA Volta)

The GLOWA Volta- Project has "fostered interdisciplinary work, both in the project itself and with its project partners, and replaced the non-integrated, mono-disciplinary approach commonly used" (GVP III, 2010, p. 178). The GLOWA Volta Project (GVP) has been conducted from 2000-2009 within three phases (May 2000-May 2003; June 2003 – May 2006; June 2006 – May 2009) and was funded by the BMBF. The primary objectives have been a) to conduct an analysis of physical and socio-economic factors of the hydrological cycle within the Volta Basin facing global and regional environmental change and b) to provide a Decision Support System (DSS) for the evaluation, sustainable use and development of the water resource in the Volta Basin and human, technical and institutional capacity building. The project started in Ghana in the first phase and has been extended to Burkina Faso in the second phase.

GLOWA Volta Phase I

For the first phase, it was important to collect data and to understand the interrelationships between water cycle, climate, and economic development. The proposal was submitted, besides ZEF, by the Department of Tropical Hygiene and Public Health of the University of Heidelberg and IMK-IFU[8] (Proposal GVP I, 1999). Scientists mainly from meteorology, hydrology, geography, agricultural science, economy and social science came together. The project was conducted within a dominating narrow interdisciplinary field of natural science. The disciplines worked in a conceptually closer environment than e.g. social science and engineering science would work together. The final report II mentioned that only a small number of experts contributed directly to the research agenda (GVP II, 2007, p.17) what

[8] IMK-IFU= Institute of Meteorology and Climate Research, Atmospheric Environmental Research

could give a hint to a disciplinary predominance in taking project-related decisions (Pohl et al., 2011). On the other hand, the effectiveness of a project would suffer from a huge interdisciplinary participation in consensus building.

The type of interdisciplinary interaction is difficult to describe according Huutoniemi et al. (2010). In phase I, the project structure showed the approach of interrelatedness. The framework was based on subprojects working with atmosphere modeling of land use change, water use optimization. Some of these SPs are connected with each other by integrating models or data providing. Some obviously interrelated SPs were not connected with each other such as the SP of health and socio-economic development. Clustering of research topics gives a hint to encyclopedic MD where the SPs from different disciplines are loosely linked by the main topic but work separately with their discipline-specific methodologies. Knowledge was produced in the specific problem setting of the subproject and banded research groups with same interests.

Within an interdisciplinary environment, disciplinary requirements had to be maintained in order to be scientifically acknowledged and accepted by a faculty, especially for doctoral students (Eguavoen, 2008). During GLOWA Volta, 81 students have been trained for master or doctoral thesis; consequently, research in GLOWA was constrained by disciplinary demand.

The attempt of data integration, contained an empirical interdisciplinarity to detect relationships between atmosphere, land use and water management. Different models, the Surface-Vegetation-Atmosphere-Transfer (SVAT) and the Land Use Dynamic Simulator (LUDAS) have been mentioned to integrate diverse data, which is an indicator of theoretical ID.

The common sampling frame (CSF) contributed to methodological ID although the specific data exchange by each SP was not explicitly described in the report. The big challenge was data providing in time and the high dependency of SP´s input/output. PhD students could not afford this insecurity of data receiving because they have been constrained by the three years of the ZEF doctoral program. Many doctoral students were from abroad and had time

limitations due to scholarship and visa deadlines. To reduce the risk of incompatible, missing data or delays in data delivering, well elaborated concepts of integration are essential. They, however, need a lot of time to be developed and accepted. The CSF facilitated data matching, data exchange and what kind of data was needed for the integrating models. Unfortunately, the CSF did not include questions of central interest for ethnography or were not scientifically sound from the disciplinary perspective of social science (Eguavoen, 2008). Another problem has been that science on household level was less relevant because the models were running mainly on regional level. In addition, the focus of integration was on a quantitative basis and the best integrating model will not be able to include and interpret all qualitative and quantitative data. As a consequence, qualitative social science on household level has been ignored (Eguavoen, 2008, p. 123). Other difficulties on the CSF will be explained in phase II.

The goal of GVP had a mixed epistemologically -instrumentally orientation. The epistemologically oriented research in GLOWA Volta is based on evidence and to understand the relationships between atmosphere, land and water in the Volta Basin. Complex interrelations between different factors could be more easily revealed and explained by taking into account different disciplines. In addition, social problems of water scarcity caused by climate variability and unequal distribution should be solved (instrumentally oriented research). Local participation increased in phase II; entering phase III with data and knowledge transfer to local authorities.

The final report of the first phase admitted the underestimation of time needed for professional coordination, for the development of joint and innovative methods and staff training at the beginning of the project (GVP I, 2003, p.89). In 2003, ID was seen as a new working condition. The different disciplines had different phases of research and analysis as well as different temporal and spatial examination levels. Some intercultural problems appeared. The high transaction costs of ID emerged by time consuming explanations and understanding of the other´s scientific background. Fast data editing and data preparation for non-experts was important for data processing and to gain new insights but, sometimes, misunderstandings could not be avoided. Communication problems happened because of necessary discipline-specific expert knowledge or different understanding of basic terms

such as sustainability and development. The clarification of central terms is essential before moving on with project activities and in GVP, the approach of clarifying terms was intentionally realized but took time.

GLOWA Volta Phase II

Phase II did not mention the interdisciplinary approach but a transdisciplinary focus (GVP II, 2007, p. 14). Local people have been trained for field assistance and have been informed about GVP and the DSS. With reference to section 2, TD is defined as the integration of local stakeholder in project development and in deciding about research structure and applied methods. This could not be revealed in the report although the GLOWA team as the setup of a local institution, the GLOWA Volta Authority (GVP II 2007, p.115) and was maybe seen as contribution to TD.

Phase II was process-oriented and data was tested and applied in numerical simulation models. Clustering in atmosphere, land and water use stayed the same but partly, new subprojects have been defined. The interdisciplinary splitting of some interdisciplinary and some disciplinary SPs was similar to phase I. For example, Multi-Agent System (MAS) modeling can be seen as an interdisciplinary model where beliefs, desires, and intentions of agents are transcribed into a matrix and their interaction with the environment computational represented. A more disciplinary WP, on the other side, is the SP of Institutional Analysis where only people from social science worked together. In general, scope, types, goals and challenges did not change although tendencies exist to a higher degree of empirical, methodological and theoretical ID. The number of interdisciplinary subprojects increased.

The phase was characterized by delays and discontinuities in several research activities due to high staff rotation, and a high share of PhDs from the first phase finalized their thesis in the second phase (GVP II, 2007, p.15). New staff members needed time to get familiar with the topic and had to be integrated into the ID community, which was time consuming, but they also provided inputs from other points of view and fresh motivation (Dr. Liebe phone interview, 12/11/2012). Surprisingly, in phase II, a common project database and problems in internal research documentation and data management was missing (GVP II, 2007, p.120).

In contrast, in phase I, the CSF and the shared database was mentioned as success. For clarification, Dr. Liebe, the coordinator of GLOWA phase III and doctoral student in the II phase revealed that the CSF worked as long as data had to be brought together. Over the long period of 9 years, it happened that a long-term arrangement, such as the CSF, was not compatible with later phases. Researchers at the beginning have not been the same people as at the end of the project and they were uncertain on what kinds of tools would be needed at the end. PhD students changed their focus to the disadvantage of the original proposal (Dr. Liebe phone interview, 11/12/2012).

GLOWA Volta Phase III

In phase III, the integration of former phase´s results, the aggregated economic analysis and the operationalization of DSS were the focus. Responsibilities should be transferred to the Volta Basin Authority, established in the beginning of phase III. Shortcomings in the second phase have been addressed in the third phase, e.g. the importance of transboundary governance of the water basin.

The report contained a new clustering of six high-order topics instead of the former three clusters; adapted more to the DSS. WPs of former phases were retrieved in other clusters. As a consequence of changes in project structure, some activities of phase I and II could not directly integrated and evaluated, and data was missed in phase III (GVP III, 2010, p.26). On the other hand, the DSS was not working at the end although it was one of the premises of BMBF. The term “Decision Support System” was seen as too blurry for the researchers. There was no description about operationalization of a DSS. There exists no unifying model which integrates all collected data. The DSS in GLOWA rather represented all models which have been used in the project and what kind of models were at disposal. Each cluster and some of its subprojects had their own data integration. Therefore, specific questions can be addressed by specific models, but an oracle giving the answer to all questions was not feasible. Noticing the number of functioning specific models data integration was successful. Strengthening human, institutional and technological capacity building has been a satisfying achievement (Dr. Liebe phone interview, 11/12/12).

Conclusion GLOWA Volta

There is a noticeable tendency from phase to phase that ID increased within the SPs. PhD topics included more, at least two, different disciplines. At the beginning, fundamental research was the premise to build up the data base for complex modeling. In this time, more disciplinary work had to be done. After basic research, data was available to be merged but after almost 9 years the project structure changed compared with the initial proposal. For this reason, GLOWA was restructured. "ID is only helpful where ID makes sense", means that the WPs do not need ID in any case (Dr. Liebe phone interview, 11/12/12). Disciplinarity is needed for basic research and basic research is needed to work interdisciplinary.

Table 1: Summary of the paper's findings

Scope	SHIFT	CoCe	GLOWA
Narrow ID	Phase I: vegetation scientists	Social Sciences, economics and natural sciences	Meteorology, hydrology, geography, agricultural science, economy and social science, IT
Broad ID	Phases II and III: inclusion of engineers and economists	-	-
Type of interaction			
encyclopedic MD	Phases I and II: connected background and objectives, dispersed expertise and implementation	The different subprojects were interlinked loosely by a general research topics	Phase I: Clustering of research topics in atmosphere (5 SPs), modeling of land use change (8 SPs) and water use optimization (6 SPs)
contextualizing MD	-	-	Subprojects bounded research group with same interest
composite MD	-	Phase II: scientific results and knowledge and communicated transferred from on subproject to another in a modularized way	Could not be identified
empirical ID	Phase III: outcomes of the economists' team had empirical links to the work of the natural scientists, but no common methodologies or theories were jointly developed,	Phase II: The research findings of each subprojects are integrated to solve an interdisciplinary research problem	Different empirical data is integrated to detect relationships between atmosphere, land use and water management
methodological ID	-	-	Joint framework, different models are integrating diverse data
theoretical ID	-	-	Integrated modeling, e.g. GV-LUDAS, M³WATER, CSF
Type of goals			
epistemologically oriented research	Phase I: diagnosis of physical and biological properties of fallow vegetation	-	To understand the relationships between atmosphere, land and water in the Volta Basin.
instrumentally	-	Phase II: working with local	Address social problems of

oriented research		interest groups for implementation of the research results	water scarcity in the region and develop a GLOWA Volta Authority
mixed orientation	Phases II and III: research on solutions and implementation.	Both instrumentally and epistemologically oriented research is mainly observed in Phase II.	Epistemologically and instrumentally oriented research is represented

5. Is Interdisciplinarity measurable? Discussion of ZEF´s projects and Huutoniemi´s framework

In the following two subsections, the authors critically reflect on the findings of the previous session and on its relations to the ZEF context, and present weaknesses identified in the use of the framework of Huutoniemi et al. (2010).

5.1 Discussion of the interdisciplinary character of the selected projects

In the analysis of the project's documentation and the information collected in the interviews a clear move towards increasing interdisciplinarity has been detected. Such move was identified within the structure of the projects and, as a consequence, also temporally in ZEF activities. All three projects moved towards an increased amount of integration in their contexts, be it for the realization that additional expertise was needed or because the projects have been planned in a logical structure that required exploratory (and disciplinary) work in the initial stages, but attempts at a more holistic approach to the problems in hands. As an example of a temporal move towards interdisciplinarity, the paper identified that the encyclopedic multidisciplinary experiences from the SHIFT-Capoeira project was one of the factors that lead future projects, such as the GVP and the CoCE projects, to take into consideration the importance of integrating disciplines. Such move towards interdisciplinarity, however, did not take place in a smooth road, and yielded valuable reflections, which are discussed below.

Some of the issues concerning the move towards increased interdisciplinarity relate directly to the process of academic work. One of the main difficulties with interdisciplinary work was the integration between researchers who rely on quantitative data and those who rely on qualitative data. This difficulty is a driving force behind the challenges in achieving

methodological interdisciplinarity, which is perceived as key challenge for research in the ZEF (Dr. Hornidge interview, 11/13/2012, ZEF). Adding to this challenge is the fact that there are no researchers in the ZEF staff who are specialized in quantitative methods in social sciences (Dr. Liebe phone interview, 11/12/2012). Data management was also a challenge for the projects, all large and diverse, especially when the structure of the work packages makes them dependent upon each other. Finally, the GVP and CoCE projects had interdisciplinary aims from the planning phase, but a lack of theoretical thinking about interdisciplinarity before the project's operationalization was identified, a phenomenon that is perceived as permeating other projects in the ZEF (Dr. Hornidge interview, 11/13/2012, ZEF).

Institutional structures, internal and external to the ZEF were also identified as relevant. The projects specifically and ZEF in general experience a high rate of staff turnover, and incoming staff tend to come from institutions that do not regard interdisciplinarity so highly. For that reason, constant learning is required for the new staff to internalize interdisciplinarity in their research. The dual role of the ZEF as a research and training organization also increases the challenges for interdisciplinary work. This is due to the fact that the addition of PhD students requires following the disciplinary lines of faculties, which did not always integrate smoothly with the projects' interdisciplinary ambitions, and because publication outlets also follow disciplinary lines. An additional factor is the requirements of funding agencies, which have, in recent years, started to hold interdisciplinarity *per se* as a precondition for a successful project application. While this can be seen as a laudable initiative, funders tend to neglect the difficulties in bringing different disciplines together, and they also do not give any instructions about the operationalization of interdisciplinary research (BMBF, 2012).

The importance of the human element, relating to individual cognition and to interpersonal relations, have also been deemed important. The move towards interdisciplinarity is seen as a cognitive barrier, to a large extent because of the disciplinary training and background of researchers. It is difficult to dominate the communicative, organizational and adaptive capacity of interdisciplinarity together with the disciplinary knowledge that is mandatory for research. Project experiences also demonstrated that the respect for different types of expertise and the acknowledgment of the importance of the work of diverse fields are key for interdisciplinary endeavors (Dr. Hornidge interview, 11/13/2012, ZEF).

5.2 Limitations of Huutoniemi´s Approach

The major limitation of Huutoniemi et al.'s approach is the lack of clearer tools to locate project within their categories. The indicators developed by the authors many times still leave room for the subjective understanding of those using their framework. For example, the distinction between the methodological and theoretical interdisciplinarity types was difficult, as both categories overlap. The lack of clarity can be attributed to the normal ambiguity in the interdisciplinarity debate or to the fact that it was initially developed for the analysis of research proposals, but the framework would profit from more empirical clarity.

Another clear limitation is the lack of clarity in the notion of "field". The authors use the term to avoid pitfalls in the use of "discipline", but fail to present a more specific definition of "field". They to some extent justify that by saying, truthfully, that lines between fields are fluid. Two options to improve this aspect of the framework would be, on the one hand, a stronger theorization on the meaning of "field" or, on the other hand, a stricter categorization of fields, which would be unavoidably arbitrary but would increase the conceptual density of the framework.

It is worth noticing that, despite these limitations, the framework has the merit of guiding research into a broader understanding of interdisciplinarity, viewed here as a multidimensional phenomenon, with distinctive characteristics in different elements of research activities. The framework shifts the effort to identify interdisciplinarity from a simple "yes or no" question into an analysis of the process of interdisciplinary work.

5.3 Limitations of the term paper

This subsection deals with the limitations identified by the authors in the production of the paper. The first limitation regards the selection of the projects. The selection did not take into consideration a possible diversity in the leading field of the projects, as the three projects were more strongly connected to staff belonging to ZEFc. During the preparation of the paper, it became clear that more interesting information could arise from a more diverse selection.

Access to information has also been a limitation experienced by the authors. The bulk of the information used has been drawn from written reports on the subject, which cannot provide all information required for the type of analysis performed here. For example, not all work packages of a large project such as the GVP can be represented in final report. This could be mitigated to some extent by the personal interviews with researchers involved in the projects, but that was also limited by the willingness of the interviewed people to provide information and by their temporal distance to project activities.

The authors could not access all reports, proposals and other meaningful documents that could have yielded more empirical density to the research. The authors also had different amounts of available information on each project, mainly based on final reports, which hindered a more thorough comparative analysis[9]. The lack of institutional memory on completed projects has, therefore, been a major barrier to this paper. In addition, many reports were only available, or had relevant parts, written in German, which can also be considered an institutional memory problem in a center where many researchers do not have a high level of proficiency in the language.

Time constraints played an important role in defining how the writing of the paper was carried out. To reduce the intrinsic subjectivity of the analysis of the projects, the initial idea was to cross-check the information on the projects by the three authors, but that was not manageable due to the limited time available. Carrying out a more extended literature review on the central concepts of the paper was also not possible.

6. Conclusion

This paper is a time limited attempt at providing a contribution, with selected projects, to the debate on interdisciplinarity at ZEF. The paper shows that clear lines between inter-,

[9] Analyzing the proposals of the research project would likely give detailed information about how each subproject develops their theoretical frameworks and methodological approaches. That would be much helpful to identify the degree of relationships and interactions among the different disciplines. It also would have enabled us to track change along the course of the research works –what has been added or reduced during the implementation of the projects.

multi- and transdisciplinarity cannot be easily drawn. There is still enough space for interpretation and discussion, for example where interdisciplinarity starts and multidisciplinarity ends or which research field is meant by a discipline. New hybrid disciplines, which would have been seen as different disciplines in the past[10], are an example of possible transitions between academic categories.

The framework of Huutoniemi et al. (2010) gives a hint on how to focus on different types and dimensions of interdisciplinarity from a more empirical basis. The ongoing theoretical debate on how to foster interdisciplinarity at ZEF's research activities could greatly benefit from a more empirically-based discussion, conducted by specialists on the theme, on how projects have handled increasing demands to do interdisciplinary research.

Besides the high input of human, social and economical resources for interdisciplinary research, the scientists, and even more the donors, have to reflect upon the need for interdisciplinary work within the specific context. Scientific specialists are necessary to find specific answers to specific questions, which cannot be solved by a generalist, but interdisciplinarity is a key to find solutions behind man-made boundaries.

ZEF is a hotspot of different cultures, different disciplines and different personalities. The concept is unique – disciplinary knowledge building can be combined with interdisciplinary information sharing which is also represented in the projects. There is an attempt to improve scientific collaboration within and between the disciplines but ZEF´s institutional composition and the structure of the building hinders communication across physical and psychological boundaries. Doors between the floors, doors between the offices, doors between seniors and juniors, and doors between the departments -- doors have to be opened with much effort and closed just as fast. But once the challenge to open the door is accepted, it might prove a worthwhile effort.

[10] For example, landscape ecology originated almost 15 years ago from a combination of biology and geosciences and is today an own research area.

References

Bundesministrium für Bildung und Forschung (BMBF) (2012): homepage, announcement of funding purpose, http://www.bmbf.de/foerderungen/20472.php, accessed 11/15/2012

Bordons, M., Morillo, F., and Gomez, I. (2005): Analysis of Cross-Disciplinary Research through Bibliometric Tools. In: Glänzel, Wolfgang and Schmoch, Ulrich (Edts.) (2005): Handbook of Quantitative Science and Technology Research: The Use of Publication and Patent Statistics in Studies of S&T Systems. Dordrecht, Kluwer Academic Publishers.

Bruce, A., Lyall, C., Tait, J., and Williams, R. (2004): Interdisciplinary integration in Europe: the case of the Fifth Framework programme. *Futures* 36: 457–470.

Bryson, B. (2003): A short history of nearly everything. London, Transworld Publishers

Committee on Facilitating Interdisciplinary Research (CFIR), National Academy of Sciences, National Academy of Engineering, Institute of Medicine (2005): Facilitating Interdisciplinary Research, The National Academies Press, Washington, D.C., USA, 332 pages.

CoCE I (2007): Schutz und Nutzung der Wildpopulationen von *Coffea arabica* in der Bergregenwäldern Äthiopiens/ Conservation and Use of Wild Populations of *Coffea arabica* in the Montane Rainforests of Ethiopia (CoCe), Phase I Final Report, Center for Development Research, Center for Development Research, Rheinische Friedrich-Wilhelms-Universität Bonn, and Ethiopian Institute of Agricultural Research (EIAR), Addis Ababa, Ethiopia.

CoCE II (2010): Schutz und Nutzung der Wildpopulationen von *Coffea arabica* in der Bergregenwäldern Äthiopiens/ Conservation and Use of Wild Populations of *Coffea arabica* in the Montane Rainforests of Ethiopia (CoCe), Phase II Final Report, Center for Development Research, Center for Development Research, Rheinische Friedrich-Wilhelms-Universität Bonn, Germany.

Darden, L., and Maull, N. (1977): Interfield Theories, *Philosophy of Science* 44: 43-64.

Eguavoen, I. (2008): Knowledge Resources (Yet) Untapped. The challenges of finding one´s place in an interdisciplinary water project on the Volta River basin, West Africa. In: Caleb R.L. Wall, Peter P. Mollinga (Eds.) 2008: Fieldwork in Difficult Environments: Methodology as Boundary Work in Development Research.

Hemmer, H.-R., Hurni, H., and Soeffner, H. -G. (2010): The Center for Development Research (ZEF), University of Bonn – Report of the Evaluation Team.

Hirsch Hadorn, G., Schmied, B., and Frischknecht, P. (2011): Transdisciplinary elements in university education: the case of the environmental science programme at ETH Zurich. In: La transdisciplinarité. Pourquoi, comment, où? (Ed C. Debru). Paris: Editions Hermann.

Huutoniemi, K., Klein, J., Bruun, H., and Hukkinen, J. (2010): Analyzing interdisciplinarity: Typology and indicators. *Research Policy* 39: 79–88.

GVP I Proposal (1999): Sustainable Water Use under Changing Land Use, Rainfall Reliability and Water Demands in the Volta Basin, Center for Development Research, Rheinische Friedrich-Wilhelms-Universität Bonn, Germany.

GVP I (2003): GLOWA Volta Phase I Abschlussbericht May 2000-May 2003 (German), Zentrum für Fernerkundung und Landoberfläche (ZFL), Rheinische Friedrich-Wilhelms-Universität Bonn, Germany.

GVP II (2007): GLOWA Volta Phase II completion report, Report period: 01.06.2003 – 30.05.2006, Charles Rodgers, Paul L.G. Vlek, Irit Eguavoen and Claudia Arntz (Eds.), Center for Development Research, Rheinische Friedrich-Wilhelms-Universität Bonn, Germany.

GVP III (2010): GLOWA Volta Phase III completion report; Report period: 01.06.2006 – 31.05.2009, Jens Liebe, Claudia Arntz and Paul L.G. Vlek (Eds.), Center for Development Research, Rheinische Friedrich-Wilhelms-Universität Bonn, Germany

Klein, J. (1990): Interdisciplinarity: History, theory and practice. Detroit, Wayne State University Press.

SHIFT (1998): Proceedings of the Third SHIFT Workshop, Reinhard Lieberei, Helmut Bianchi, and Karsten Voss, Manaus, Brazil.

Mollinga, P. (2008): The rational organization of dissent: Boundary concepts, boundary objects and boundary settings in the interdisciplinary study of natural resources management. Working Paper Series 33. Center for Development Research, Rheinische Friedrich-Wilhelms-Universität Bonn, Germany.

Mollinga, P. (2010): Boundary Work and the Complexity of Natural Resources Management. *Crop Science* 50:1-9.

Petts, J., Owens, S., and Bulkeley, H. (2008): Crossing boundaries: Interdisciplinarity in the context of urban environments. *Geoforum* 39: 593–601.

Pohl, C., Perrig-Chiello, P., Butz, B., Hirsch Hadorn, G., Joye, D., Lawrence, R., Nentwich, M., Paulsen, T. Rossini, M., Truffer, B., Wastl-Walter, D., Wiesmann, U.,and Zinsstag, J. (2011): Questions to evaluate inter- and transdisciplinary research proposals. Working paper, td-net for Transdisciplinary Research, Berne.

Schön, D. (1983): The Reflective Practitioner - How Professionals Think in Action. Aldershot, Hunts: Ashgate.

Wray, K. (2005): Rethinking Scientific Specialization. *Social Studies of Science* 35(1): 151-164.