Assessing Ten Years of Inter- and Transdisciplinary Research, Education, and Outreach

The Competence Center Environment and Sustainability (CCES) of the ETH Domain

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Abstract
Research centers have emerged as organizational structures to meet the manifold expectations raised towards sustainability science, a field characterized by high levels of inter- and transdisciplinarity. In this article, we assess the impact of the Competence Center Environment and Sustainability (CCES) of the ETH Domain. Encompassing more than 800 participants from six research institutions in Switzerland, the research center has been in operation for ten years (2006 to 2016). Focusing on its three areas of activity – research, education, and outreach – we analyze which decisions have influenced the development and legacy of CCES. We formulate five recommendations, which could prove useful for the future design and evaluation of comparable enterprises. Finally, we conclude that the academic incentive and reward system has to open up for inter- and transdisciplinarity.

Keywords
competence center, environmental science, impact assessment, inter- and transdisciplinary research, program evaluation, project evaluation, research center, sustainability science
The Competence Center Environment and Sustainability (CCES) of the ETH Domain

Under the direct supervision of the Swiss Federal Council and the Parliament, the ETH Board, the strategic management body of the ETH Domain, established four inter- and transdisciplinary research centers in 2006 and provided funds for an operation of ten years (two phases: 2006 to 2010 and 2011 to 2016). One of the four so-called competence centers was the CCES, with the mission to “identify the relevant questions and the appropriate answers to foster the sustainable development of our future society while minimizing the impact on the environment” (CCES 2005, p. 1). This was to be accomplished within the scope of three areas of activity: research, education, and outreach.1

Organization, Thematic Definition, and Review Process

Three governance bodies were established:

- a Steering Board, consisting of the leaders of the main participating institutions, which was responsible for the overall strategy and planning, the allocation of resources, and the scientific and institutional profile of CCES;
- a Management Board, consisting of senior researchers, responsible for defining the thematic areas as well as acquiring and prescreening submitted research proposals;
- an Executive Office with an Executive Manager. Located at the leading house ETH Zurich, the Executive Manager was in charge of the administrative and financial functioning of the center.

As it turned out in the early phase of CCES, there were striking conflicts of interest associated to the Management Board, as some of its members had envisaged submitting a project proposal themselves. Consequently, the Management Board was dissolved once it had defined the thematic scope (table 1, p. 228), replacing it with a Delegate of the Steering Board.

Launched in early 2006, the call for proposals attracted 24 submissions. This number was quite considerable in light of two constraining factors: first, the proposals were required to be drafted by researchers from at least three of the six participating institutions, which, in many cases, meant that cooperation had to be initiated between researchers who had not previously known each other. And second, many of those researchers had little to no prior experience in drafting inter- or transdisciplinary research proposals.

For the evaluation of the proposals, an ad hoc Research Council consisting of members of the ETH Zurich research commission complemented by researchers from EPFL, Eawag, and WSL was established. All proposals were sent out for review, which turned out to be a rather intricate endeavor due to the unavailability of enough independent experts capable of evaluating inter- and transdisciplinary projects. This led to an unsatisfactory review process, which was in turn heavily criticized by the applicants. Finally, the Research Council recommended the Steering Board to fund 18 of the 24 projects in the first phase (2006 to 2010) (table 1).

Because of these negative experiences, the Steering Board appointed an international Advisory Board composed of eight highly regarded academics and of one industry representative. The Advisory Board was tasked to continuously evaluate the progress made within CCES and to select the projects that qualified for the second phase (2011 to 2016), for which the ETH Board had provided half of the funds of the first phase. On the basis of written proposals, presentations, and interviews, the Advisory Board recommended eight projects (see table 1).

CCES in Numbers

More than 800 people from all six ETH Domain institutions were involved in CCES: roughly 300 professors and senior researchers, about 200 PhD students and postdocs, while the remaining participants included Master students, project engineers, technicians, laboratory, and administrative support staff. About one fifth of the overall CCES Community members were female, with a lower share on the level of principal investigators and project partners (14 percent). The overall CCES budget provided by the ETH Board was CHF 45 million of which 30 million were spent during the first phase, and 15 million during the second. Funds had to be “matched” at least by an equivalent of institutional in-kind funding and additional external third-party funds. The overall funding volume added up to about CHF 130 million. Performance indicators of the CCES activities are summarized in table 2 (p. 229).

Evaluation and Impact Assessment

As publicly funded research is becoming subject to ever more intensive accountability (Martin 2011), evidence-based evaluation is gaining more and more relevance. But while methods for the assessment of departments or individual researchers are well established, evaluations of whole research centers raise new questions. Existing approaches, especially quantitative ones, lack the capacity to capture some of the core characteristics of research centers and their participants, like their diversity (Kassab et al. submitted). On the other hand, purely qualitative evaluation approaches generally come with the advantage of scrutiny at the expense of time and generalizability (Bornmann 2013, Newcomer et al. 2015).

1 The ETH Domain comprises the two Federal Institutes of Technology in Zurich (ETH Zurich) and Lausanne (EPFL), as well as four research institutes: the Paul Scherrer Institute (PSI), the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), the Swiss Federal Laboratories for Materials Science and Technology (Empa), and the Swiss Federal Institute of Aquatic Science and Technology (Eawag).

2 The themes of the other three centers were: Energy and Mobility (CCEM), Materials Science and Technology (CCMX), Biomedical Imaging (NCCBI).

3 The concept of “outreach” here is understood in the sense of “popularization” (Jensen et al. 2008), as activities done by researchers aiming at the non-specialized public. The information flow is one-way and there is no involvement of the public per se in the sense that public feedback is not required or specifically sought (Rowe and Frewer 2005, p. 255). Table 2 (p. 229) summarizes these activities as documented in the annual reports.
Besides, research centers typically perform not just research, but also training or active knowledge transfer into society (outreach). The wide spectrum of activities has immense implications when it comes to impact assessment. While there are somewhat established measures for the assessment of scientific impact (mainly through bibliometric indicators), a huge debate is held over how to capture the "societal impact" of research (impact that transcends the ecosystem of academia, i.e., into society or industry) in a scientifically meaningful way (Etzkowitz and Leydesdorff 2000, Gray et al. 2001, Spaapen and Van Drooge 2011, Bornmann 2013). Despite some advances including policy document analysis, or social media readership, there is by far no consensus yet among scholars and policy makers (Van der Weijden et al. 2012, Piwowar 2013, Wiek et al. 2014, LERU 2017).

**TABLE 1: Overview of the 18 CCES projects. They cover the five thematic areas climate change, food, natural hazards, natural resources, sustainable land use as well as a data management platform. Projects indicated with (*) have received funding for both phases of CCES (phase 1: 2006 to 2010, phase 2: 2011 to 2016). An overview with more detailed descriptions of the individual projects is available online: [https://www.oekom.de/supplementary-files.html#c12531](https://www.oekom.de/supplementary-files.html#c12531).**

<table>
<thead>
<tr>
<th>EDUCATION AND RESEARCH UNIT (ERU)/RESEARCH PLATFORM</th>
<th>PROJECT ACRONYM/INSTITUTIONAL PARTICIPATION (affiliation of principal investigator named first)</th>
<th>PROJECT SYNOPSIS</th>
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<tr>
<td><strong>CLENCH – Climate and Environmental Change</strong>&lt;br&gt;www.cces.ethz.ch/research/clench</td>
<td>BigLink&lt;br&gt;ETH Zurich, WSL</td>
<td>biosphere-geosphere interactions: linking climate change, weathering, soil formation and ecosystem evolution</td>
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<td><strong>BioChange</strong>&lt;br&gt;Eawag, ETH Zurich, WSL</td>
<td>genetic diversity, contemporary evolution and the maintenance of biodiversity in changing alpine environments</td>
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<td><strong>ClimPol</strong>&lt;br&gt;ETH Zurich, EPFL, Eawag</td>
<td>climate policy making for enhanced technological and institutional innovations</td>
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<tr>
<td><strong>OPTIWARES</strong>&lt;br&gt;PSI, ETH Zurich, Empa</td>
<td>optimization of the use of wood as a renewable energy source</td>
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<tr>
<td><strong>MAIOLICA</strong>&lt;br&gt;ETH Zurich, EPFL, Eawag, WSL, Empa</td>
<td>modelling and experiments on land-surface interactions with atmospheric chemistry and climate</td>
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<tr>
<td><strong>FEH – Food, Environment and Health</strong>&lt;br&gt;www.cces.ethz.ch/research/feh</td>
<td>BactFlow&lt;br&gt;ETH Zurich, EPFL, Eawag</td>
<td>impact of environmental “stealth” pathogens on food safety and human health</td>
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<td><strong>GEDIHAP</strong>&lt;br&gt;WSL, ETH Zurich, Eawag</td>
<td>role of genetic diversity in host-pathogen interactions in dynamic environments</td>
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<td><strong>HazRi – Natural Hazards and Risks</strong>&lt;br&gt;www.cces.ethz.ch/research/hazri</td>
<td>APUNCH&lt;br&gt;ETH Zurich, EPFL, WSL</td>
<td>advanced process understanding and prediction of hydrological extremes and complex hazards</td>
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<td><strong>COGEAR</strong>&lt;br&gt;ETH Zurich, EPFL</td>
<td>coupled seismogenic geohazards in Alpine regions</td>
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<tr>
<td><strong>EXTREMES</strong>&lt;br&gt;EPFL, ETH Zurich, WSL</td>
<td>spatial extremes and environmental sustainability: statistical methods and applications in geophysics and the environment</td>
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<tr>
<td><strong>TRAMM</strong>&lt;br&gt;WSL, ETH Zurich, EPFL</td>
<td>triggering of rapid mass movements in steep terrain</td>
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<td><strong>NatuRe – Natural Resources</strong>&lt;br&gt;www.cces.ethz.ch/research/nature</td>
<td>ADAPT&lt;br&gt;ETH Zurich, Eawag, EPFL</td>
<td>adapt planning and operation of large dams to social needs and environmental constraints: integrated water resource management study in the Zambezi Basin</td>
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<td><strong>CARMA</strong>&lt;br&gt;ETH Zurich, EPFL, PSI</td>
<td>carbon management in power generation</td>
<td></td>
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<tr>
<td><strong>GEOTHERM</strong>&lt;br&gt;ETH Zurich, EPFL, PSI</td>
<td>geothermal reservoir processes: research towards the creation and sustainable use of enhanced geothermal systems</td>
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<tr>
<td><strong>RECORD Catchment</strong>&lt;br&gt;Eawag, ETH Zurich, WSL, EPFL</td>
<td>coupled ecological, hydrological and social dynamics in restored and channelized corridors of a river at the catchment scale</td>
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<td><strong>SuLu – Sustainable Land Use</strong>&lt;br&gt;www.cces.ethz.ch/research/sulu</td>
<td>GeneMig&lt;br&gt;WSL, ETH Zurich, EPFL, Eawag</td>
<td>genetic variation and species migration under environmental change: views of science, environmental management, and the general public</td>
</tr>
<tr>
<td><strong>MOUNTLAND</strong>&lt;br&gt;WSL, ETH Zurich, EPFL</td>
<td>prioritization for adaption to climate and socio-economic changes – backcasting tolerable future states to match supply and demand for ecosystem services in mountainous areas</td>
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<tr>
<td><strong>Research Platform</strong>&lt;br&gt;www.cces.ethz.ch/research/platforms</td>
<td>Swiss Experiment&lt;br&gt;WSL, EPFL, ETH Zurich, Eawag</td>
<td>the Swiss Experiment interdisciplinary data management platform</td>
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Our Approach to Research Center Evaluation

Given the complexity of research centers and the breadth of their impact, we propose a case study approach using mixed methods to assess the phenomenon in depth. Aligning our approach to the practice of program evaluation (Newcomer et al. 2015), we understand the evaluation of a research center, borrowing from Patton (1997, p. 23), as a systematic collection of information about the context, resources, processes, outputs and impacts to make judgements about the research center, its effectiveness, and inform decision-making (Carew and Wickson 2010, Madrillon Group 2010).

The overall context and which resources have been mobilized in the case of CCES have been described above. Our approach therefore evaluates the process, output, and impact (Van Drooge and Spaanpen 2017, Holzer et al. 2018). When speaking of process, we refer to the activities integral to the work at the research center, including the problem definition, the design of the research strategy, data collection, knowledge production, teamwork, networking, discussion, and synthesis (Talwar et al. 2011, Holzer et al. 2018). Output, in turn, is defined as tangible products resulting from the process, such as scientific publications, PhD theses, conferences, press articles, or public information events. And lastly, impact is understood as the “net effect” of the research center on the scientific community or society (Rossi et al. 2003, Link and Vonortas 2013). The evaluation should be concerned with both direct and indirect, but also with intended and unintended impacts, especially as the latter tend to be systematically disregarded in a “tunnel view” (Stockmann and Meyer 2014).

The following is structured along the three areas of activity of CCES: research, education, and outreach. The scope of the evaluation is defined with view on the five CCES goals as stated in the research center’s business plan (CCES 2005, p.1) and summarized in table 3 (p. 230). To also capture the organizational structure of CCES, we distinguish between two groups of actors: 1. the CCES Management, consisting of the Executive Office, the Steering Board, the Delegate of the Steering Board, and the Advisory Board, and 2. the members of the CCES Community on the project level, mainly represented by the principal investigators and the leading project partners. Our mixed methods approach is based on the document analysis of archival data (about 100 annual project reports), the synthesis of expert reports (by the Advisory Board), ten semi-structured interviews with principal investigators and project coordinators, and a comprehensive bibliometric analysis.

Research

I think it was CCES that kind of turned us into environmental scientists. [...] Before that, we have been ecologists, and bio-geochemists, and so on, but [...] for the very first time, we stopped being a collection of disciplines, and that was a big effect.

Senior CCES participant

CCES Management

Process: The CCES Management was primarily involved in managing financial resources and reviewing the annual reporting. At the same time, it also tried to increase the coherence among the CCES Community by organizing field excursions or scientific conferences (goal 3). However, the success was rather moderate. The projects remained quite isolated, and if at all, there were links within the five thematic areas due to the multiple role of researchers, institutional ties, or academic proximity. Even though CCES has surely contributed significantly to the densification of the inter-institutional network within the ETH Domain, we note that some of the participants saw it primarily as “yet another funding source”.

Output: In view of the overall output generated at CCES (table 2), the targeted funding of environmental and sustainability science has indeed led to advancements in the area (goal 1). Likewise, it contributed to the national and international visibility of researchers and their respective institutions (goal 2).

Impact: CCES facilitated research that could not have been carried out by a single ETH Domain institution alone. Principle investigators praised CCES for having “catalyzed the scientific process” (goal 1). Despite the initial reservation, numerous leading researchers devoted a considerable amount of their time to inter- and even transdisciplinary research. Beyond the financial contributions by CCES, the opportunity to “widen individual networks” was identified as a major driver. And as is evident by the newly stimulated research beyond CCES (e.g., in the context of EU funded projects), the return on investment has been reached and exceeded (goal 1).
CCES Community (Examples)

Process: Hardly any of the researchers involved in the TRAMM project had known each other before CCES. While at the beginning it was a great challenge even to decide on common terminology, it was the early implementation of joint field experiments that triggered “key experiences” conducive to the team cohesion process (goal 3). The project furthermore benefited from the close collaboration with the association Fachleute Naturgefahren FAN (Swiss Practitioners in Natural Hazards), an established expert community that supported the identification and involvement of key stakeholders. The MOUNTLAND project, in turn, profited from the existence of an executive “project coordinator”, who actively took charge in overseeing and fostering the inter- and transdisciplinary process along the way (Pohl et al. 2015). Over the course of MOUNTLAND, an aspect regarded as instrumental to the process was the strong “personal connection” researchers and stakeholders alike had to the case study regions. This significantly contributed to the commitment and ownership of the project and its results, even beyond its completion (Huber and Rigling 2014). While an unclear allocation of responsibilities can often lead to misunderstandings and inefficiencies in the process, the RECORD project has been able to avoid many problems by an explicit “division of tasks”. For instance, social scientists, whose role more often than not is somewhat vague in solution-oriented research, were mainly responsible for structuring the project process and coordinating the transdisciplinary stakeholder involvement (Schrömer 2013), bringing an added value to the entire project team.

Output: Table 2 summarizes the outputs of the CCES Community members over the course of ten years. At first glance, the absolute numbers might appear rather low given the size of the research center. However, considering that a significant part of the researchers were engaged in CCES only on a part-time level, the achievements can be judged as quite satisfactory (goal 1). Moreover, the findings of a comprehensive bibliometric study have shown that participation in CCES, on average, had modest positive impacts on the individual’s research performance (Kassab et al. submitted).

Impact: Through its applied research, TRAMM has shown new pathways for practice. Based on the project’s findings, the Swiss Federal Office for the Environment (BAFU) has developed a concept for an Early Warning System (EWS) for rapid mass movements, which has been proposed to the Swiss Federal Council (goal 5). An important legacy of the ADAPT project is an “Open-source data base for the Zambesi river basin”, which makes all data collected in the project publicly accessible (Matos et al. 2015). With this platform, ADAPT not only provided data management, analysis and visualization tools, but also contributed to the empowerment of stakeholders, who often experience “research tourism” (Huber and Rigling 2014), especially in North-South relations. In view of the significant hydropower potentials in the Zambesi river basin, the exchange database represents an important contribution in favor of the African partners (goal 5).

Education

I learned that it is not only about how I bring my results to the practitioners, but also the other way round.

CCES winter school participant

CCES Management

Process: The CCES Management focused on a few educational activities that could not be performed by the projects. These activities were launched in the first, and carried out in the second phase. The positioning of the Executive Office at ETH Zurich was pivotal in this respect, as it was embedded in a broad institutional and personal network and extensive experiences.

Output: In close collaboration with the MINT Learning Center at ETH Zurich, the CCES Management coordinated the CCES@School project, for which several CCES participants have “translated” their findings into Swiss high school teaching materials (Hänger et al. 2017). Partnering with ETH Seed Sustainability, the Public Admin Dialog project coordinated a series of Bachelor and Master theses on the interface between CCES and Swiss Public Administration (i.e., cantonal environmental offices). And finally, the CCES Winter School Science Meets Practice (Stauffacher et al. 2012), which trains early career researchers to conduct a dialog with external stakeholders, benefited from the expertise of the Transdisciplinary Lab (TDLab) at ETH Zurich, where the format is still maintained today (goal 4).

Impact: Since there is still rather little room in the Swiss high school curriculum for interdisciplinary, problem-driven education, the teaching materials of CCES@School had to be broken down into disciplinary units. Those, however, have been received with enthusiasm by a large number of teachers (goal 4). While the Public Admin Dialog was indeed able to build some bridges between universities, individual researchers, and public administrations, the academic reward structure continues to represent a major hurdle to such initiatives. For many researchers, the effort associated with supervising inter- and transdisciplinary Bachelor or Master theses was disproportionate to the “scientific return” (i.e., data, funding).
Lastly, more than 150 PhD students and postdocs took part in the six editions of the CCES Winter School. The majority of the participants judged this experience as a “very useful asset” in their professional education.

**CCCES Community (Examples)**

**Process:** Many of the CCES projects organized regular meetings (colloquia) for their PhD students. Especially the exchange among students from different subunits of the projects increased team cohesion and fostered inspiration. In addition to the broad network, they were exposed to alternative ways of thinking, research approaches, and methods. In some projects, researchers from different institutions jointly supervised the Master and PhD theses, which also densified the CCES Community network at the level of the more senior researchers.

**Output:** Within the projects, 417 Master theses and 185 PhD theses were completed over the course of ten years. A total of 92 courses for PhD students and summer schools were staged by the projects, such as the Winter School on Landscape Genetics organized by the GENEMIG project (Bolliger et al. 2010), or the Bernoulli semester on Risk, Rare Events, and Extremes organized by the EXTREMES project at EPFL.

**Impact:** The most eminent and lasting educational impact of CCES was the opportunity given to a large number of students and early career researchers to get involved in inter- and transdisciplinary research and outreach. Getting involved in such activities can significantly contribute to the visibility of young researchers to external stakeholders, which in some instances even resulted in placements in industry or public administration. It should, however, also be pointed out that this type of research entails a certain “risk” for young researchers, including the dependency on other team members, as well as task overload, thus commonly requiring a closer supervision than in purely disciplinary research.

**Outreach**

*The problem is whether these activities are valued or not. If I invest a month to produce a stakeholder publication, I will eventually be asked: where are the scientific papers?*

**Senior CCES participant**

**CCCES Management**

**Process:** With significant administrative duties during the first phase, there was little room to stage major outreach activities. However, a pragmatic approach to those duties made possible, for example, the use of the annual project reporting for communication and outreach purposes (goal 5).

**Output:** Over the course of ten years, the CCES Management hosted a website (including intranet) with comprehensive information about all activities at the research center. Updating their respective project websites was one of the tasks of the project leadership in the context of the annual reporting, which guaranteed an ongoing maintenance of the overall online presence. Besides, the CCES Management coordinated a **CCCES Newsletter** almost throughout its entire operation. During the second phase, the newsletter was included as a separate chapter in 19 issues of the *ProClim-Flash* journal of the Swiss Academy of Sciences (SCNAT). Appearing twice a year, the journal has a broad readership from specialist associations and public administration. Another initiative launched together with the SCNAT was the *Science Policy Dialog*. At two workshops, 50 high-level representatives from politics, public administration, business, science, and the science-policy interface discussed and identified strategies and institutional prerequisites for improving the dialog between science and politics. Among others, a strong political polarization of the debate or dissent within the scientific community was identified as hindering factors. Direct personal contact between researchers and politicians or the readiness to engage in dialog on equal footing, in turn, were recognized as favoring factors. And lastly, four large public conferences and symposia (in 2007, 2010, 2014, and 2016) significantly increased the visibility of CCES and its activities (goal 5).

**Impact:** In light of the relatively constrained scope the CCES Management operated in, the outreach activities achieved a considerable impact beyond the involved scientific community (goal 5). While the CCES Management did not address society at large, it did reach many key players and decision-makers in science, politics and administration.

**CCCES Community (Examples)**

**Process:** To render the knowledge transfer as effective as possible, **ADAPT** had carried out a comprehensive “needs assessment” with stakeholders in advance. Corresponding outreach formats were then “tailored” to meet their demands, including several workshops with participants from research and policy in Zambia and Mozambique, a larger conference, and a summary brochure. The *Klimahörpfad* (*climate audio path*) of the BigLink project is another good example for transdisciplinary outreach. In close cooperation with a climate protection foundation and a tourism association, the project developed an audio guide that can be combined with a mountain hike. Visitors can follow stations of a path and experience in a truly “tangible” way what insights the project has produced (goal 5).

**Output:** More than 1400 outreach activities directed towards stakeholders were realized by the members of the CCES Community (table 2). The largest share (35 percent) were dissemination activities via newspapers, radio, or television broadcasts. Other significant formats were stakeholder publications (16 percent), seminars and workshops (16 percent), activities at schools (12 percent), or public information events (10 percent).

**Impact:** The ADAPT stakeholder brochure summarized the research results with concrete technical recommendations. However, many of the recommendations were lost in the complex fabric between research and application and were not considered in the
construction of a new dam in the region. A similar phenomenon occurred in MOUNTLAND. Although some of the core findings were disseminated through leading professional journals, they were not perceived by all the key people in charge of the decision-making. In summary, we must note that even a very thoughtful outreach strategy does not yet guarantee for a successful knowledge transfer (goal 5).

Assessment Summary
The five goals of CCES have been achieved to varying degrees. While goal 1 was primarily attained on the level of the CCES Community, goals 2 and 3 were reached through a complementary approach between CCES Community and CCES Management. Goal 4 was not reached in terms of establishing an educational program, but rather in the sense of fostering the capacity building of young researchers. Although all projects in the CCES Community made substantial efforts to highlight and promote the societal impact of their research (goal 5), only few actually contributed to the immediate solution of a “real world” problem. The activities initiated by the CCES Management could also only contribute in part to achieving the broader impact and thus to achieving goal 5 overall.

General Conclusions and Recommendations
Those who have already explored the challenges of inter- and transdisciplinarity in greater detail (or have been exposed to them) may find confirmation in many of our experiences summarized below. Nevertheless, we hope that our conclusions and recommendations are beneficial for all those who are interested in, supportive of, or tasked with the design of research, education and outreach in inter- and transdisciplinary contexts.

Provide incentives to facilitate inter- and transdisciplinary capacity building: For many of the participants, CCES was associated with a comprehensive learning experience, especially in terms of the capacity to design, plan and implement inter- and transdisciplinary research, education, and outreach. While many of the participants were rather reluctant to take part in such a complex enterprise at the beginning, CCES managed to motivate numerous leading researchers to get involved through concrete incentives like funding and networking opportunities. As a result, the broad participation in CCES has contributed to community building within the ETH Domain, which has materialized, for example, in the form of numerous inter- and transdisciplinary follow-up projects. Another capacity building process stems from the three-part funding scheme. Quite indicative, the acquisition of third-party funding has increased by 40 percent per project between the first and second phase (Bozeman and Corley 2004, Bunton and Mal- lon 2006).

Coordinate inter- and transdisciplinarity through integrative leadership: Due to their complexity, all CCES projects were divided into subunits, many of which worked along disciplinary lines. While this division may be necessary for operational purposes, the actual “crux” of inter- and transdisciplinarity lies in the integration process (Klein 2008). One key design aspect the successful projects had in common was the appointment of an executive “coordinator” (Elkins and Keller 2003, Gray 2008, Lang et al. 2012) from the very beginning of the projects. Beyond catalyzing the collaboration among the disciplines, the project coordinator could oversee the external stakeholder engagement to increase the mutual benefit of the transdisciplinary exchange. Timely trainings for designated project coordinators could provide an incentive (Kuefer et al. 2012). There is also an abundant number of handbook-like instructions for the design and conduct of inter- and transdisciplinary projects (Talwar et al. 2011, Lang et al. 2012, Pohl et al. 2017).

Benefit from synergies in governance bodies for operation and evaluation: The Advisory Board was established and entrusted with assessing the progress of the projects, which ultimately provided a transparent and legitimate basis for the funding decision for the second phase (see above). This allowed the Steering Board to concentrate on the operational issues of the research center. Both the division of tasks as well as the interaction between the two boards proved to be very fruitful. Advisory boards composed of members both reflecting the disciplinary diversity as well as having experience with inter- and transdisciplinary research can create an added value not only for a smooth operation, but also for an integrated evaluation.

Operate a lean management and reporting policy: Research, education, and outreach in inter- and transdisciplinary contexts are quite demanding and time-consuming. In turn, unnecessarily complicated bureaucratic requirements are counterproductive. CCES researchers were grateful for a supportive mentality on the part of the CCES Management, lean administration, and minimal reporting. However, such a policy also implies that one must be willing and prepared to “advance trust” towards the participants, which, in the case of CCES, has worked to the satisfaction of both sides. Ultimately, the fact that relatively little capacity had to be allocated to administrative matters has effectively enabled participants to focus more on their core tasks in research, education, and outreach.

Maintain networks through data management and research infrastructure: Research in the field of environment and sustainability often generates huge amounts of data. In order to make this data available to other researchers, minimize redundancies, create synergies, and to facilitate the scientific progress, a professional data management is integral. Even after the completion of CCES, the data management and storage platforms developed in the projects are still used. The same applies to the field installations which were set up for experiments in several CCES projects. Beyond generating data, they have also played an important role in team building processes. And lastly, they have provided a platform to engage with external stakeholders, for example in the context of excursions or workshops.
Research Centers as Drivers of Cultural Change

CCES represents a clear, visible and measurable added value to the whole ETH Domain with regard to science and capacity building, particularly to strengthening the interdisciplinary approaches leading to transdisciplinary solutions with impact for science and application at the local, national and global level.

A comprehensive evidence-based evaluation can provide a constructive contribution and remedy alike. The greatest methodological challenge remains the assessment of societal impact (Mostert et al. 2010, Bornmann 2013). First attempts for quantitative approaches have already been made, such as the use of so-called altmetrics, which rely on user statistics of social media (Thelwall et al. 2013). For the evaluation of other impacts, for example in policy or industry, there are also ways forward, based on policy document analyses or patents (Dietz and Bozeman 2005) and spin-offs (Steffensen et al. 2000), respectively. To get to the bottom of the phenomenon of societal impact, however, we have chosen semi-structured interviews with key participants of the research center. This ensured the identification of the effect and allowed us to trace the causal process with empirical precision. Needless to say, when using a case study, the question of generalizability arises. Through the different and complementary methods, however, we tried to find a good balance between depth and width to synthesize the above recommendations.

We conclude that there is a need for a cultural change to reward (and not punish) researchers engaged in inter- and transdisciplinary projects. This does by no means infer that disciplinary research should become less valued, but rather that the academic system should further broaden its evaluation and incentive scheme. Science policy makers and research funding organizations play a crucial role in this respect, because simply providing more funding for inter- and transdisciplinary research will not bring about the cultural change as long as the incongruity between mandate and reward remains in place. Besides the evidence-based evaluation on a case study level, one more pragmatic way forward could be “awards” to convey appreciation, consequently increasing a researcher’s visibility and career promotion. MOUNTLAND, for example, was awarded with the swiss-academies award for transdisciplinary research (td-award) in 2013 (Huber and Rigling 2014).

Research centers like CCES can facilitate this cultural change, in at least three concrete ways: 1. Compared to the relatively small community of (mostly) social scientists that focus on theory and practice of inter- and transdisciplinarity, research centers as instruments have the capacity to mobilize researchers from various disciplinary backgrounds and other stakeholders to work on complex themes of high societal relevance. Engaging this “critical mass” of researchers, some of which may be enjoying a high reputation in their disciplines, can significantly improve the image of inter- and transdisciplinarity. 2. As experienced in the case of CCES, research centers can contribute to community building, yielding follow-up projects in inter- and transdisciplinary fields. 3. With young researchers who get trained and motivated to work on solution-oriented sustainability themes, research centers can contribute to forming a new generation in key fields, further enlarging the “critical mass”.

Reflecting upon ten years of CCES, it is our hope that future generations will encounter better framework conditions to pursue an academic career in the field of sustainability science. We believe that research centers like CCES can help provide the necessary academic environment.

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