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Article

Redrawing Soil Salinity Innovation-Focused Stakeholder Interaction for Sustainable Land Management in Khorezm Province, Uzbekistan

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Abstract: Addressing soil salinity in irrigated drylands is tightly linked with water and land management decisions thus requiring interdisciplinary engagement. The salinity mapping approaches in Central Asia are undertaken through field sampling and laboratory analysis, which is a time consuming process. As a consequence, salinity maps are not available on time to estimate water requirements to cope with varying levels of soil salinity. Reducing the time lag between assessment and delivery of such maps would enable authorities to determine in advance appropriate water volumes for leaching the salts before and during the growing season. Research initiated in Uzbekistan context explored transdisciplinary and participatory approach to innovation development with local stakeholders. As one of the innovations, an electromagnetic induction meter (EM), a tool for rapid salinity assessment, was chosen and jointly with local salinity mapping related institutions tested, validated, and local capacities for its use developed. This paper redraws this process of innovation-focused stakeholder interaction and transdisciplinary research and discusses it with reference to ongoing debates on participatory and/or transdisciplinary innovation research. The existence of strong path dependencies within implementation oriented organizations could be observed, meaning that the innovation demands many changes to the existing system. Furthermore, the encountered challenges of participatory, transdisciplinary research in the hierarchically shaped setting of post-soviet Uzbekistan are illustrated in selected qualitative field notes and assessed. For improved joint learning and research in a transdisciplinary team, feedback cycles of mutual learning and critical reflection of how to theoretically and practically work in a transdisciplinary manner turned out to be crucial and not to be underestimated.

Keywords: transdisciplinary research; Follow-the-Innovation; innovation development; electromagnetic induction meter (EM)

1. Introduction

Land degradation due to increased soil salinity in the Aral Sea Basin has become widespread [1,2]. Globally, salt-induced land degradation is common in arid and semi-arid regions where agriculture is not viable without irrigation. Over-irrigation, as well as insufficient and ill functioning drainage in irrigation schemes are among often mentioned factors causing salt accumulation in the upper soil layer that negatively affects soil properties as well as crop productivity [1]. Resulting secondary salinization also triggered by other forms of poor agricultural management affects large areas worldwide, estimated figures reach millions of hectares with varying levels of soil salinity. In some countries salt-affected area consists of over half of the total irrigated land [2].

Among those countries with a large share of salinized land is Uzbekistan. Although the share of salinized land differs within the country, provinces located in the lower reaches of the Amudarya river are the most salinized, salinity affected areas exceed 90% of the total irrigated land [1]. Such difference is attributed to hydrogeological features of downstream areas of the Amudarya river, particularly of Khorezm and Karakalpakstan that are located in low accumulative plains characterized by poorly drained alluvial lowlands making these areas prone to salinization (Figure 1).

Figure 1. Map of Uzbekistan and the irrigated areas in the southern parts along the Amudarya river [2] (note: Khorezm province is delineated with a white boundary).

To reclaim soils that accumulated excessive amounts of salts in the root zone, water is applied to leach the salts out of the intended soil layer. Leaching of the salts in the lower reaches of the Amudarya river is a common practice, consuming around 25%–30% of the water diverted for irrigation, to keep the soils suitable for crop growth [2] and is carried out under the blanket norms specified at the provincial level without much reference to actual salinity levels due to inadequate soil salinity mapping and monitoring. Field studies [3] demonstrate that water for leaching applications rather excessive and wasteful.

The salinity mapping approaches in Uzbekistan are undertaken through field sampling and laboratory analysis, and results are then transferred to salinity maps at district, regional, and national scales, which is a time consuming process. As a consequence, the salinity maps are not available on time to estimate water requirements to cope with varying levels of soil salinity [2,3]. Reducing the time lag between assessment and delivery of such maps would enable authorities to determine in advance appropriate water volumes for leaching the salts before and during the growing season.

With the aim to improve the current methods of salinity assessment in Uzbekistan, the Center for Development Research (ZEF) of the University of Bonn under its project "Restructuring Land and Water Use in Khorezm Province, Uzbekistan" in 2008 started a transdisciplinary process of innovation testing and adaptation. As a part of the Follow-the-Innovation (FTI) component, together with stakeholders [4,5] an electromagnetic device for rapid salinity mapping was tested. The technique had not been used in Uzbekistan so far. The key objectives of this process were: (i) to create awareness among selected stakeholders about the methods; (ii) to validate the use of the device as an express method for salinity assessment and mapping with stakeholders; and (iii) to assist in capacity building of the relevant stakeholders for wider outscaling.

This paper aims to redraw this process of innovation-focused stakeholder interaction and joint transdisciplinary research and to assess it with reference to ongoing debates on participatory and/or transdisciplinary innovation research. Taking into account that effective researcher-stakeholder collaborations are challenging to establish, develop only over a period of at least few years, and require substantial investments of energy and time to maintain [6], the presented process of research jointly with local stakeholders was one of four transdisciplinary innovation development processes [5,7]. While all four approaches were designed as 'transdisciplinary' research approaches, the line between transdisciplinary and participatory innovation research with local stakeholders in the fostering of the actual, practical processes was not always clear. However, instead it was regularly, mostly implicitly, debated and the theory redefined through practice. As such, this paper aims to empirically contribute to respective ongoing debates on transdisciplinarity.

Methodologically this paper is based on the empirical experience of fostering a transdisciplinary innovation research process for salinity measuring from early 2008 to early 2011. It thus draws on the personal experiences of the authors, researchers, driving or accompanying the process as well as a stock of over 20 documents such as workplans, minutes of the meetings, and capturing the steps taken during this time.

2. 'Transdisciplinary' versus 'Participatory' Research with Stakeholders

The study, in designing the overall transdisciplinary research component FTI explicitly rejected linear approaches to innovation diffusion such as the 'Transfer of Technology' (ToT) approach [8] or 'Diffusion of Innovations' [9]. Linear approach here means developed by one actor group and scaled out to others, often in a top down manner. Instead, the 'Follow-the-Technology' (FTT) framework [10] was chosen as starting point. FTT as a participatory approach to innovation development, is composed of a set of steps assuming that once there is an innovation with a 'plausible promise' that may work and raise interest of users, innovators engage in a process in which the innovation is experimented with, in real-life situations by users [11]. The process itself is one of trial and selection, leading finally to a point where the innovation is sufficiently robust to be released more widely or abandoned because it has proven to be unsuitable for the region. The methodology FTT, uses this intervention as the entry point into a complex situation, and then allows what is discovered to determine what is important [10,12]. Douthwaite's idea to 'follow the technology' was then adapted to include both technical and institutional innovation packages.

With the aim with stakeholders to jointly test the innovation packages and adapt them to the actual real-life situations of potential users, the so far interdisciplinary team opened and included stakeholders into the innovation development processes. The actual interaction between researchers and stakeholders consequently was hoped to be one of equal partnership and respect and therefore be fostered through participatory approaches. Reference to participatory approaches as methods and tools for facilitating transdisciplinary interaction and research can be found in many definitions of transdisciplinarity [13–15]. Wiesman [13] states: "Collaboration between science and society in transdisciplinary research implies participatory processes". Häberli [16] underlines the involvement of local stakeholders and state: "The core idea of transdisciplinarity is, different academic disciplines working jointly with practitioners to solve a real-world problem. It can be applied in a great variety of fields." Hoffmann-Riem [17] points to this aim of transdisciplinarity to produce solutions to real-life problems and distinguish four aspirations: "Transdisciplinary research, therefore aims at identifying, structuring, analyzing and handling issues in problem fields with the aspiration (a) to grasp the relevant complexity of a problem, (b) to take into account the diversity of the lifeworld and scientific perceptions of problems, (c) to link abstract and case-specific knowledge, and (d) to develop knowledge and practices that promote what is perceived to be the common good". Overall, transdisciplinary and participatory approaches in general are bottom up in character and thus are more likely to be accepted and taken up by larger groups of people.

Gibbons [18] and others distinguish Mode 1 (or disciplinary and interdisciplinary science) and Mode 2 (or transdisciplinary science) knowledge production [18–20]. According to the authors, Mode 1 knowledge production is characterized by the search for universal explanations, a hierarchically higher valued rationality, as organized within the science system and a largely Western definition of the moral values of intellectual ideals. In contrast to this, Mode 2 knowledge production is socially contextualised research with the research questions being generated from the research problem itself, leading to the production of heterogeneous knowledge, heterarchically organized and based on new forms of relation between scientific and non-scientific organizations.

For fostering these new forms of relation between scientific and non-scientific stakeholders, leading to heterarchically organizations, heterogeneous knowledge participatory approaches are commonly applied. Elzinga [21] points to the diversity of reasons, leading to the adoption of participatory approaches. The range of reasons is quite broad, those that are relevant in the here assessed Follow-the-Innovation approach are to access and include tacit knowledge of local stakeholders in the process of testing and adapting innovations. This of course entails the critical question of the participatory approach being instrumentalized by the researcher for merely sending a message, or actually for inspired communication and enhanced creativity [22]. A basic condition for participatory (and at the same time also transdisciplinary) research to work, based on the experiences presented in Cleaver [23], is that trust has to exist, or to be built, between the participants involved. This trust forms the fundamental basis for the mutual exchange of knowledge [5]. In order to avoid the development of mistrust, which is highly counterproductive to any form of participatory process, Elzinga [21] points to the importance of three criteria: the participant should be independent, involved in the research process as early as possible, and be given resources to effectively influence decision-making.

Critical literature on participatory approaches such as by Cleaver [23], Shutt [24] or Mosse [25], amongst many others, repeatedly point to the important aspect of participatory (and the same holds true for transdisciplinary) processes being significantly driven by the stakeholder him/herself, rather than dominantly by the researchers or donor-funded programs. There is strong dependence of outlined transdisciplinary and participatory processes to innovation testing and further development on the stakeholders' interest. Innovation-focused interaction taken in this study reflect the stakeholder's interest, however, the process has been challenged in many other aspects. In the following, we assess these challenges and discuss the positive and negative outcomes and lessons learnt.

3. Materials and Methods

3.1. Study Area and Context

Stakeholders engaged in the study are located in the Khorezm province which is part of Uzbekistan, situated in the upper delta plain of the Amudarya river. Agriculture as the major sector in Khorezm provides 40% of employment. The modern landscape of the province has been heavily altered by men harnessing the river water to cultivate 270,000 ha of irrigated land. Waterlogging and salinity affect almost all of the area that is under irrigation due to seepage losses from earthen canals and inadequate drainage infrastructure. Major crops grown in the area are cotton, winter wheat, and rice that altogether occupy around 70%–80% of irrigated land.

The province is located on alluvial lowlands with elevations ranging from 77 to 132 m. Khorezm experiences a continental climate, average annual temperature is around 12–15 °C, however, hot and dry summer temperatures reach 45 °C, and cold winter minimum temperatures reach −20 °C. Annual precipitation is around 100 mm. Most of the soils are loamy soils, about 80% of soils consist of silt loams (USDA soil texture classification), sandy loams, and loams [26].

The conventional method of soil salinity assessment in Uzbekistan based on soil sampling at different depths and subsequent analysis to determine total dissolved solids (TDS) was described by [27]. As an alternative to TDS, the electrical conductivity (EC) meter and a method developed by local stakeholder was also included in the evaluation matrix. The method refers to EC of 1:1 ratio of soil:water solution measured directly in the soil solution by EC meter. Both, TDS and EC, are considered as destructive soil salinity testing.

The area for evaluation of salinity assessment methods conducted by local stakeholder was located in Khanka district, experimental farm comprised of 60 ha of irrigated land. Soils were predominantly of silt loam texture and 20 locations were randomly sampled over the study site. Samples for TDS and EC analyses were collected at 30 cm increments down to a depth of 150 cm. Evaluation and reflections provided by the stakeholder were based on comparing TDS and EC with the proposed innovation.

3.2. Electromagnetic Induction Meter—The Innovation

Several techniques, such as soil electrical resistivity [28], time domain reflectometry (TDR) [29], and electromagnetic induction (EM) [30] have been deployed elsewhere to rapidly assess and map salinity. The electromagnetic induction meter (EM) is considered as a non-destructive soil salinity monitoring method that measures bulk apparent electric conductivity (EC_a) [28], and has been introduced from geophysical applications. These provide an effective measuring depth of up to 1.5 m, suitable for both, deep- and shallow-rooted crops [28]. Furthermore, the calibrations of EM devices to transfer readings into commonly used indicators of electrical conductivity of the saturation extract (EC_e) or TDS have already been conducted [27,28].

EM could potentially offer greater advantage in terms of speedily mapping the salinity without inducing non-sampling errors [31]. The devices can be easily mounted on vehicles equipped with storage, connected to a computer, and used with geographic information systems (GIS) to rapidly and frequently map salinity for various spatial scales. Besides, EM surveys allow for the identification of fine-scale spatial variation because they offer continuous measurements.

Studies conducted with an EM device to estimate soil salinity at farm scale in the Khorezm region [26,32] demonstrated that this device can accurately map the spatial distribution of soil salinity and consequently monitor soil salinity dynamics as a basis for the evaluation of alternative land reclamation and land management strategies in the Aral Sea Basin. The cost of using EM over a large area of 6400 ha, which comprises about 1/3 of a district in the highly saline province of Khorezm, Uzbekistan, equals 3.75 $/ha, compared to 146.42 $/ha using a conventional survey involving analyses of 43,200 samples [28].

3.3. The Process—Team Formation

The formation of the interdisciplinary team proved to be an interesting process in itself. It took almost one year before the team could confirm its final active membership, and garner collective interest in pursuing the innovation. Initially, the members of the group were specialists engaged in water and salinity topics and others who nominated themselves during the FTI training conducted in May 2008. These members comprised three core members or experts of salinity assessment, groundwater and hydrology, and five support members from allied disciplines. During team formation, the members opted for the key scientific expert from the discipline of the innovation to lead the team and process [4,5]. The group leader followed an informal approach of seeking ideas, advice, and inputs from other members verbally and taking responsibility for incorporating these into the planning processes, and then sharing the draft planning documents with the group members. This in consequence led to opaqueness that then had to be discussed.

In the team's own assessment, for an initial period of almost a year, the FTI process was driven by a one-man team comprising the team leader, as other members would tend to simply agree to what he would propose. The team leader questioned the rationale of continuing FTI as there was a lack of interest from other team members. The ideas for withdrawing this innovation from the FTI process were exchanged with the FTI team members, FTI coordinator, and the project management as well. The team leader realized at that stage that he had misunderstood FTI as a straightforward extension type of exercise rather than a process of interaction, dialogue, and joint research with stakeholders.

On the other hand, it was hard to speed up the process as rapport building with stakeholders was very important but time consuming. The challenges that the team were struggling with were clarified with the FTI and project coordinators, as outlined in Box 1. During an internal FTI review workshop, held in May 2009, it was decided that the FTI facilitator would join the team to support the process with his expertise as well as an expert on groundwater, who knew the local stakeholders well, would get actively involved in the group more directly (Box 1).

Box 1. Group Dynamics—Excerpt of Minutes.

Date: 13 May 2009
Location: Project office
Participants: FTI team leader, FTI facilitator, FTI assistant, water specialist, project coordinator

Background:
The meeting was a follow up of discussions at an internal FTI review (April 2009). The team leader felt like "one-man" team as his team members tend to agree to everything proposed. In his view, the team had not made much progress since November 2008, and thus triggered opinions during the FTI review that this innovation should be shelved on account of lack of interest by members. At the same time, a number of potential stakeholders were identified, and several showed keen interest in the innovation.

Outcome:
The following roadmap was agreed on:

(a) Team leader will write a brief description of the innovation for the stakeholders;
(b) FTI facilitator will join the team as a member and visit potential stakeholders together with the team leader to bring the potential of the innovation to the attention of these organizations;
(c) If stakeholder interest was not high enough, a final documentation would be prepared describing the results of this FTI effort and explaining why stakeholders were not interested;
(d) If any potential stakeholder is interested, there will be a follow-up, depending on the interest.

Based on these discussions, a road map was drafted indicating activities, responsibilities, and timelines as illustrated in Figure 2.

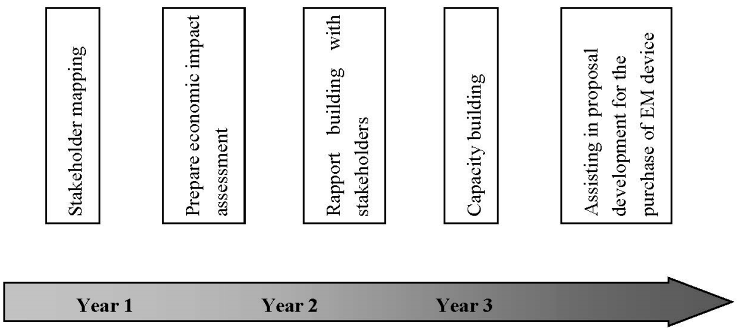

Figure 2. Roadmap of the Salinity Assessment Team.

3.4. Stakeholder Selection

A list of potential stakeholders was initially assembled by the collective knowledge of the team members, and shared across many others for the inclusion of additional potential stakeholders. Once listed, the team then prepared a matrix with stakeholders' mandates, jurisdiction, location, and perceived interest in the innovation, based on the advantages the innovation offered. A split was made based on the differences between the stakeholders directly using tools to measure in practice (implementing institutions) and those who educated and trained others on how to use tools to measure soil salinity (educational institutions).

In the following these stakeholders are coded as follows: Stakeholder 1 is a research organization, Stakeholder 2 is a salinity mapping organization, Stakeholder 3 is an educational institution, Stakeholder 4 represents an administrative unit with salinity mitigation mandate, and Stakeholder 5 is an applied research institute.

The suitability of the presented innovation needed to be assessed by the stakeholders and their interest confirmed in terms of their needs and financial constraints. After the stakeholders' interest was verified, the team expected to work with a delegated specialist/person from the stakeholder's institution.

Out of 11 potential stakeholders the team discerned five key stakeholders using the following criteria: (a) direct mandate to assess and map soil salinity, (b) dependence of ongoing activities on soil salinity assessment, and (c) promotion of innovative methods in natural resource management. While the project staff itself also carried out soil salinity assessments using EM, direct involvement of the selected stakeholders in the project's on-going measurements was found to be complicated because most stakeholders were located far from Khorezm. The possibility to bring the stakeholders to the project site in Urgench would not be as useful as to let them use EM in practice during their field work. Therefore, based on an analysis of stakeholder mandates, the following stakeholder-specific engagement strategies were outlined:

- Visit on-going Stakeholder 1's soil survey expeditions in the Khorezm region at their site to show and use the equipment;
- Collaborate with Stakeholder 2 because of their direct mandate to assess and map salinity and location within the same city as that of the project's location;
- Conduct training on the use and calibration of EM to selected educational institutions;
- Discuss with Stakeholder 5 the possible calibration of EM;
- While some institutions had the capacity and experience of initiating and funding projects, other institutions lacked that capacity. Demand from interested stakeholders could be pooled together to organize and initiate a collaborative funding proposal for the purchase of EM.

4. Results and Discussion

4.1. Process Implementation

The initial steps, i.e., roadmap writing and stakeholder mapping, were employed as planning tools, while remaining flexible for refining the roadmap based on the stakeholder engagements and their interests.

For the interactions with the potential stakeholders, a brief description of the device and its use was prepared in Uzbek and Russian languages that included key results of the correlation of the device readings with soil salinity data measured in the laboratory. Additionally, the device was taken along for demonstration. A number of activities were undertaken by team members in 2009 and 2010 towards initiating the transdisciplinary processes with potential stakeholders in 2009 (Table 1).

Table 1. Steps taken during 2009–2010.

#	Activity	Time
1	Roadmap preparation	15 January 2009
2	Land management program secretariat visited	10 March 2009
3	Seminar organized by an international agricultural research center	23 March 2009
4	Team internal discussion (e-mail)	4 May 2009
5	Internal discussion about future plans	18 May 2009
6	Discussion with Stakeholder 1 regarding survey in the region	19–20 May 2009
7	Stakeholder 1 letter for joint experimentation	22 May 2009
8	Collaboration with Stakeholder 1 to join EM survey with their soil survey in the region	28–30 May 2009
9	Initial meeting with Stakeholder 2	13 June 2009
10	Initial meeting with Stakeholder 3	29 June 2009
11	Initial meeting with Stakeholder 4	30 June 2009
12	Meeting with Stakeholder 1	7 July 2009
13	Meeting with Stakeholder 5	3 August 2009

4.2. Stakeholder 1

Stakeholder 1's primary mandate is research in soil science and also providing support in soil surveys to state organizations. Initial contact with a managerial-level staff was positive, who showed keen interest in the innovation as it would ease their job related to salinity mapping, though the need for sampling based analyses would still remain, as the organization could not change the standard procedures. The FTI team undertook EM measurements when the stakeholder's field team implemented their soil survey in Khorezm region during spring 2009. The purpose was to (a) interact with field staff, (b) demonstrate EM at work on their site, and (c) prepare maps to present at the Stakeholder 1 meeting. Follow up was to be decided based on reactions from Stakeholder 1 staff after the presentation. A letter from Stakeholder 1 expressing interest in collaboration and inviting the project staff to undertake an EM survey in parallel with their routine soil survey was received in May 2009 confirming their interest. The FTI field assistant joined the Stakeholder 1 team for 3 days to jointly conduct a salinity survey. The FTI team leader visited the site for backstopping and meeting with the Stakeholder 1 team and to explain the purpose of the EM measurements. Several questions ranging from the working principles of the instrument and influencing factors to the device readings to the practical use of EM for the purpose of soil surveys were explored. The soil survey team leader had reservations due to different working principles that led to suspicions about the accuracy of its measurements. The fact that the device was of foreign origin, and not yet certified by agencies in Uzbekistan might have caused further objections. During the discussions, Stakeholder 1 was mainly concerned about the high price, the necessity to carry and walk to map large areas in addition to their main work load of soil profile descriptions, and the detailed laboratory analyses they routinely do to obtain salinity types and ion compositions regardless of the express methods that Stakeholder 1 owns to measure soil salinity. The Stakeholder 1 team leader mentioned that the existing express methods based on electric conductivity to measure soil salinity, which were already certified and were in use by some other salinity assessing organizations within Uzbekistan, were rarely used by his organization. This in part implied that the organization was relatively conservative in their approach and thus was reluctant in making use of innovative approaches.

Results from EM surveys conducted by the FTI team were shared with Stakeholder 1 for comparison. However, lengthy soil survey expeditions in other regions, and the time required for laboratory analyses of the soil samples collected were presented by Stakeholder 1 as the main reasons for a lack of their progress in comparing the two methods. Several attempts from the FTI team to inquire about the progress later on did not yield much. Consequently, the FTI team decided not to pursue with Stakeholder 1 unless the stakeholder addressed the project out of the stakeholder's interest. After this, there was no further follow-up on collaboration from either side.

4.3. Stakeholder 2

The primary responsibility of Stakeholder 2 is to monitor salinity within the stakeholder's respective province. These maps are then sent to their national superior office. The FTI team saw that since Stakeholder 2's mandate was closer to what the innovation could deliver and because the organization was located within Khorezm province, the discussions proceeded faster and a high level of enthusiasm for partnership about testing the innovation was observed. The chief technical-level staff was approached for the first contact, who had a reputation of an expert interested in modern methods. The interaction gave an initial impression that the stakeholder would be interested in partnering with FTI. Despite an initial warm response and enthusiasm, as the process dynamics in Box 2 show, staff change, busy schedule and the need of confirmation from the managerial-level of Stakeholder 2, resulted in the engagement with the stakeholder being on hold during the entire 2009–2010.

Box 2. Initial Meeting with Stakeholder 2—Excerpt of Minutes.

Date: 11 June 2009
Location: Office of Stakeholder 2, Urgench
Participants: 2 technical-level staff of Stakeholder 2, FTI team leader, FTI coordinator, FTI groundwater specialist

As a routine, Stakeholder 2 selects three farms per season per district to estimate salinity, and these selected farms are rotated every year. The soil salinity surveys are carried out during the autumn period. Soil samples are taken and analyzed in Stakeholder 2's laboratory in the provincial capital, Urgench. Stakeholder 2 seems to be open to the innovation, as they have already tested alternative methods which they found suitable for moist conditions while not accurate for dry soils.
Also, they have often been called by government agencies to provide quick estimates of soil salinity in fields which puts additional pressure on Stakeholder 2's lean staff capacity. Furthermore, farmers often ask for advice on the salinity levels (distinguishing between not saline, moderate or highly saline) of their fields.
The demand for speedy results from interested agencies and farmers seemed to be the main advantage of EM for the stakeholder. Stakeholder 2 staff asked for the manual in Uzbek or Russian languages to familiarize themselves. Additionally, the FTI team suggested conducting measurements with EM during Stakeholder 2's salinity survey on farms, as well as presentations to interested staff and farmers on the use of EM, working principle, and maps generated using EM readings in July. The FTI team also promised to make a small write-up in Uzbek language on the use of EM, which could then be expanded into a guide book. The Stakeholder 2's representative agreed to appraise the team on a suitable date for presentation and further discussions.

However, the Stakeholder 2 did not keep its promise of appraising the FTI team on their interest further. The team leader called a few times and learnt that the chief technical specialist had been transferred to another organization.

4.4. Stakeholder 3

The discussions with Stakeholder 3, which has primarily a teaching mandate, led the team to believe that while such institutions might be more interested in testing and validation, the use of the innovation by such institutions would not necessarily result in wide scale adoption if successfully verified, because the innovation would remain in the realm of an educational facility. Besides, academic testing of the innovation had already been undertaken by the ZEF project and any replication would not add value to the innovation, unless it was undertaken in the stakeholder's real-life situation. The collaboration was therefore not pursued further.

4.5. Stakeholder 4

Additionally, Stakeholder 4, responsible for land rehabilitation, and inspired by a TV interview with the stakeholder's managerial level on methods for salinity assessment, was contacted (Box 3).

Box 3. Meeting with Stakeholder 4—Excerpt of Minutes.

Date: 30 June 2009
Location: Office of Stakeholder 4, Tashkent
Participants: Managerial-level of Stakeholder 4, FTI team leader, FTI facilitator

The host expressed interest in the innovation and its capacities as well as attached costs and suggested to meet with the managerial-level staff responsible for the respective department in the Ministry of Agriculture and Water Resources, to discuss possible implementation. Additionally, the host promised that he would present the innovation to its board and if approved, would let us know to discuss and proceed further.

In a follow-up phone call the stakeholder nevertheless confirmed his interest in the service itself, but not the use of the tool by his institution. With this the potential for joint experimentation ceased. Furthermore, the project team contacted several internationally funded projects and donor agencies dealing with salinity mitigation. The dialogues with these stakeholders nevertheless indicated that they were interested in purchasing the services of well-equipped and scientifically valid service providers for covering large-scale as well as in trainings for the use of EM, but not interested in working with the innovation itself or in a transdisciplinary, joint experimentation and validation of the tool together with the project.

4.6. Stakeholder 5

The FTI team thought that Stakeholder 5 would be potentially interested in the innovation due to its mandate on both, research and implementation aspects of salinity assessment. Besides, Stakeholder 5 in the past had been engaged in the local assembly and the use of different express methods of soil salinity assessment using electrical conductivity. Furthermore, other stakeholders had voiced their interest in working with institutions simply providing the service of EM-based salinity assessment. From a project perspective, Stakeholder 5 seemed potentially to be this service provider. As outlined in Box 4, the technical-level stakeholder representative during the first meeting showed interest in validating and potentially outscaling the tool. This was then followed up with a meeting with the managerial-level for full approval and support for the further transdisciplinary process.

Box 4. Initial Meeting with Stakeholder 5.

Date: 30 June 2009
Location: Office of Stakeholder 5, Tashkent
Participants: Technical-level of Stakeholder 5, FTI team leader, FTI coordinator

As conventional soil salinity analyses and the classifying categories used are not accurate, Stakeholder 5 analyses large amounts of data to improve accuracy of salinity EC probes within given soil moisture ranges. Most of the work is done for research purposes and the upscaling of the results remains a practical challenge.
The FTI team indicated the accuracy of the EM calibration ranged from mainly 60% to 80% which seemed low to the host. During the meeting the participants agreed that the stakeholder's laboratory would calibrate EM on their study area. The project would support the work during this calibration period with transport, field assistants, and other necessary inputs. The laboratory would prepare a formal 'statement of record' with the results of calibration. This calibration would be a first milestone for further planning.

The interest of the stakeholder was further confirmed in a meeting with the managerial-level (Box 5), where a tentative roadmap of collaborative innovation testing was discussed, prepared, and formally agreed through a partnership agreement.

Box 5. Meeting to Confirm Collaboration.

Date: 3 August 2009
Location: Office of Stakeholder 5, Tashkent
Participants: Managerial- and technical-levels of Stakeholder 5, FTI team leader, FTI facilitator

The host was supportive of the initiative and formally delegated the technical-level contact person. The participants agreed that a draft agreement would be initiated by the project, and then the stakeholder would modify it. A 2-step approach in calibration and dissemination was agreed on. The Stakeholder would calibrate the EM on their site in Khorezm region in parallel with soil survey and analysis by one of their staff. The necessary support in conducting this calibration work would be provided by the project.
The next step would be taken depending on the results of calibration and include training to the staff of Stakeholder 2, who would then impart regular training to other salinity assessment organizations from all the regions, which is part of the mandate of Stakeholder 2, and is already supported financially by the Ministry of Agriculture and Water Resources of Uzbekistan. A training module of 1-day including 2-hour lecture and probably demonstration if the EM device could be included in these regular trainings.

The partners moved quickly into action, and field activities were commenced within two weeks (Table 2).

Table 2. Steps taken during 2009–2010 with Stakeholder 5.

#	Activity	Time
1	Meeting for gauging interest	30 June 2009
2	Reaching an agreement	29 August 2009
3	Collaborative field testing of EM	19–22 September 2009
4	Data analyses for draft report	11 December 2009
5	Meeting—revisiting goals of collaboration	15 December 2009
6	Draft report submitted	14 January 2010
7	Participatory monitoring and evaluation	December 2010–January 2011

The main conclusion of the draft report submitted by Stakeholder 5 (Activity 6 in Table 2) and the "statement record" (Box 6) was that EM could be considered for a rough/approximate estimation of soil salinity level. Additionally, the results of the calibration work were summarized by Stakeholder 5 in two articles.

Box 6. Summary of salient points from the "Statement Record" issued by Stakeholder 5 after completion of the Calibration Study.

1. Interpretation of results was complicated due to the influence of many factors including the variation of the groundwater table, pronounced soil textural difference laterally and vertically. Results indicate that at least 3–4 factors influence device readings (porosity, texture, moisture, and layering) which result in approximate salinity level assessments only.
2. Shallow groundwater table increases salinity in the 0–60 cm soil layer. Device readings tended to be higher where groundwater table was shallow, perhaps due to salinity of the groundwater.
3. Correlation analyses with several factors measured were weak.
4. Splitting surveyed locations into two groups based on soil moisture (above or below 20%) of 0– 60 cm soil layer showed very high correlation between device readings and electrical conductivity measured in the laboratory. However, such interpretation would require data on soil moisture.
5. Classification of device readings into salinity levels was better when based on correlation with sodium content.
6. It is necessary to conduct the calibration study in other conditions, on more uniform soils where groundwater influence is low. Once completed, the method could be introduced to other organizations.

As a follow up of the calibration work conducted together in Khorezm in 2009, there was a formal request letter from Stakeholder 5 to borrow the EM-tool to use in other regions (letter 01/338 from

9 August 2010). Stakeholder 5 organized a trip to these regions in September 2010 in which the FTI team leader together with the device joined in and jointly conducted the calibration work.

4.7. Stakeholder 5 Innovation Evaluation

The primary evaluation criteria of Stakeholder 5 were influenced by three key interests: (a) possibility of speedy monitoring; (b) acceptable (and low) initial cost; and at the same time (c) increased accuracy of the information regarding salinity distribution. Thus, EM was tested in terms of its reliability and applicability on diverse natural and soil-hydro-geological conditions of Uzbekistan.

According to the stakeholder, the draft report and the "statement of record" provided by the stakeholder's specialist were sufficient proof of the innovation being validated. Out of the perspective of the project nevertheless a joint final evaluation, a participatory monitoring and evaluation of the pros and cons of the innovation in the real-life setting of a salinity mapping institution in Uzbekistan seemed necessary and eventually Stakeholder 5 agreed to such an exercise. Thus, 15 evaluation criteria were jointly formulated (Table 3), focusing on the validation of the tool, as well as, but secondary on its potential outscaling. There was a consensus to compare the performance of the innovation with TDS as well as with EC meters. The stakeholder chose three grades for scoring, "0", "1", and "2", which corresponded to no or negligible, intermediate, and yes or high, respectively for each formulated criteria. Finally, the conducted matrix ranking consisted of 15 criteria and three salinity assessment techniques.

Table 3. Participatory evaluation of alternative salinity assessment methods.

Rank		Criteria	Evaluation/Score		
			Destructive Method		Non-Destructive Method
			Total Dissolved Solids (TDS)	Electric Conductivity Meter (EC)	Electromagnetic (EM)
Validation	1	Availability and affordability of the instrument	1	2	0
	2	Availability of trained staff and accessories	2	1	1
	3	More information to generate salinity spatial distribution	0	1	2
	4	Operational efficiency of obtaining information	0	1	2
	5	Level of field worker qualification (and necessity of special training)	1	1	0
	6	Savings in expenses in laboratory analysis, instruments, chemicals	0	1	2
	7	Convenience in the use (technological simplicity)	0	1	2
	8	Labor costs—field	0	0	1
	9	Labor costs—laboratory	0	1	2
	10	Current costs at field work stage (i.e., auger, equipment)	1	1	0
	11	Level of detail of information—layers	2	2	0
	12	Level of detail of information—further analyses for chemical composition	2	1	0
Outscaling	13	Popularity and acceptability of the method	2	1	0
	14	Readiness of practitioners to use	2	1	0
	15	No need for promotion and training	2	1	0

* 0–no/negligible; 1–intermediate; 2–yes/high.

The ranking of the criteria was done by Stakeholder 5 and the top 5 included access to hardware (criterion 1) and skills required for calibration and conducting survey using any of the methods (criteria 2 and 5). The other two included criteria pertinent to the method; that is, the accuracy and operational efficiency (criteria 3 and 4). If the former three criteria (1, 2, 5) from the top 5 can be solved by providing hardware and upgrading skills of the staff the latter two criteria are critical, both methods, TDS and EC, cannot provide as good as EM.

Various costs included in several criteria were not as important as the convenience or simplicity of the method, awareness about the method and the readiness and interest of the practitioners to work with it. The least important criteria were detailed information about the salinity within particular soil layers, and about the chemical composition of salts in the soil.

In Table 3 criteria 1–12 are related to the validation dimension of the tool, while the remaining three (criteria 13–15) focus on the potential for outscaling.

The sum of scores accrued by each method is illustrated in Table 4. EC and EM scored higher than TDS with regard to the validity of the tool and method. Regarding the potential for outscaling, the TDS scored higher than EC and EM. This is mainly explained by the fact that TDS is already in use and therefore does not require any change to the system in place. On the other hand, despite the EM tool scoring high in terms of validity, it requires the availability of the equipment and trained staff, training of field specialists of the concerned organizations as a precondition to any form of adoption or outscaling.

Table 4. Comparison of criteria categorized into validation and outscaling dimensions.

Criteria	Total Dissolved Solids (TDS)	Electric Conductivity Meter (EC)	Electromagnetic (EM)
validation	9	13	12
outscaling	6	3	0

Although quantitative information from a number of stakeholders would be ideal to formulate conclusions, the real-world case dictates different conditions where the number of stakeholders was limited to start with. There was a small number of stakeholders who have a mandate to provide either methodological or operational soil salinity assessment. These were state supported and mandated organizations that were approached, and only one had experience with different innovations in soil salinity assessment and was open to suggested innovation. Experiences and opinions drawn in this study were therefore based on the process that involved identification and mapping of eleven stakeholders, engaging with seven, interacting with five and finally testing the innovation with only a few.

5. Challenges Faced and Lessons Learned

The above outline of a transdisciplinary process of innovation research in post-Soviet Uzbekistan illustrated a number of challenges faced and lessons to be learned from these. In the following, we discuss these as shaped by the three interacting spheres: (a) the innovation itself and its specific characteristics, (b) the stakeholders' specific situations and (c) the project staff, interests and perspectives on the process.

With regard to the innovation itself, most of the stakeholders perceived the innovation as a new promising tool to provide exactly the same detailed analyses at a higher accuracy as obtained by sampling methods and laboratory analyses. Communicating the potential value in a trade-off between high accuracy and scale, at a better resolution and in less time posed a challenge. This was further enhanced by the costs for the device and the complexity involved in the adoption of a new approach and method, altering the existing way of doing things. Most stakeholders initially contacted, were especially concerned about the precision in measurements under different environments, such as different moisture levels and varying soil textures, affecting the readings of the equipment. This was compared to the advantages, such as the ability to assess salinity without destroying the soils, time saving, as well as the capacity of the device to provide high resolution and thus better accuracy of the soil salinity variation.

It consequently became obvious during the different interaction processes that the innovation itself only covers part of the mandate of most implementation stakeholders, and thus either will need to be improved in a way that it not only can map salinity quickly, but also can split up the results into related parameters and sub-components, such as ionic composition of salts. For Stakeholder 1 it might create operational difficulties due to the specifics of the surveys conducted. For example, the benefit of the use of EM is counter-balanced by other issues such as the travelling distance, the cost of additional numbers of equipment per survey group, walking distance, and burden of carrying the device. While potentially useful, it seemed that the EM device does not fit into the routine soil survey work, where soil samples should be taken anyway, because any salinity mapping exercise by Stakeholder 1 that is not accompanied by detailed soil profiling is unacceptable on quality aspects for Stakeholder 1.

Perhaps, the expectation of the FTI team that the device would be well accepted by staff that undertook the survey was too high, or more time was needed for Stakeholder 1's staff to familiarize themselves with the tool and digest the information before on-field testing, so that they were prepared to field test and then discuss the implementation. On the other hand, the contact person of Stakeholder 1 belonged to the managerial-level of the institute, which initially speeded up the collaboration, but prematurely left the operationalization of collaboration to technical level staff to make further progress. It seems that unless the managerial-level and other lead staff pursue the collaboration regarding innovation with zeal and zest, the innovation is not accepted by technical specialists within the organization, who rely more on their well-practiced methods.

Despite, and possibly even due to the technical aspects of this innovation, which have been researched and reported in Western peer reviewed publications, the additional calibration work initiated and conducted by Stakeholder 5 was crucial for developing the required level of confidence and ownership. As the discussion above showed, the stakeholder subsequently took initiatives to use the device in other areas of Uzbekistan.

This characteristic of the innovation being a technical device, tool and method produced and commonly used in Western countries nevertheless also contributed to what we called the 'salesman-challenge'. The team, and especially the team leader, at times felt like a salesman trying to 'convince' stakeholders of 'his' device, while in fact he was mainly interested in finding one actually interested stakeholder who would be willing to test and validate the device in the stakeholder's real-life setting of everyday salinity mapping in Uzbekistan. It seemed that this especially came into play, when interacting with the managerial-level first, often focusing on the limitations and constraints of the tool, rather than on the potential. Later interactions suggested, that cooperating with technical-level staff first, gauging actual technical interest, and only later involving the managerial level might be more fruitful in certain settings. Furthermore, the 'salesman-challenge' was partly overcome once Stakeholder 5 was identified and the collaboration taken a step further than the initial meetings with other stakeholders, simply raising awareness but not yielding follow-ups.

The earlier stakeholder interactions, or 'mini-FTIs', showed that while a local specialist as a person might very well like the innovation, it is no guarantee that he/she acts as an advocate, or a 'product champion' for the innovation within his/her organization. This might especially be true in hierarchically organized societies in which a sense of belonging to one or another informal network seems crucial for everyday life organization. From the perspective of the local project staff, this was perceived as people not wanting to spoil their relationships with their colleagues for 'outsiders'. It here also became obvious that the personality of each partner in the interaction process plays a crucial role in the outcome of the collaboration and is often far more decisive than the quality or potential to locally fit of the innovation itself.

Here the existence of strong path dependencies within implementation oriented organizations could be observed, meaning that the innovation in parts simply would demand too many changes to the existing system, and therefore make its adoption unlikely. For example in the case of Stakeholder 2, apart from the lack of incentives and motivation to improve the monitoring system, the poor staffing and strong hierarchical control seem to be withholding factors to look for innovative ways for fulfilling their mandate. For the education oriented organizations, such as Stakeholder 3, the interest in the innovation is only limited to its application and use as an alternative tool for postgraduate students research, and does therefore not directly, but possibly indirectly, lead to an uptake by any of the potential users. For the demand by the donor supported projects, who count on service providers and need one or more of the implementation organizations or NGOs to undertake the assignments within the specified areas of the chosen projects, the methods and tools chosen are of much less interest compared to the information generated by the process of innovation testing and attempted diffusion. Stakeholder 5 nevertheless, and differently to the other stakeholders, may possibly act in the future as a catalyst for introducing salinity assessment innovations. A few years back, for instance, they started promoting EC probes, which are now at least accepted as an alternative to soil sampling. This combined with the attempts to gauge any other serious local interest in taking the innovation further, suggests that the best route of EM being implemented in Uzbekistan is via Stakeholder 5, upon which the FTI team has already embarked. One can turn to Page [33] quoting an old Bostonian rhyme "I eat my peas with honey. I've done it all my life. It makes 'em taste quite funny, but it keeps them on the knife" as a metaphor to explain that some start out eating their peas with knives and honey, and never move on to the fork or spoon, while others actually do. Page [33] looks at path dependence to understand why some countries succeed and some not and argues, that it "requires a build-up of behavioral routines, social connections, or cognitive structures around an institution".

Yet, besides challenges posed by the local environment and the socio-political and cultural context of the stakeholders, we also encountered challenges induced by the project team involved in the process. Here it became quite obvious that the selected innovation required a subject specialist who at the same time possessed a high level of understanding of innovation development processes, transdisciplinary research tools, and participatory methods as well as other soft skills for interacting with the stakeholders, while at the same time also documenting and analyzing the process. While this posed an immense challenge for the team, it also made the team members go beyond their own disciplines, learn alternative approaches to research, and consider verbal conversation with stakeholders as "data". As a learning process we nevertheless realized that a lot more time for learning within the project team should have been allocated, especially for those teams with mainly natural science backgrounds. For improved joint learning and research in a transdisciplinary team, feedback cycles of mutual learning and critical reflection of how to theoretically and practically work in a transdisciplinary manner turned out to be crucial and not to be underestimated.

All practical concerns for actually using the tool in the local context were discussed on an equal footing and eye-level between researchers and soil salinity assessment stakeholders. The tool was tested and the practices of testing commonly conducted by the stakeholders were adjusted in ways that EM as a tool was taken on by those potential end users and became theirs. As such, the transdisciplinary process assured not only the adjustment of the tool according to the local contexts, needs and considerations, but also that the joint dialogue structured around the use of the tool in Uzbekistan setting served as a learning and exchange platform for all involved.

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