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Final report

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List of Acronyms

ACIAR – Australian Centre for International Agricultural Research

ACT – Australian Capital Territory

ASSIB – Adapting to Salinity in the Southern Indus Basin

BCM – Billion Cubic Metres

C2MARS – Climate Change Mitigation, Adaptation and Resilience for Sustainability

CET – Community Engagement Team

CIAD – Critical Institutional Analysis and Development

CRAM – Capability, Risk, plant Adaptation and Mitigation

CSIRO – Commonwealth Scientific and Industrial Research Organisation

CSU – Charles Sturt University

FAO – Food and Agriculture Organization

FFC – Fauji Fertilizer Company

GDP – Gross Domestic Product

IBIS – Indus Basin Irrigation System

ICBA – International Center for Biosaline Agriculture

IPA – Impact Pathways Analysis

IUCN – International Union for Conservation of Nature

LIFE – Livelihood Improvement through Facilitated Extension

LWR – Land and Water Resources

MAR – Managed Aquifer Recharge

MCM – Million Cubic Metres

MNSUAM – Muhammad Nawaz Sharif University of Agriculture, Multan

MUET – Mehran University of Engineering and Technology

NGO – Non-Government Organisation

NSW – New South Wales

PARC-AZRI – Pakistan Agricultural Research Council – Arid Zone Research Institute

PCRWR – Pakistan Centre of Research in Water Resources

PID – Punjab Irrigation Department

PKR – Pakistan Rupees

RAP – Representative Agricultural Pathway

SAU – Sindh Agriculture University

SERL – Stakeholder Engagement for Research and Learning

SIAGI – Promoting **S**ocially **i**nclusive and Sustainable **Ag**ricultural **I**ntensification in West Bengal and Bangladesh

SID – Sindh Irrigation Department

SIDA – Sindh Irrigation and Drainage Authority

SOFT – Society of Facilitators and Trainers

SRA – Small Research and Development Activity

SSRI – Social Science Research Institute

UAE – United Arab Emirates

1 Acknowledgments

This project was undertaken as a co-inquiry with rural and coastal communities living in salinity-affected areas. We consider the people from these communities as part of the ASSIB team. Their contributions shaped the trajectory, findings and outcomes from the project. We acknowledge that contribution with profound gratitude.

Our project successes are always associated with community receptiveness. We appreciate all the project 'bright spot' community members who collaborated with us for providing logistical support, and for welcoming national and international project team members even when these clashed with busy times at their farms.

Women and youth have played an especially significant role in achieving the targets of the project. They have enthusiastically implemented new ideas shared by local and other expert stakeholders involved in the project. Some activities such as kitchen gardening have been successful because of their interest and full participation in the events.

Networking among service providers, experts and the communities we engaged with was another key element of the project. This networking brought organisations, individuals, and businesses together on one platform to share knowledge and services rendered. In particular, we acknowledge the support provided by provincial government agriculture and irrigation departments in both Punjab and Sindh who engaged with our project via their field-level professional team participation as members of the project's stakeholder forums. We also appreciate the back-end support provided by provincial departmental secretaries and other senior officials who gave valuable time to participate in meetings and workshops.

The network also included a number of Pakistan-based organisations (i.e., PCRWR, SAU, SIDA, Sindh Agriculture Department and PARC-AZRI) who became collaborators with us, actively contributing to achieving our project's research outcomes. PCRWR's regular participation in our project's coordinating team deliberations was especially appreciated. We also acknowledge with appreciation the enthusiastic participation of a range of senior donor, government and other officials at our networking events. We especially thank Dr Muhammad Azeem Khan and Ms Kanwal Waqar for their positivity and dedicated attention to engage with the entire team including 'bright spot' community representatives as part of the final review process.

Finally, we acknowledge the financial support provided by the Australian Centre for International Agriculture Research (ACIAR) to carry out our research activities with the farming communities. The guidance and administrative support provided by the Pakistan country office is highly appreciated and acknowledged. We also acknowledge financial and in-kind support provided by Charles Sturt University, and the co-investment in-kind support provided by all other partner organisations.

2 Executive Summary

The Adapting to Salinity in the Southern Indus Basin (ASSIB) project championed co-inquiry as a research process. This co-inquiry process involved salinity-affected communities taking a leading role in investigations into how they could 'live better with their salinity', with the ASSIB project team and other stakeholders joining as co-researchers. These pilot, small-scale 'living with salinity' investigations were done on the properties of individuals affected, with the results owned by them for their benefit. The process we used to achieve co-inquiry among communities, researchers and other stakeholders is known as Stakeholder Engagement for Research and Learning (SERL).

SERL was used to co-design co-inquiry research with salinity-affected communities who became part of the ASSIB project team. Three sets of 'bright spot' communities (Tippun Dublo and Malwah in Sindh, and Jalalpur in South Punjab) became demonstration sites for a range of agriculture and aquaculture adaptations. Their activities will be ongoing post-project as the farmers involved have the capacity to scale out these adaptations in creative and contextually relevant ways, with some elected to take responsibility for scaling out SERL as a farmer-to-farmer facilitated approach to learning and action. This use of SERL thus sets the stage for a longer-term 'living with salinity' research program.

The longer-term salinity adaptation research agenda in Pakistan needs to incorporate system-wide trends, especially those associated with climate change. The ASSIB project thus also contributed to the science of what drives salinity presence in the landscape and its consequences, offering a wealth of new Pakistan-specific information for use by management authorities. Analysis of basin and canal command scale water use trends and its implications has been developed and presented with acclaim. Models of groundwater dynamics were developed with support from provincial government irrigation departments to simulate scenarios involving broader-scale salinity adaptation options: green infrastructure to improve coastal climate change resilience; and changes to cropping patterns in response to excessive groundwater pumping in South Punjab and waterlogging in Sindh. These and ASSIB's other system-wide research outcomes contribute to Pakistan's need for strategies to adapt and transform to climate change.

ACIAR's decision to invest in the ASSIB project builds on a decades-long history of ACIAR research into salinity management strategies for Pakistan. Australia and Pakistan share similar challenges of developing agriculture within water-scarce, salinity-affected landscapes, with considerable scope for co-learning through research collaboration. The research and practice in Pakistan over the decades have put forward many solutions for adapting to salinity. A key issue has been limited uptake of the proffered 'solutions'. SERL has been the game changer, offering a pathway for increased uptake and adaptive learning. ASSIB's focus on identifying contextually relevant salinity adaptations with communities has also led to advances in the science of saline agriculture. The Capability, Risk, plant Adaptation and Mitigation (CRAM) framework offers the means to identify suitable salinity tolerant crops and relevant management practices that fit with the conditions of a particular salinity-affected landscape.

Much of the co-inquiry and salinity trends research has been led by early career researchers employed by Pakistan-based organisations. The capacity built thus stays in Pakistan, ready to support the longer-term 'living with salinity' research program. For many involved, the opportunity to practice their research with farmers has been transformational, with farmers now respected as co-researchers and teachers. The process has also built confidence among local communities. As with Landcare's development in Australia, the stage is set for long-term, community-led active adaptive management. Pakistan's government agencies together with national and international donors are well-placed to support the longer-term agenda for locally and collaboratively determined adaptation planning and action. Enhancing capacity for such locally and collaboratively led active adaptive management will be crucial as Pakistan's rural communities adapt and transform in response to the impacts from climate change.

3 Background

The ASSIB project commenced in 2021 to explore how to best 'live with salinity' as a co-inquiry with selected communities in salinity-affected landscapes across the southern Indus Basin. The project built on directions set by prior ACIAR projects: its co-inquiry approach sought to implement and further develop the practice of co-learning with farmers that was a key outcome from the LWR/2014/074 'Farmer Learning' project. The focus on collaborating with salinity-affected communities in the southern Indus Basin was driven by discussions on priority next-step research directions emerging from the LWR/2015/036 'Groundwater' project. Our efforts to better understand trends and drivers of salinity in the landscape also built on the 'Groundwater' project, as well as the Sustainable Development Investment Portfolio's research work by CSIRO involving Pakistan.

The ASSIB project built on these prior projects by bringing together a range of relevant interdisciplinary expertise from Australia and Pakistan, and from the International Center for Biosaline Agriculture (ICBA) based in the United Arab Emirates. Including internationally recognised salinity adaptation experts was recognised early in the project as essential. The opportunity to include ICBA representatives and Professor Edward Barrett-Lennard from Murdoch University, Australia, on the team was therefore embraced. The inspiration-generating and morale-boosting role that ICBA played for the Pakistan project team turned out to be especially important during the initial project period impacted by Covid travel restrictions when they were able to visit Pakistan in January-February 2022, and by hosting the team at UAE in March 2022.

The desire for Australia-Pakistan bilateral collaboration to explore how best to 'live with salinity' was supported by recognition that both countries share challenges of developing agriculture within water-scarce, salinity-affected landscapes. In both contexts, salinity is driven by processes categorised as primary (i.e. a natural phenomenon) and secondary (i.e. human-induced salinity/waterlogging from irrigation). Put another way, salinity has always been part of Pakistan's landscape, but its level and extent are rapidly increasing. This 'secondary salinisation' is primarily a result of irrigated agriculture, with one estimate suggesting that approximately 15 million tonnes of salt are added annually to the Indus Basin (NESPAK & MMI, 1993). Estimates of the extent of salinity vary, with one of the more conservative suggesting that it affects at least 4.5 million hectares of land across the country, and 54% of the lower part of the Indus Basin (Qureshi et al., 2008). Increased dependence on poor quality groundwater, due to limited and unreliable surface water supplies, is accelerating the extent and severity of land salinisation. Impacts from climate change are also emerging as a key driver for increased salinisation, especially along the coastal belt of the Indus Basin.

ACIAR has been responding to the challenge of increased salinity in Pakistan for decades, including by investing in research that led to a handbook into saline agriculture (Qureshi & Barrett-Lennard, 1988), which is highly regarded and still in use. Some ACIAR projects focused on products from saline systems, for example projects FST 1986/033 and FST/1993/016 considered timber and other woody products, CIM/2006/177 sought suitable wheat varieties, and suitable forage species were trialled in projects FOG 1986/019, LWR1/1993/002/ and LPS/2016/022 (Norman & Barrett-Lennard, 2019). Management of on-farm and district saline processes were explored through engineering solutions such as raised-beds in LWR2/1998/131 and LWR/2002/034, and canal and groundwater management in LWR/2005/14. Biological amelioration through plants was attempted, unsuccessfully, in LWR/2000/013. While some of these trials, such as raised-beds and forage species showed that productivity and profitability could be increased, upscaling and uptake has been slow. The findings from ADP/2015/004 are also relevant to this research: policy settings, reactive rather than proactive agencies, and economic constraints feature in the poor scaling-up of the capacity built through the raised-bed project. The inadequate uptake of ACIAR's salinity research recommendations is an aspect where we proposed a new project should make a difference.

As part of the ASSIB project's co-design stage, selected Pakistan-based participants were taken on a field trip through the Murray-Darling Basin in Australia to learn from Australian past and current experiences in salinity management (Mitchell et al., 2020). These participants were especially impressed by their encounters with farmers actively involved in farmer-based organisations such as Landcare. They stayed on the farm of one farming couple who had helped establish a Landcare organisation decades ago to inspire a collective response to the salinity issues their farming community was facing. The impact on project co-design was twofold. First, we recognise that farmers can take the lead in collectively acting and planning for living with their salinity. Second, this is not just about short-term fixes. Living with salinity requires ongoing and adaptive action over the longer-term.

We also commissioned a report during the project's design stage to review Pakistan's salinity management strategies (republished as Ali, 2023). The desktop review highlighted the mixed success of these strategies, and a need to perceive salinity as more than just a biophysical problem that needs eradicating; other options for 'living with salinity' can also be explored. We adopted Ali's (2023) recommendation to pursue a broad, holistic approach through small-scale, community-based pilot investigations co-designed with affected farmers (see Figure 1).

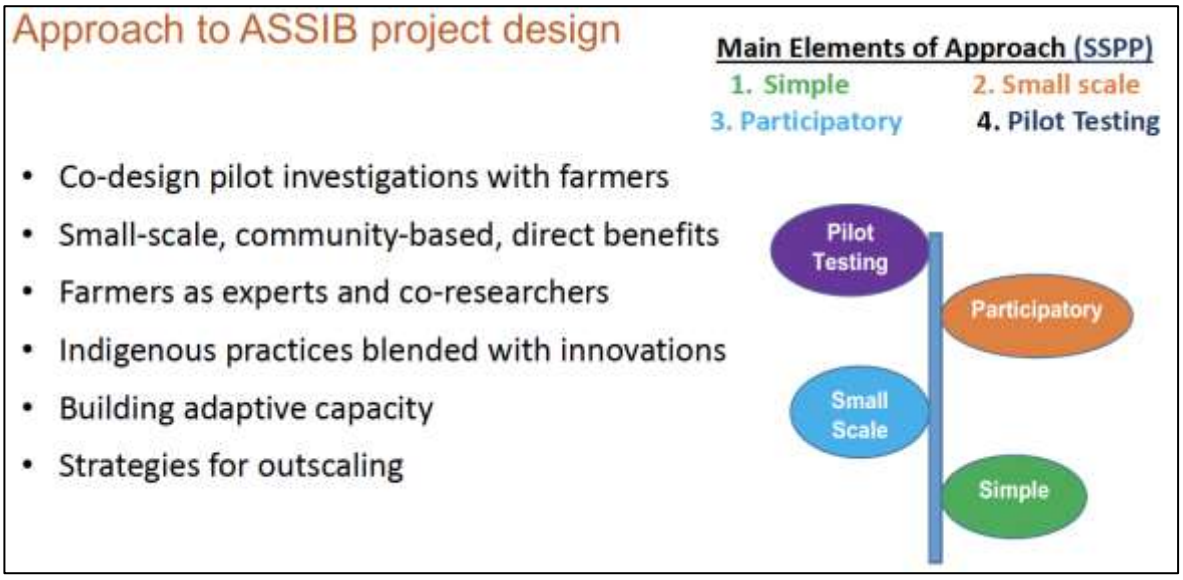


Figure 1: Slide inspired by Ali (2023) used to introduce ASSIB's project design at the National Salinity Workshop held in Islamabad on 15 September 2022 (see Jabeen et al., 2023 for details about the workshop).

The need for farmer participation to enhance the effectiveness of Pakistan's salinity management strategy was further cemented by a follow-up salinity policy review we commissioned to the Pakistan Council of Research in Water Resources (PCRWR) (Ashraf et al., 2022). Their conclusions were drawn from both a review of the literature and interviews with key informants. Their other two recommendations related to enabling capacity for a long-term salinity management strategy and for consolidation of data and research across the multiple entities involved.

The long-term and holistic research agenda needed to address Pakistan's salinity issues also required the team to identify ways to integrate research pursuits across different disciplines. Building on the experience of the LWR/2015/036 'Groundwater' project, we framed this in terms of transdisciplinarity – i.e. "research that traverses across and beyond scientific disciplines, and engages research users and other key stakeholders in its design and execution" (Mitchell et al., 2017, p. 2). Having research users and beneficiaries engaged as part of a project's design stage is an aspect we asserted was a crucial distinguishing feature of ACIAR's approach compared with those of other research-for-development donors, and is an approach we championed (see Figure 2).

In the ‘Groundwater’ project, provincial irrigation departments as research users were key partners from the outset. As that project developed, we recognised that systemic change required behavioural change at multiple levels, not just among groundwater users, but also among groundwater managers (Mitchell et al., 2021). However, for the ASSIB project, our design was influenced by how we envisaged the project could develop over a longer 10-year timeframe. The first ‘formative’ stage of the project would therefore focus on demonstrating how stakeholder engagement might work at a local scale. Our demonstrations sought to emphasise local-level engagement with relevant agricultural service providers, including those employed by provincial government departments (see Section 7.3.1). These local-level efforts to engage with government officials were supported by determined actions to engage higher-level government officials, including the departmental secretaries, to garner their support as well as influence their departmental policy directions. Using these methods, we envisaged that engagement with provincial government agencies would evolve through this first stage, and that these agencies would then be invited to take on a key or lead role in the next stage, as befitting a fully transdisciplinary approach, and as articulated as Intended End-of-Project Outcome 4. The ASSIB project also established an interdisciplinary process for integrating knowledge and theory across disciplines, as described in Section 5. Pakistan-based organisations that had been partners in prior ACIAR projects actively collaborated with the ASSIB project, notably PCRWR, who regularly participated in the project’s coordinating team’s deliberations.

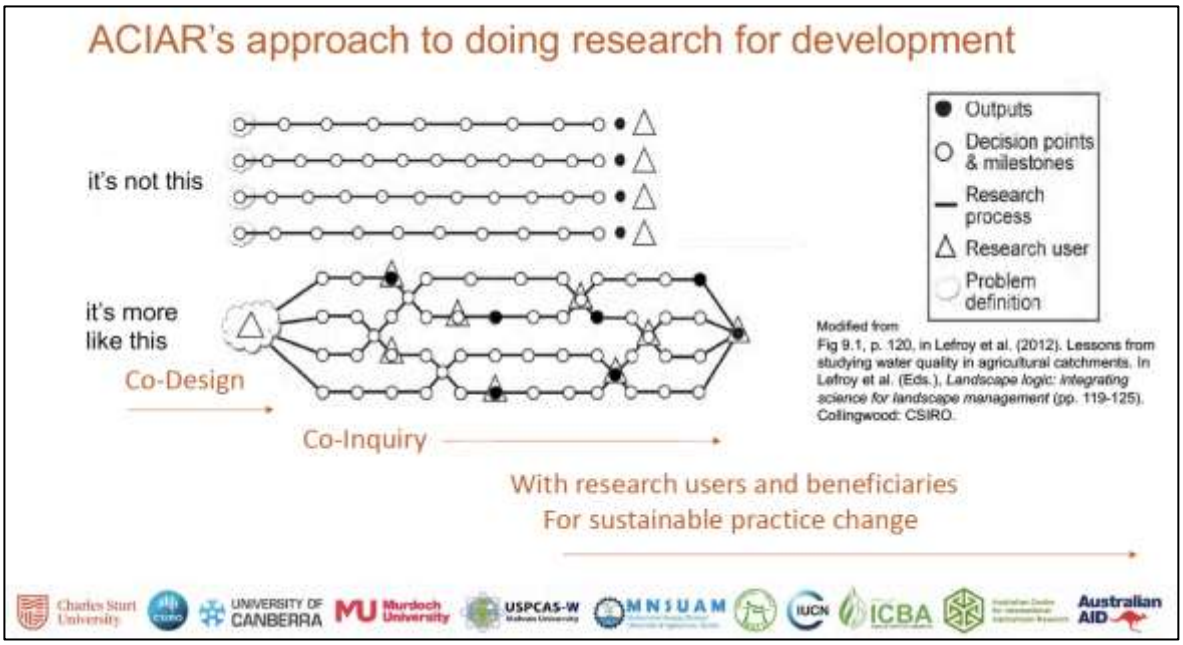


Figure 2: Slide used at the National Salinity Workshop held in Islamabad on 15 September 2022 to champion ACIAR’s approach to project co-design and partnership delivery. Source: Modified from Lefroy et al. (2012), as indicated, with permission from CSIRO Publishing.

4 Objectives

4.1 Aim

The ASSIB project aimed to develop and investigate adaptation options and strategies with people managing and living in salinity affected agricultural landscapes in the southern Indus Basin. As shown in Figure 3, the southern Indus Basin is defined as all areas of the Indus Basin in Sindh and the areas of Punjab south of the confluence of Chenab and Ravi Rivers (two tributaries of the Indus River). Opportunities for collaboration allowed us to extend beyond this area of focus.

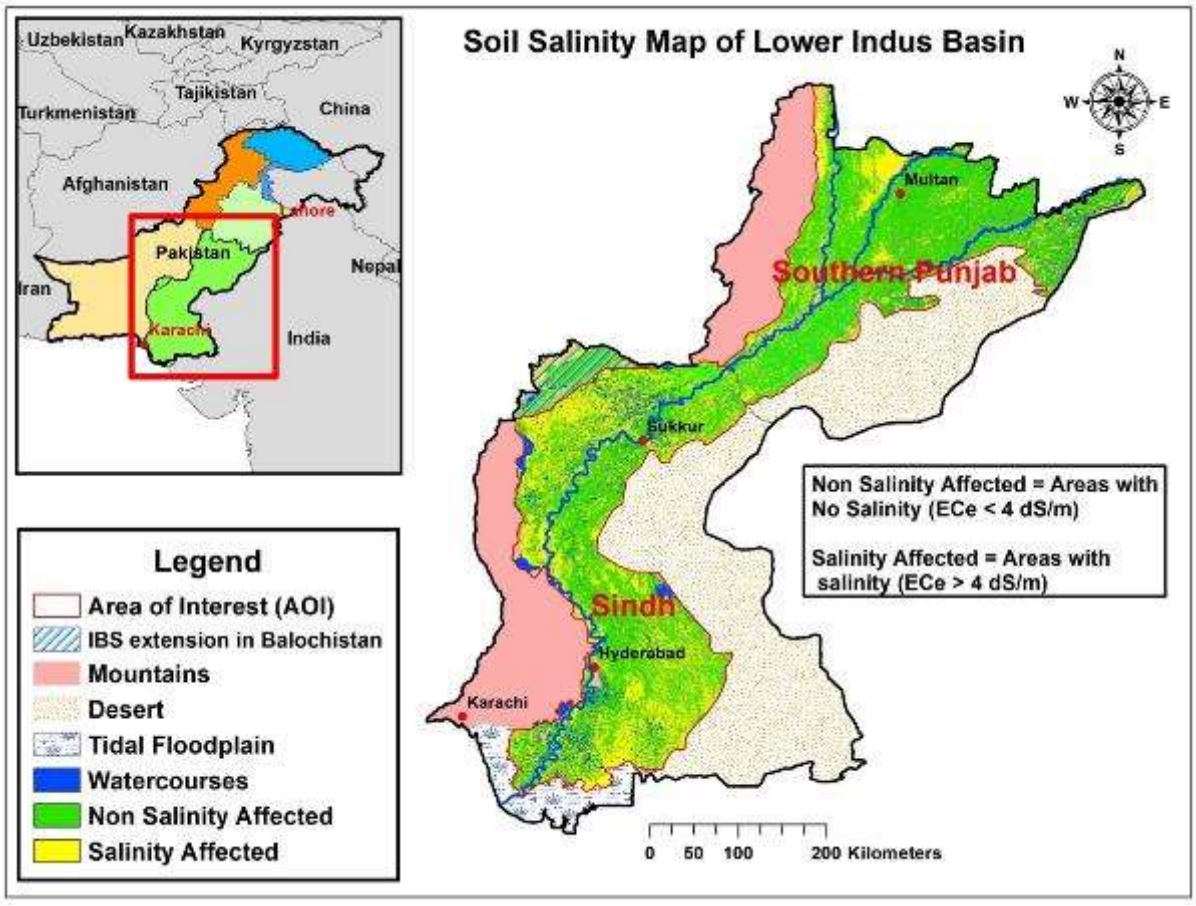


Figure 3: The project's area of interest (AOI) is the southern Indus Basin System (IBS), excluding the area of the IBS that extends into Balochistan

We used a process of participatory impact pathways analysis (IPA) (Christen et al., 2019) to determine a research strategy to deliver the project aim. The use of IPA suited the project's need to account for the complex contexts wherein the project's aim was to be delivered. We developed the IPA using participatory methods to ensure co-design of our research strategy and intended outcomes (Mitchell et al., 2020; Strategy Evaluation and Engagement for Development Pty Ltd, 2019).

The result is that the development of our project's research questions was informed by our collective discussion of what we intended the project would be able to achieve, and vice versa: the research questions also informed how we envisaged our project's impact pathways. We endorse Christen et al.'s (2019) recommendation to use participatory IPA as a fundamental element of transdisciplinary project co-design.

4.2 Research Questions

The ASSIB project sought to address the following research questions as a first step in a longer-term 'living with salinity' research agenda:

1. What are the current and possible future trends (biophysical and social/institutional) in relation to agricultural production systems in salinity affected landscapes across the southern Indus Basin?
2. What are the currently available options for adapting to salinity, and the features that influence (positively or negatively) their effectiveness, uptake, spread and continued use?
3. What capacity building is required, and among whom, to ensure that affected agricultural communities are supported and encouraged to choose and plan their own futures for adapting well to salinity?

As the project unfolded, it became apparent that research questions 2 and 3 manifested as though they were two sides of the same coin. Because our investigations into salinity adaptation options involved co-inquiry with salinity affected communities, we were at the same time investigating and demonstrating best practice approaches for building community adaptive capacity.

4.3 Intended Project Outcomes

We were one of the first ACIAR projects to use a new project proposal template that had been designed to ensure the project's intended outcomes appeared upfront so that these were seen to inform the project's intended implementation. We welcomed being pioneers to use the new template as it fitted well with our use of participatory IPA as a co-design method.

The intended end-of-project outcomes we envisaged in the co-design stage remain unchanged, as follows:

1. Newly developed and existing knowledge about salinity in the southern Indus Basin of Pakistan is available for the staff of Pakistan-based projects, programs and organisations relevant to agricultural development.
2. The project's case study community members and their institutional support networks have improved understanding of the opportunities for, and constraints to, current options for adapting to salinity.
3. Individuals and groups (including women and youth) from the project's case study communities are building capacity to plan their own futures for adapting well to salinity.
4. Relevant government departments, policy makers, donors and other institutions have engaged with and are supporting locally and collaboratively determined adaptation planning and action, including through co-development of future participatory research projects.

The full IPA is attached as Appendix 1.

We have been able to achieve these outcomes to varying extents, as discussed in Sections 7 and 8.

5 Methodology

The project's co-design stage established some key elements for the ASSIB project methodology:

1. The ASSIB project was initially perceived as part of a longer-term participatory action research program. The initial project would demonstrate the value of co-inquiry research to form the foundation for a future 'living with salinity' research agenda that would eventually be directed by Pakistan-based agencies working collaboratively with affected communities at multiple scales.
2. Systemic inquiry was identified as another basic research operating premise necessary for pursuing the broad, holistic approach recommended by Ali (2023).
3. We pursued this holistic systemic inquiry at multiple scales so that the results involving broader trends impacting presence of salinity in the landscape informed the kinds of adaptation responses we could recommend with affected communities at local scales, as well as among the regional, provincial and national scale organisations with responsibilities to support farmers and fish-farmers.
4. Our priority was thus to demonstrate that co-inquiry research for living with salinity can be established through co-design with farmers and others living in salinity-affected communities, and then implemented on-property by farmers and fish-farmers taking the lead.

5.1 Participatory Action Research

Many ACIAR projects have adopted participatory action research as their mode of operation. First described in the 1970s (Chambers, 1974; Hall, 2005; Fals Borda, 2006, Woodward & Hetley, 2007), the concept of 'participatory action research' links back to 1940s descriptions of action research (Lewin, 1946). The participants in such approaches are usually perceived as being communities of place, but participatory action research can also be undertaken by researchers collaborating with organisations, or through building collaboration between communities of place and organisations, as has been the case for the ASSIB project. We therefore identified participatory action research as core to our longer-term research methodology in the early design stage.

The impetus behind developing a longer term 'living with salinity' research program can be sourced to ACIAR's In House Review (IHR) of the LWR/2017/027 preliminary project proposal submitted in June 2018. The IHR saw 'living with salinity' as an admirable focus for how Australian researchers could collaborate with their Pakistan partners to respond to a complex issue shared by both countries, and asked us to re-fashion the proposal as part of a longer-term program that would evolve over ten years. Such a long-term integrative and transdisciplinary approach was recommended given the complexity and dimensions of the challenges to be addressed (Christen et al., 2019). Drawing on inspiration from SIAGI, another ACIAR project (LWR/2014/072), we developed a strategy that would evolve through three stages: formative research, participatory research, and action research (Jana & Carter, 2018). The formative–participatory–action staging is intended to explain how a longer-term research approach can be built that gradually facilitates increasing participation and eventual ownership of the research by the intended users and beneficiaries of the research (as modelled through the typology shown in Figure 4).

With reference to Figure 4, the ASSIB project sought to shift the 'mode of participation' beyond one of 'collaboration' among local communities, outside researchers and other stakeholders, so as to demonstrate how a 'co-learning' mode would work in practice. In terms of the staging, we saw this as a key outcome of the 'formative stage', which would then further evolve through a 'participatory' stage. But Figure 4 can also be interpreted in a different way. Instead of the 'local community' understood as being ASSIB's bright spot

communities, the local community can also be interpreted as Pakistan-based researchers who are in a co-inquiry relationship with Australian-based researchers. If interpreted in this way, the vision for the longer-term 'living with salinity' research agenda would become characteristic of 'action' research, i.e. where the Pakistan-based organisations would take over responsibility to direct and implement the 'living with salinity' research agenda.

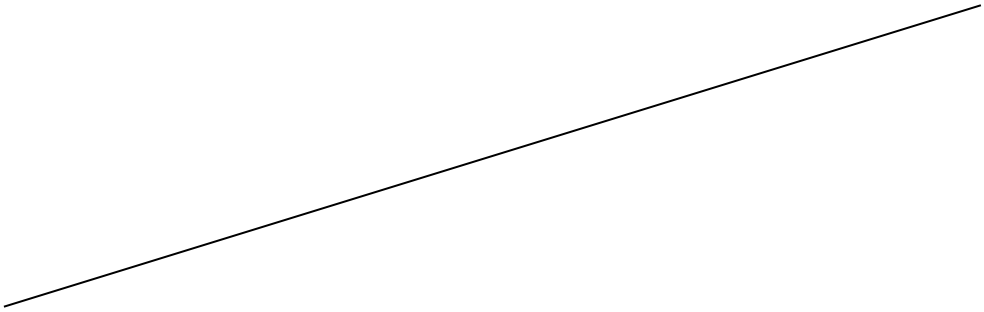
Input into decision making of project – what to study, how, collecting data, analysing, conclusions						
Mode of participation	Cooption	Cooperation	Consultation	Collaboration	Co-learning	Collective action
Role of community	Subjects	Employees, subordinates	Clients	Collaborators	Partners	Directors
Type of participation	Tokenism: representatives are chosen but have no real input or power	Tasks are assigned with incentives, outsiders decide agenda & direct the process	Options asked: outsiders analyse information and decide on a course of action	Local community work together with outsiders to determine priorities; outsiders have responsibility for directing the process	Local community & outsiders share their knowledge to create new understanding & work together to form new action plans; outsiders facilitate	Local community set & implement their own agenda

Figure 4: A typology of participatory research as a continuum of approaches. Source: Mitchell (2008) based on Race & Buchy's (1999) adaptation of Cornwall's (1995) typology

5.2 Systemic Inquiry for Enhancing Adaptive Capacity

Systemic inquiry was adopted as fundamental to the research methodology for the longer-term 'living with salinity' research aim of enhancing rural community adaptive capacity. This decision was made during the project's co-design stage, influenced by documented lessons from Landcare in Australia (e.g. Curtis, 1998; Robins, 2018) and overseas (e.g. ACIAR's LIFE project in the Philippines ASEM/2012/063), and research related to climate change adaptation (Folke et al., 2010; Nettle et al., 2015; Panda, 2018) and systems thinking (Colvin et al., 2008; Ison, 2010). We provide a brief review of the literature below to elaborate on systemic inquiry as a methodology for enhancing adaptive capacity.

Humans individually and collectively are unique among species in being able to anticipate futures, and make decisions accordingly (Davidson, 2010; Tschakert & Dietrich, 2010). The LWR/2017/074 project led by Sandra Heaney-Mustafa emphasised the potential for collaborative problem solving, asset-based community development and farmer-facilitated whole-of-community co-learning as integral to how rural communities can enhance their capacity for sustainable change. Despite this, only a few natural resource management organisations have put adaptive planning and management into practice, with Australian-based organisations being trailblazers (Sellberg et al., 2018). There is even less experience of how to build adaptive capacity among natural resource dependent communities, with Australia again taking a lead (Jacobs et al., 2016).

Globally, farmers often rely on passive responses to climate change (e.g. Tripathi & Mishra, 2017), and so we sought to explore and support strategies for active adaptive management. For communities to take a more active approach requires strategic planning at a range of scales through improved access to better knowledge. This includes how farm-scale adaptations link with broader-scale marketing opportunities as explored

through value chain analysis, including the role of bridging and bonding social capital between producers and government, non-government and business entities (Canevari-Luzardo et al., 2020). We also expect that the adaptation response for some communities living in salinity affected landscapes will be transformational in character, requiring capacities for both adaptation and transformation to be considered and explored (Folke et al., 2010; Maru et al., 2017; Panda, 2018).

The research opportunity also means exploring how to build adaptive capacity within the constraining rigidity of existing policy and practice (Allan et al., 2013; Benson & Craig, 2014; Benson & Garmestani, 2011; Mitchell et al., 2014), as well as the time and other boundary constraints imposed by operating through 'projects' (Allan, 2012). There are many extant challenges to building collaboration and a partnership approach among different government departments and levels, among government and non-government organisations and the private sector, and between communities and organisations. Although challenging, such collaborations are essential to move beyond reactive responses to the symptoms of living with salinity, and towards proactive and anticipatory actions that tackle the systemic drivers that constrain adaptability and the enhancement of livelihoods for communities living in salinity affected landscapes.

5.3 Enacting Systems Thinking at Multiple Scales

To put the methodology of systemic inquiry into practice, we sought to integrate research undertaken at multiple scales. The broader systemic context – related to drivers, trends, extent and impacts of salinity – was principally driven by the biophysical scientists working at the Indus Basin level, as well as targeted regional scale levels.

Offering evidence of the extent of salinity-affected areas across Pakistan has long been vexed by reliance on decades-old land surveys, and diversity in more recent estimates. Using land surveys to establish the extent of salinity requires significant investment of time and money, which helps explain why they have not been undertaken for decades. Instead, there has been growing appreciation for the prospect of interpreting salinity presence in the landscape using satellite imagery, which provides expansive, high precision and regularly updated remote sending data. There are also well-recognised limitations of existing disaggregated datasets for the regional-scale areas selected. This influenced the project's CSIRO team members to investigate a novel approach to understand land cover and associated salinity dynamics using advanced geo-information techniques, the results from which are described in Section 7.

The areas chosen for regional-scale analysis were collaboratively determined by the two teams leading this research (CSIRO-led trends analysis research team, and the multi-partner team involved in groundwater modelling and management research). Their discussions were informed in part by the initial Ahmad et al. (2021) Indus Basin Irrigation System (IBIS) water balance analysis that confirmed IBIS canal command areas with significant issues arising from groundwater overuse. Two canal command areas were selected, one for South Punjab, and one for Sindh (see Figure 5). In South Punjab, the Sidhnai, Mailsi, and Lower Pakpattan were selected as areas with deep and rapidly declining groundwater. The project's 'bright spot' communities (as explained below) located near Jalalpur are located within this area. In Sindh, the Pinyari canal command area was selected due to problems from the variability in shallow and saline groundwater conditions being experienced. Another of the ASSIB project's 'bright spot' communities, Sujawal, is located at the tail end of the Pinyari canal command area. The groundwater modelling work extended the area of its modelled analysis beyond Pinyari canal command area to take in the coastal areas of Sujawal district.

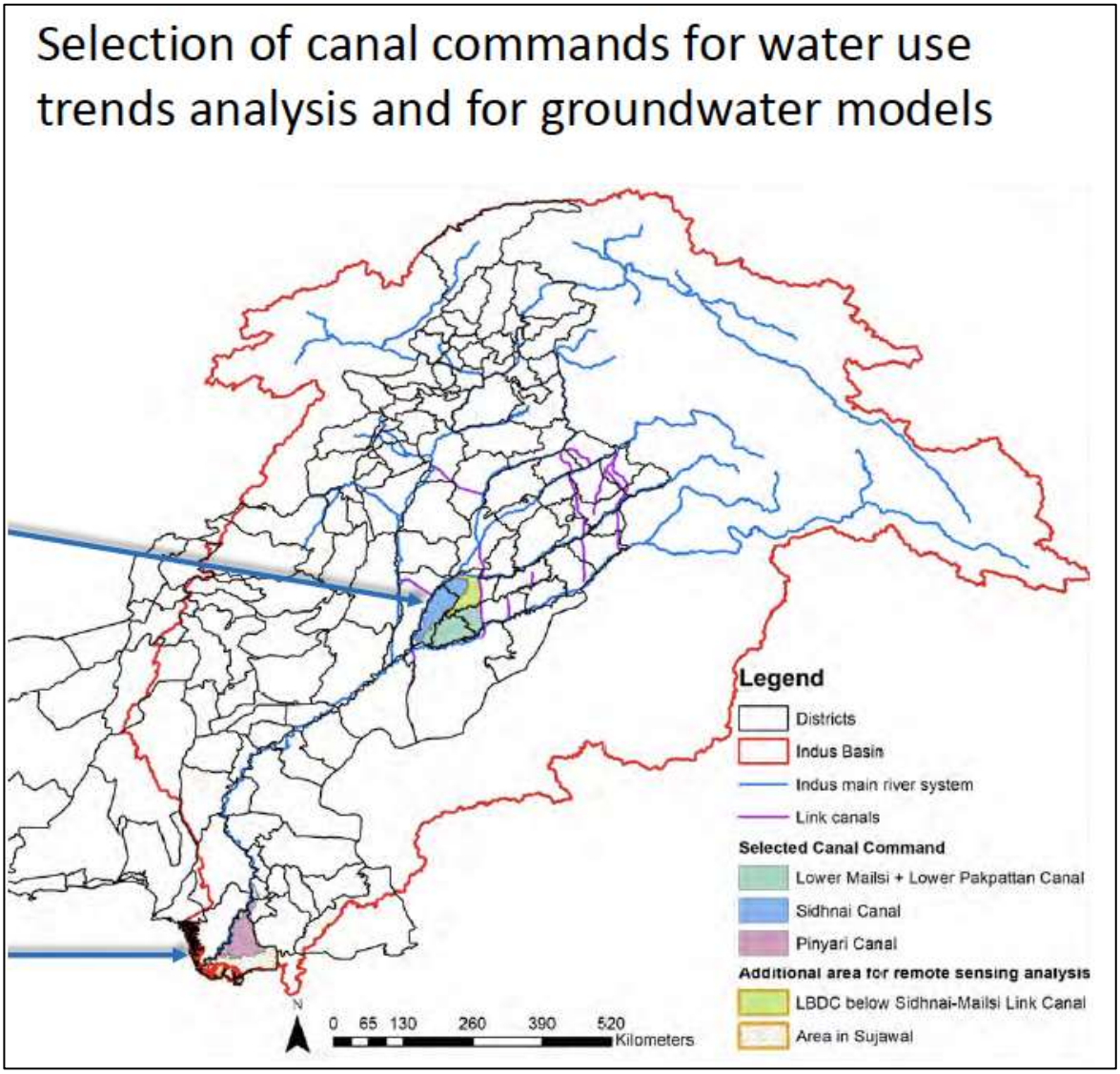


Figure 5: Excerpt from slide used at the National Salinity Workshop held in Islamabad on 15 September 2022 to show the regional-scale study areas.

5.4 Local-Level 'Bright Spot' Community Selection Process

To pursue systemic interventionist action research (Midgley, 2003), we needed to identify local-level communities exhibiting potential to take advantage of co-inquiry. As part of the project's co-design stage, we adopted the term 'bright spot' to describe communities we would identify as having the potential for "sustaining and perhaps enhancing their livelihoods through active community-driven adaptations" (Mitchell et al., 2020, p. 13). Noble et al. (2006) had originally used 'bright spot' as a term to describe simple innovations adopted by farmers that improved their livelihoods while enhancing resource use sustainability. We applied the term to describe communities, developing a nomination process and set of selection criteria (as listed in Appendix 2). The first selection criterion was "a partner or collaborating organisation willing to champion collaborative research activities with the community (usually the organisation providing the nomination)." This enabled IUCN, MUET and MNSUAM to nominate communities with whom they had already established collaborative relationships that they could then build on and entrench. In the case of IUCN, their long-term active engagement with coastal communities near Keti Bandar (Tippun Dublo) was significant, with an articulate and active member of the community employed as one of their community mobilisers from the outset. MUET was also able to build on prior co-inquiry research engagements developed with a community along the Malwah distributary through the 'Groundwater' project (LWR/2015/036).

Using the nomination process, five communities were pre-selected prior to the start of the project (three in Sindh: Malwah, Sujawal and Tippun Dublo; and two in Punjab: Jalalpur Pirwala and Muzaffargarh – see Figure 6). In the case of Jalalpur, our co-inquiry research activity in one village (Basti Kulab) drew the attention of a farm labourer living in another village (Meerkot). This occurred early in the project, with co-inquiry research activities held simultaneously throughout the project in both villages. Our collaboration with a consortium headed by Sindh Agriculture University (SAU) led to the prospects of two more 'bright spots' being selected (in the districts of Tando Muhammad Khan and Mirpurkhas), but co-inquiry activities with these communities did not proceed due to disruptions associated with the national flood emergency of 2022, which affected both communities severely. These disruptions also prevented co-inquiry activities from proceeding at Sujawal. Instead, we took advantage of the impact of the flood event on an individual property nearby to the proposed Tando Muhammad Khan 'bright spot' community, which was owned by an SAU academic. This property was used to conduct field-based trials involving a range of salinity adaptation options (see Rajpar, 2024). Our collaboration with PARC's Arid Zone Research Institute led to the nomination of villages in Cholistan where some successful co-inquiry activities took place. These represented a strategic extension that took our 'living with salinity' co-inquiry research to the edge of the IBIS and beyond.

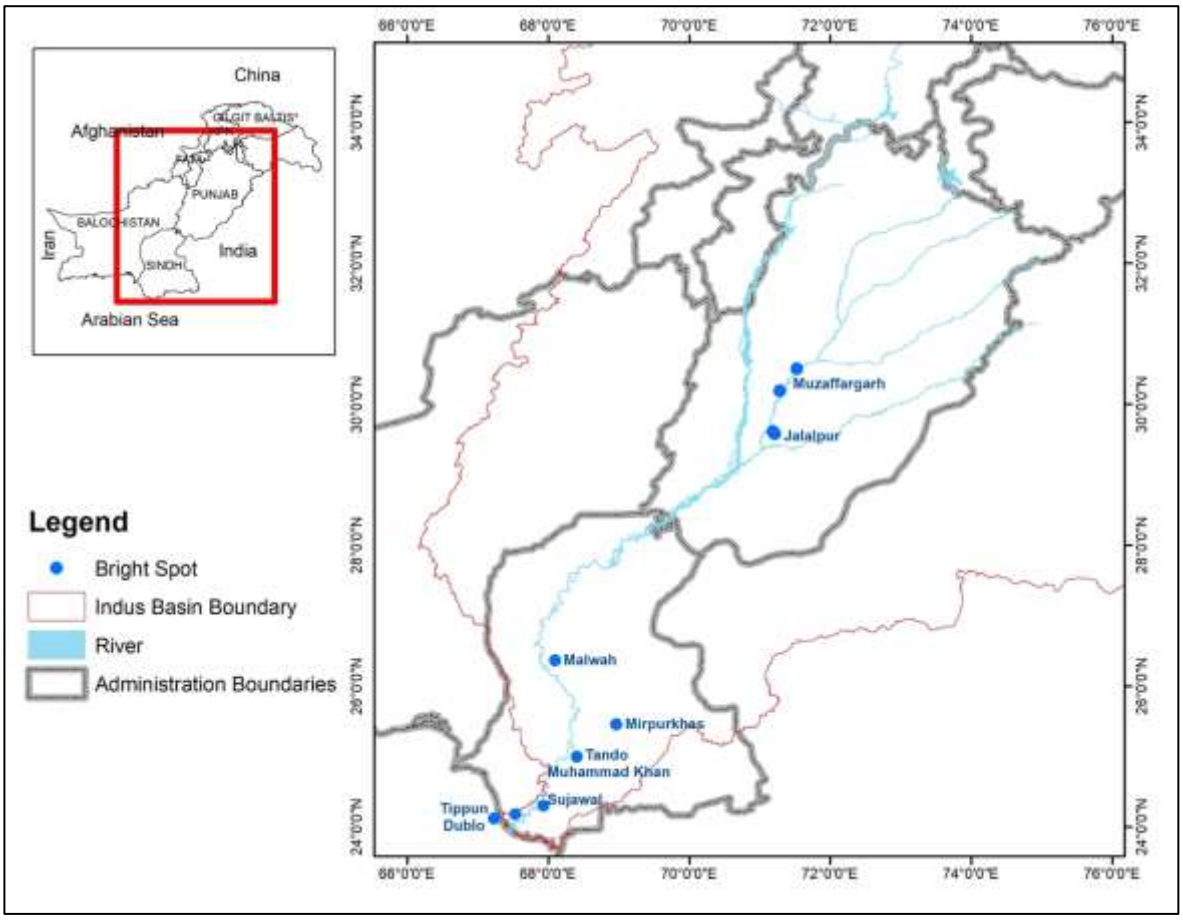


Figure 6: Locations of 'Bright Spot' Communities who Collaborated with the ASSIB Team

5.5 Co-design and Co-inquiry with Communities Living in Salinity-affected Areas

The structure of the collaborative research within the bright spot communities was the 'Stakeholder Engagement for Research and Learning' (SERL) approach to co-design and co-inquiry with the 'bright spot' communities. SERL is described in detail in Heaney-Mustafa et al. (2023) and summarised in Section 7.3.1 below.

6 Achievements Against Activities and Outputs/Milestones

Research Question 1: What are the current and possible future trends (biophysical and institutional) in relation to agricultural production systems in salinity affected landscapes across the southern Indus Basin?

No.	Activity	Outputs/ milestones	Completion date	Comments
1.0	Create a Data Repository	ASSIB repository Data portal	Mar 2024	ASSIB documents repository has broad access by ASSIB team members and others. Data portal has restricted access. Permanent home at MUET.
1.1	Republish Ali (2018) Report	Ali (2023)	Aug 2023	Gulbali Report No. 1
1.2	Surface Water and Cropping Trends Analysis	Ahmad et al. (2021a; 2023) Gao et al. (2023; under review) Peña-Arancibia et al. (2023; under review)	May 2024	4 peer-reviewed publications (2 under review). 2 internal CSIRO reports. List of outputs does not include conference presentations and fact sheets. See Section 7.1.1
1.3	Groundwater Monitoring and Modelling	Raheem et al. (2022; 2024a; 2024b; under review) Ahmed et al. (2024b) Jamali et al. (2024; in preparation) Punthakey & Raheem (2024) Punthakey et al. (2024)	May 2024	1 peer-reviewed paper included in conference proceedings. All reports led by Pakistan-based early career researchers. 2 journal articles led by Pakistan-based early career researchers being prepared for submission before end of June 2024. Policy briefs and fact sheets also produced. See Section 7.1.1 and 7.1.2
	Documents Detailing how MUET & MNSUAM can Contribute to Water Resource Management and Planning	Workshops led by MUET and MNSUAM	Jun 2024	Preparatory discussions held with SID/ SIDA & PID in 2023-2024 Workshops held with SID/ SIDA & PID in May 2024. Workshop outcomes included as part of Lashari & Memon (2024) Future Research Roadmap – see Activity 3.5.
1.4	Policy Review	Ashraf et al. (2022)	Mar 2022	Workshops held and policy brief used to disseminate results and recommendations.
	Institutional Analysis	5 internal reports with 2 analysed 2 workshops Mitchell & Bond (in preparation) Nadeem et al. (in preparation)	Jun 2024	'CIAD' institutional analysis reports prepared for 5 communities. 2 of these reports (for Malwah and Jalalpur) analysed to offer recommendations for building community adaptive capacity, with workshops held to provide feedback. Mitchell & Bond (in preparation) draws on reflections by ASSIB co-researchers. Nadeem et al. (in preparation) presents a case study application of CIAD.

1.5	Future Trends Analysis	Ahmad et al. (2021b) Kirby & Ahmad (2022a)	Mar 2022	2 peer-reviewed publications. List of outputs does not include conference presentations and fact sheets. See Section 7.1.1

Research Question 2: What are the current available options for adapting to salinity, and the features that influence (positively or negatively) their effectiveness, uptake, spread and continued use?

No.	Activity	Outputs/ milestones	Completion date	Comments
2.1	Salinity Adaptation Framework and Guidance	Land and water capability assessment framework and survey.	Jan 2022	Survey has been extensively trialled and used; translated into Urdu. Forms the basis for the mobile and web-based application (Activity 3.2).
		Pakistan team trip to UAE hosted by ICBA.	Mar 2022	Internal report of learnings produced, available upon request.
		Workshops to obtain feedback on draft handbook.	Sep 2023	Draft salinity handbook launched at International ACIAR Salinity Futures Symposium; being considered by ACIAR for publication.
		Barrett-Lennard handbook drafted (under review)	Mar 2024	
2.2	Merged with Activity 3.1			
2.3	Value Chain Analysis	2 internal reports forming the basis for Ahsan et al. (under review a; b)	Jun 2024	The journal article led by a Pakistan-based early career researcher presents value chain systems analyses of okra and pomegranate as two salinity tolerant interventions subject to investigations by Jalalpur farmers.
	Representative Agricultural Pathways (RAPs)	Ashfaq et al.'s (2023) internal report forms the basis for Alam et al (in preparation) Alam et al. (2024)	Jun 2024	The journal article led by a Pakistan-based early career researcher presents an analysis of the outcomes from the LWR/2015/036 project's use of RAPs. The second report details preliminary developments in the use of RAPs to support the Jalalpur and Dera Haibat communities develop longer-term plans for adapting to salinity.
2.4	Scaling Out Strategy	Salam et al. (2024) Heaney-Mustafa & Ashraf (2024) Farmer-to-farmer training materials available at repository	Jun 2024	The first report published by PCRWR details 'sun-satellite model' experience of farmer-to-farmer learning by ASSIB 'bright spot' communities. The second report combines that experience with the farmer-to-farmer facilitated scaling out strategy adopted by the ASSIB project.

Research Question 3: What range of capacity building efforts are required, and among whom, to ensure that affected agricultural communities are supported and encouraged to choose and plan their own futures for adapting well to salinity?

No.	Activity	Outputs/ milestones	Completion date	Comments
2.2 & 3.1	Salinity Adaptation Co-inquiry	>100 feedback cards, success stories, brochures, posters and other reports and 17 SERL workshop reports available at repository. Heaney-Mustafa et al. (2023) Faried et al. (2024); Jarwar et al. (2024); Qureshi et al. (2024); Soomro et al. (2024) Rajpar (2024)	Jun 2024	SERL guidelines published. Listed are 4 technical reports prepared for publication related to the 3 'bright spot' sites that have become the project's 'demonstration' sites for the future, plus an internal report on field trials run by an SAU academic. 4 Pakistan-based early career researchers and 1 MUET professor have taken the lead to prepare 6 journal articles based on their experiences of co-inquiry with the 'bright spot' communities: Kumbhar et al. (under review); Malik et al.; Mohiuddin et al. x 2; Qureshi et al.; Riaz et al. (all in preparation) See Sections 7.2 to 7.4.
3.2	Decision Support Applications	Khan et al. (2024)	Jun 2024	A journal article building on Khan et al. (2024) is in process. See Sections 7.1.1 and 7.1.2.
3.3	National Salinity Workshop 2022	Jabeen et al. (2023)	May 2023	Report summarising stakeholder engagement to date included with Annual Report 2022-23
3.4	International ACIAR Salinity Futures Symposium	Jabeen & Lashari (2024) Symposium Booklet	Event held in Mar 2024 Summary report May 2024	35 ASSIB project team members participated (3 additional team members were unable to attend at the last minute). 18 team members contributed to 11 oral presentations. 10 team members gave poster presentations. 19 4-page abstracts by team members were included in the symposium booklet.
3.5	Salinity Research Roadmap	Lashari & Memon (2024)	Jun 2024	Published Nov 2024, includes 3 future project Concept Notes as appendices
3.6	Impact Evaluation	Allan et al. (2024) Allan et al. (in preparation).	Apr 2024	The Allan et al. (2024) report forms the basis for the journal article (Allan et al., in preparation).

7 Key Results and Discussion

In keeping with the ASSIB project's emphasis on its impact pathways analysis, we have organised presentation of our key results according to the project's intended outcomes.

7.1 Results Related to Outcome 1

Newly developed and existing knowledge about salinity in the southern Indus Basin of Pakistan is available for the staff of Pakistan-based projects, programs and organisations relevant to agricultural development.

7.1.1 Development of Knowledge on Salinity Trends and Impacts

This sub-section includes results related to the biophysical aspects of the ASSIB project's first research question: i.e. current and possible future trends in relation to agricultural production systems in salinity affected landscapes across the southern Indus Basin.

Surface Water and Cropping Trends Analysis

Irrigation has been well-established as a driver behind secondary salinisation across the Indus Basin Irrigation System (IBIS) in Pakistan. Improving knowledge of IBIS surface water flows will thus inform presence of salinity in the landscape in ways that could prompt recommended policy and practice change. To this end, the ASSIB project developed the first consistent long-term (1981-2012) water balances across the IBIS canal commands (Ahmad et al., 2021a). This analysis supported existing information used to identify key canal command areas where groundwater use is becoming less sustainable, guiding the project, together with other initiatives in Pakistan, to focus on the canal commands of South Punjab (Sidhnai, Mailsi, and Lower Pakpattan, with deep and rapidly declining groundwater) and southern Sindh (Pinyari, with shallow and saline groundwater conditions) for detailed investigations.

Given limitations of existing disaggregated datasets for such canal command areas, we applied advanced geo-information techniques to provide remote sensing based systematic high-resolution (30 m) assessments at 10-day intervals to understand trends in water use (evapotranspiration), seasonal land cover and associated salinity dynamics at regional scales (South Punjab and southern Sindh) (Ahmad et al., 2023; Gao et al., 2023; Peña-Arancibia et al., 2023; Gao et al., under review; Peña-Arancibia et al., under review). This analysis provided a unique spatially disaggregated quantitative understanding of the gap between water supply and consumption and its relationship with shifts in land use dynamics towards aquaculture and water-intensive crops. It revealed that, despite continuing declining groundwater in Punjab, there is shift towards water intensive land use such as rice, maize, and aquaculture. Based on this analysis, different management strategies were identified, especially to improve management of water demand management. These recommendations have been discussed with provincial stakeholders and documented in fact sheets for broader dissemination.

The investigation into future trends related to system-scale water availability focused on the key issues of climate change and dam sedimentation (Ahmad et al., 2021b). This analysis identified that climate change is likely to reduce the reliability of surface water supplies, especially in Rabi season and result in increased the crop water demand (under existing cropping patterns). Scenarios of potential spatial change of different crops implied by the changes to surface water supply and demand were also investigated. These findings reinforced the longer-term need for farmers to implement mulching as a strategy championed by ASSIB 'bright spot' communities to reduce non-beneficial evaporation in agriculture areas, which will increase with climate change.

The future water trends analysis was extended to consider other factors, including growth in population, food demand and GDP (Kirby & Ahmad, 2022a). An integrated population-GDP-food-water model was developed to examine the impact on groundwater demand under a set of development scenarios for Pakistan relevant to food and water security (Kirby & Ahmad, 2022a). While predicted groundwater demand varied under the different scenarios, results suggest initial worsening conditions of increased demand until later in the 21st century when the population growth rate is expected to slow and crop yields increase. The impacts of climate change on water supply and demand were also found to be uncertain: a hotter future climate will worsen the situation, while a wetter climate might reduce the severity. The key message that arose from this research is that, under any plausible future climate scenario, Pakistan faces serious water challenges, unless multiple mitigation and adaptation strategies are implemented immediately and concurrently (Kirby & Ahmad, 2022a).

Groundwater Modelling

Future scenarios were also produced using groundwater modelling simulations developed for the two regional areas (Southern Bari doab in South Punjab – see Raheem et al., 2024a; and Pinyari canal command area and coastal Sujawal in Sindh – see Jamali et al., 2024). Excessive pumping and impacts from climate change were the focus for the former; the latter investigated strategies to manage waterlogging and salinity which is widespread in the coastal district of Sujawal, and mapping of freshwater lenses that can be used by communities for small-scale agriculture, domestic and livestock needs. In the coastal zone, the modelling focused on potential future strategies to reduce climate change driven impact of seawater intrusion. These models and scenario outputs were developed in consultation with the relevant provincial irrigation departments, with one of the reports (Raheem et al., 2024a) co-authored by a groundwater specialist employed at the Punjab Irrigation Department. Our emphasis has been that these models are there to be used and updated by these agencies. We also produced companion reports offering advice on strategies to improve groundwater monitoring and management for the two provinces (Raheem et al., 2024b; Ahmed et al., 2024b).

- ***South Punjab***

Summary: A significant concern in South Punjab is the escalating depletion of groundwater which is used to supplement shortfalls in surface irrigation supplies. Resource managers and water policy experts have long advocated the need to improve irrigation efficiency. Yet water savings are often used to expand irrigation or increase cropping intensities. To better understand groundwater dynamics into the future, the groundwater team simulated a range of climate change scenarios to understand possible future outcomes from increasing groundwater use for agriculture and its consequential impact up to 2100. What they found was that increased groundwater use trends coupled with climate change poses an existential threat to agriculture and livelihoods in South Punjab. By quantifying the extent of the impacts for the first time, the team found that a tipping point would be reached around 2040 beyond which groundwater level declines will increase dramatically. The window for changed management is thus about 15 to 20 years away before current practices start to severely impact on food security and livelihoods in South Punjab. To understand how agriculture and water management practices will need to change, the team simulated a mix of adaptation strategies, including changed cropping strategies, enhanced recharge, and nature-based solutions. What they found was disturbing. Despite implementing these adaptation strategies, groundwater declines and salinity mobilisation would continue to impact on agricultural livelihoods. This suggests new strategies will be required to adapt water and land management practices to the looming threat of climate change.

In detail: The South Punjab model indicated that between 2010 and 2020, pumping accounted for 91.9% of outflow from the aquifer underlying the Southern Bari doab canal command area, resulting in a decline in net groundwater storage of -517.4 MCM/yr. Using

climate change scenarios, it was projected that groundwater pumping would increase and leave a large area of the modelled top layer dried out. Such increased levels of pumping will not be sustainable and will have long term impacts on the quantity and quality of groundwater. To monitor actual groundwater conditions, PID currently relies on around 3,300 piezometers and 4,000 farmer-owned tubewells, which are monitored biannually for groundwater level and quality. 'Hot spot' areas with continuously declining groundwater levels and/or emerging water quality issues will require instrumenting bores with water level, temperature and EC loggers to provide reliable time-series data, which will be essential to allow for informed groundwater management and planning decisions.

A key suggested strategy emerging from the South Punjab modelling analysis is increased use of managed aquifer recharge (MAR). While MAR has not yet been widely adopted in Pakistan, large-scale MAR projects are currently being considered by PID, including to divert monsoon flood waters from the Islam Barrage into the Old Mailsi canal (Zakir-Hassan, 2023). Such projects offer a framework through which PID could consult with agricultural water users in the area to help select locations best suited. By engaging with farming communities, capacity building to improve on-farm water management, climate smart agriculture and other options for managing declining groundwater levels and quality can be pursued in tandem, especially for identified 'hot spot' areas. Engaging with groundwater users and irrigators is necessary to co-design active adaptive management approaches to sustainably manage groundwater use given future stresses, especially from climate change (see, for example, the strategy involving Use of Representative Agricultural Pathways, pursued in a nearby area described by Nasir et al., 2021).

More broadly, moderating the impacts of overexploitation of groundwater and insufficient surface water supply under projected climate change conditions will require additional options for managing groundwater sustainably. A vital component for designing additional adaptation options is the development of area-specific groundwater management plans and associated co-development of a water-sharing plan with strong community buy-in (Punthakey et al., 2021; Ahmed et al., 2024a). As knowledge of each area involved increases, and there is greater trust between institutional actors and groundwater users, the regulation of pumping may also be required in 'hot spots' to allow equitable access to groundwater for smallholder farmers.

A policy brief related to groundwater in South Punjab has been developed (Punthakey & Raheem, 2024), along with two fact sheets for PID:

1. Climate Change Impacts on Availability of Groundwater Resources in Southern Punjab: Adaptation Strategies for Groundwater Sustainability.
2. Groundwater Sustainability in Southern Punjab: Policy Guidance to Improve Groundwater Management.

- ***Sujawal and Coastal Sindh***

Summary: A range of climate change scenarios were simulated for Sujawal including its coastal areas to understand possible future outcomes from reduced canal water supplies for agriculture and climate induced rising sea levels and their consequential impacts up to 2100. A mix of adaptation strategies were then simulated, including transforming cropping systems towards water efficient crops, and nature-based solutions in the coastal belt. The findings from these scenarios were disturbing. Despite implementing these adaptation strategies, waterlogging and salinity would only be marginally reduced, while salinity mobilisation under climate change would accelerate. The team's simulation of nature-based solutions and changed cropping strategies show that adaptation option will help communities to adapt, but only for a limited time. In the longer term, climate change impacts will force institutional actors and communities to find new adaptation options and strategies. For example, the team found that green barriers would help in the medium term but, as sea levels continue to rise, new strategies including engineering options such as barrier dikes, vertical drainage, and the politically difficult task of increasing flows in the Indus River will be required to reduce the impacts of sea level rise.

In detail: For Sujawal, a key constraint for farmers using groundwater is that watertables are generally shallow and the groundwater is too saline for irrigation. This means that the primary source of irrigation is via the Pinyari Canal, which is non-perennial. Such canal supplies are only available during the kharif (wet) season, but this is when waterlogging and salinity are widespread in parts of the command. Agriculture during the rabi (dry) season is marginal and rainfall dependent. Some clever farmers have acquired skills to judiciously use freshwater lenses that develop on top of the underlying saline aquifer following monsoonal rain events. They recognise that overuse will increase salinity of the water being pumped due to lateral intrusion from saline areas surrounding these freshwater lenses, and the risk of upconing from deeper saline groundwater. This will require the Sindh Irrigation Department (SID) to implement a robust monitoring strategy encompassing marginal quality zones in Sindh and guidelines codeveloped with communities on strategies for long term use of these lenses.

The coastal zone of Sujawal and Badin has already lost about 2.95 million acres (1.194 hectares) due to seawater intrusion and inundation (Khaskheli et al., 2018), with significant impacts on coastal communities who need to find alternative livelihood opportunities. This loss of agricultural lands and livelihoods is a cause for significant concern. Adaptation measures such as the series of green barriers along the coastal belt proposed by Jamali et al. (2024), including plantations of trees, salt bush and other salt tolerant plants, is needed to make this ecosystem productive and healthy and to maintain biodiversity. Modelling indicates that inflows from constant head boundaries are already posing a risk to coastal ecosystems and by 2150 these risks may extend to the southern edge of the Pinyari Canal command area due to sea level rise and extreme climate events. The coastal zone contributes to the marine ecosystem, shrimp and fisheries, as well as providing livelihood opportunities for coastal communities. A specialised monitoring program is thus required to improve understanding of impacts on the unique coastal ecosystems in Sindh and to preserve and enhance the biodiversity of the Indus Delta. Our suggested options will play an important role to mitigate waterlogging and salinity intrusion risks in the medium term, but these alone will not mitigate the overarching risk posed by rising sea levels and climate change. Adaptation strategies will need to change, and new strategies and financing to mitigate adverse impacts will become increasingly important as climate change intensifies. Effective mitigation of sea level rise impacts will likely require politically sensitive issues be addressed, such as additional allocation of freshwater to the Indus River for release below the Kotri Barrage, and construction of physical barriers such as dikes or polders, drainage of shallow saline groundwater, and extensive land reclamation.

More broadly, a recent study of the Lower Indus Basin indicates groundwater extractions in Sindh have increased from 1.6 BCM to 19 BCM (Salam et al., 2023). This is concerning as there is a dearth of groundwater information in Sindh and insufficient technical capacity in SID for improving groundwater management. The recently released Sindh Water Policy recognises that groundwater use needs to be monitored and managed as it is vital for food production and farming livelihoods.

A policy brief related to groundwater in Sujawal and the Indus Delta has been developed (Punthakey et al., 2024), along with two fact sheets for SID:

1. Climate Change Impacts on Availability of Groundwater Resources in Southern Sindh: Adaptation Strategies for Sustainability of Agriculture.
2. Groundwater Sustainability in Pinyari Canal Command and Coastal Sindh: Policy Guidance to Improve Groundwater Management.

- ***Development of Mobile and Web Decision Support Applications***

While the above trends analyses emerging from computerised processes using available and newly created data can contribute to broader policy and practical initiatives, the project has also sought to identify strategies through which remote sensing and newly created data can be used at the local property level to improve on-farm planning and

decision-making. This work built on prior mobile and web decision support applications developed as part of the LWR/2015/036 ‘Groundwater’ project (Apna Pani and Apna Farm – see http://mriaz-khan.com/DSS/ and Khan et al., 2021).

The impetus behind the ASSIB project’s development of such decision support applications was the value of a field-scale land and water capability assessment to inform decision involving agriculture adaptation options for salinity-affected fields. Initial work involved production of a paper-based rapid assessment survey (published as an appendix in Barrett-Lennard, under review). This survey was translated into Urdu and has been extensively trialled. Its use reinforces the soil and water sampling taken up by many of our ‘bright spot’ community co-inquirers. The paper-based tool was then modified for use as a mobile and web-based application, enabling the user to then also have access to other relevant open-source data (Khan et al., 2024).

The mobile and web-based application can: (1) store data entered by users they can provide (e.g. groundwater depth and quality, soil characteristics, and weather); (2) enable access to stored data that users can update; (3) access open-source agrometeorological data; and (4) access satellite remote sensing data at high 10 metre resolution with five-day intervals. The application is also able to perform analyses that: (1) offer location- and time-dependent advice on land operations based on local soil, weather and water characteristics; (2) compute crop water requirement using the FAO-Penman-Monteith method; and (3) compute measures of crop health, moisture, nitrogen and chlorophyll activity using remote sensing analytics. We have begun exploring use of the application as a decision support tool to enhance crop management and farm production (Khan et al, 2024).

7.1.2 Improving Availability and Use of this Knowledge

The project team members involved in the above knowledge developments have regularly engaged relevant national and provincial government department representatives to guide the kinds of knowledge that need to be developed and to present knowledge outcomes and recommendations. Team members have also been invited to give keynote presentations of their work (Kirby & Ahmad, 2022b; Ahmad, 2023; Punthakey, 2024). The implications of our research were also presented to a range of donors and government and non-government organisations during the team visit to Pakistan in September 2022. The policy and practical recommendations emerging from this research were appreciated by many as pertinent and cutting edge (for example, see Figures 7 and 8).

Preliminary Observations: Punjab

- Despite rapid groundwater level decline, the gap between (surface) water supply and demand is growing – especially in the Rabi season
- Increasing groundwater use – leading to increased risk of secondary salinisation
- Decline of cotton areas; increase in rice, summer grain and aquaculture (?)

Possible Management Options:

- Re-evaluation of provincial scale water allocations to halt groundwater decline
- Improving **mid-season water planning** to improve water use efficiencies
- Policy adjustments to promote sustainable land use and cropping patterns – demand management
- Introduction of salt and drought tolerant crops/vegetation/land uses (while considering the linkages/impacts on system scale water balance)

Figure 7: Excerpt from a slide used by Mobin Ahmad during presentations of his team's work during September 2022, including to PID staff and secretary, 8 September 2022

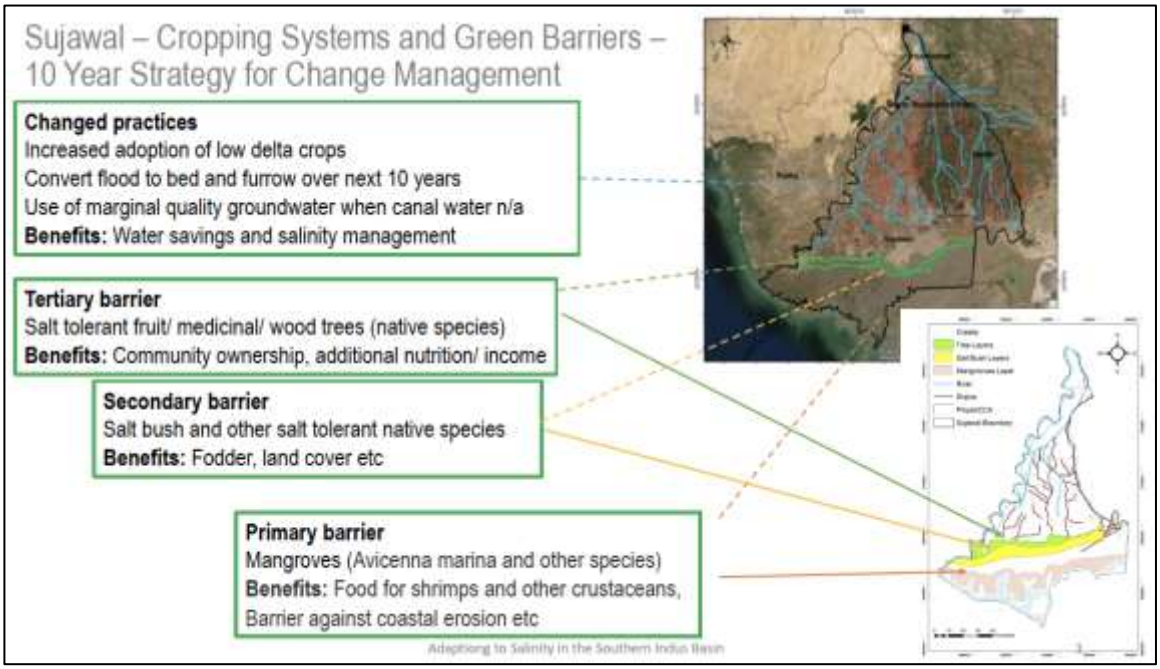


Figure 8: Excerpt from a slide used by Jay Punthakey at the National Salinity Workshop held in Islamabad on 15 September 2022 to introduce preliminary ideas for scenarios his team could investigate using the Sindh groundwater model.

Local- and provincial-level representatives of government agencies responsible for water resource management and planning in Sindh and South Punjab have also been interacting with project team members to learn how their management and planning work could benefit from the research outputs and capacity that now reside with MUET and MNSUAM. These interactions have culminated in two workshops held in May 2024, where staff from MUET and MNSUAM have taken the lead in detailing the range of ways in which their can continue to support water resource management and planning. Detailed policy briefs have also been developed to offer practical suggestions for how SID and PID could make use of the results that have emerged from the ASSIB project's groundwater modelling research (Punthakey et al., 2024; Punthakey & Raheem, 2024).

The development of the mobile and web-based application has been driven by our desire to improve availability and use of available knowledge. The application is freely accessible and will be promoted via the Barrett-Lennard (under review) salinity handbook. The team involved have regularly interacted with provincial agricultural and irrigation department staff to introduce the application and encourage its use.

7.2 Results Related to Outcome 2

The project's case study community members and their institutional support networks have improved understanding of the opportunities for, and constraints to, current options for adapting to salinity.

7.2.1 Improved Understanding for Adapting to Salinity

Much of the co-inquiry investigative research with our 'bright spot' communities have involved existing options for adapting to salinity. The reports about these 'bright spot' co-inquiry investigations (Faried et al., 2024; Jarwar et al., 2024; Qureshi et al., 2024; Soomro et al., 2024) elaborate on how our project's success has been to engage individual farmers and fish-farmers in investigating for themselves adaptation options that suit their local landscape conditions and family aspirations. This has thus been the way that we have addressed the project's second research question: to explore the features that influence (positively or negatively) the effectiveness, uptake, spread and continued use of existing salinity adaptation options.

A key feature of the co-inquiry approach has been the way in which it has provided opportunities for learning by both farmers/ fish farmers and researchers. The interaction created from this co-learning has had a significant impact on saline agriculture research (as discussed in Section 8.1.1). Decisions about what types of salinity crops are suitable for different types of salinity-affected landscape conditions are now enhanced by their coupling with decisions involving land management practices, such as mulching, land preparation, and use of gypsum. In some places, notably along Sindh's coastal areas, agriculture as a source of livelihood has needed to be replaced by other sources such as aquaculture. The groundwork has been laid for widespread scaling-out of established salinity adaptation options, using the Barrett-Lennard (under review) saltland Capability, Risk, plant Adaptation and Mitigation (CRAM) framework.

Tippun Dublo 'Bright Spot'

ASSIB project partners collaborated with three Tippun Dublo 'bright spot' community villages located at increasing distances away from the coastline: (1) Ayub Dablo, comprising villagers who are climate refugees – their traditional lands on offshore islands are no longer able to support them so they have been forced to relocate to the mainland; (2) Haji Musa Katiyar, a village that relies on both aquaculture and agriculture; and (3) Pir Allah Bux Shah, where agriculture is still seen as the villagers' main source of livelihood.

The project's co-designed interventions developed with the first two communities focused on enhancing their resilience and livelihood sustainability through aquaculture (Jarwar et al., 2024):

(1) Ayub Dablo village: Shrimp aquaculture in an estuarine pond.

(2) Haji Musa Katiyar village: Cage aquaculture in a tidal river with shifting salinities.

Both experiments were carried out in three cycles during 2022 and 2023. They proved eye-opening for the coastal communities involved, creating confidence that their small-scale community-based shrimp and cage fish enterprises will be replicated (Malik et al., in preparation). Key learnings involved collectively deciding how to respond to limitations, mainly regarding limited availability of shrimp or fish juveniles to 'seed' the aquaculture productions, as well as a lack of commercial shrimp feed and reliance on poor quality fish feed. The communities responded to the first challenge by relying on wild seed caught from the sea and sourced through traditional channels – thus drawing on their indigenous knowledge and intrinsic strengths. In response to the challenge related to feed supply, the communities were able to trial reliance on raw feed, including rice bran, oil seed cake and wild caught fish/shrimp bycatch from the local fishing boats that employ men from the community for their success. The experiment established a "could be" game changer model that has provided a base for replication and the model is being followed by others in the coastal communities.

The farmer's land at Pir Allah Bux Shah proved especially challenging for the pursuit of saline agriculture. It involved a moderately to highly saline plot of around one acre with insufficient access to canal irrigation. The initial trial of green chili during kharif season 2022 was performing well until the crop was devastated by climate change induced extreme heat that impacted the area. These ongoing rising temperatures during summer that are indicative of a changing climate are of deep concern to farmers across all ASSIB project sites, leading to keen interest in novel strategies that might help modify crop micro-climates. Indeed, despite the set-back experienced by this initial chili trial, the researchers involved note that the experiment's results "have given important new information to the national conversation on sustainable agricultural development" (Soomro et al., 2024, p.3). In particular, it showed that land management techniques can be used to grow crops that would otherwise be considered unsuitable in such highly saline soil – in this case, related to irrigation application. The farmer's subsequent trial of chili in 2023 was successful, an achievement that resulted from earlier planting of seedlings together with improved management practices. The best results from this land, however, related to the woman farmer's kitchen garden. The difference between vegetables grown with mulch compared with those without mulch was striking, and growing multiple types of vegetables with the use of vertical frames was also a success, as has been observed in the project's other 'bright spot' sites.

Malwah 'Bright Spot'

The 'bright spot' known as Malwah involves disparate farms located within an area served by the Malwah canal distributary in Tehsil Qazi Ahmed, district Shaheed Benazirabad, Sindh, Pakistan. This community had previously been engaged with the LWR/2015/036 'Groundwater' project with a well-established stakeholder forum. The widely respected leading couple for this community is based in the village of Mitha Khan Dharejo. A wide range of interventions emerged from the SERL co-design workshop process, including high-yielding wheat and brassica variety selections suited to local soil and water conditions, use of small doses of gypsum in salt-affected and normal soils, ridge cultivation of wheat under limited water supply, mulching in vegetable production, income diversification for women through kitchen gardening, and farmer capacity building training. The use of co-inquiry as the mode of investigation resulted in a noticeable sense of ownership of the results by the farmers involved and has equipped the farming community to continue to design and investigate salinity adaptation options in the future (Qureshi et al., 2024). Several farmers have been appointed by the community to take on the role of

facilitators, keen to scale out the ASSIB approach with neighbouring farming communities through farmer-to-farmer workshops using SERL.

Another feature of the Malwah experience has been the strength of the role played by the stakeholder forum, and the linkages the community has established with service providers, including fertiliser companies Engro, FFC, government and private seed suppliers, extension representatives and researchers, especially those based at MUET. Soil testing was rarely practised in the past but is now appreciate as important and useful, including by women. The farming community sees themselves as being better connected socially. Their ongoing connection with researchers at MUET means the community will continue to benefit from the pursuit of co-inquiry research, which will at the same time give young Masters research students real-life experiences from which to learn and grow.

Jalalpur 'Bright Spot' – Basti Kulab and Meerkot

Jalalpur Pirwala (or Jalalpur for short) is an agriculture-based area within the Multan district, located around 90 kilometres south of Multan. A challenge for those reliant on agriculture in this area is that much of it is elevated, making it difficult for farmers to access canal-supplied water for irrigation. Farmers thus rely heavily on groundwater. Most farmers in this area are small landholders. While some initial trials involved a larger farm in Basti Kulab village with a landlord who lived in town, most of the investigations have involved women and men farmers operating on small pockets of land. Activities in the second village, Meerkot, was sparked by a farmer who worked as hired labourer on the initial farm. In all cases the assumption behind farmers engaging with the project was that for them to live productively with their salinity, they needed to explore changes in farming practices. Investigations involved changed practices are best initiated and investigated through a process of co-inquiry so that local farmer knowledge and on-ground experience can be incorporated. Researchers with diverse expertise from MNSUAM interacted with the farmers to jointly determine advice to improve crop cultivation for each farm context, and to offer assessments on how the interventions undertaken were helping to improve livelihoods. This feedback and evaluation from farmers played a crucial role in shaping the research process and ensuring its relevance and effectiveness.

Through the SERL workshop process, several alternative interventions were prioritised, with detailed plans pursued. Such collaborative planning was seen as a highly successful aspect to the experimentation undertaken at Jalalpur. Farmers and researchers co-learned together through a process of active adaptive management. As was the case at Malwah, the farmers involved also benefited from detailed soil and water sampling and analysis. Interventions included vegetable raising through nurseries, kitchen gardening, raising crops using multiple types of mulches, introduction of salinity tolerant grasses, improved orchard management, vertical vegetable cropping and developing new value-added products. Outcomes-based field trials were a feature, notably those that involved women and nursery transplantation of vegetables (okra and onion) into fields and kitchen gardens. These trials had the added benefit of improving family access to nourishing foods and as an income supplement (Faried et al., 2024; Mohiuddin et al., in preparation a).

The effectiveness of a farmer-to-farmer led approach became evident when other women in the area willingly adopted what they witnessed as an improved vegetable production system. The researchers involved have also delighted in witnessing the success of collaborative learning and effectiveness of farmer field experimentation.

These 'bright spots' indicate that the new approach to salinity management with CRAM to improve land, water, plant and soil management can be readily adopted by small farmers and assist those who work with farmers to provide the farmers with more informed better options for 'living with salinity'.

7.3 Results Related to Outcome 3

Individuals and groups (including women and youth) from the project's case study communities are building capacity to plan their own futures for adapting well to salinity.

7.3.1 Improved Capacity for Adapting to Salinity: A Sustained System of Communities Learning from Each Other

Stakeholder Engagement for Research and Learning (SERL)

We have established a process and demonstrated examples through which salinity-affected communities can learn from each other about how they can best adapt to living with salinity. That process is SERL (Heaney-Mustafa et al., 2023) and is our answer to the project's third research question. That is, SERL is the process that addresses how adaptive capacity for living with salinity can be built and among whom. It lays the foundation through which affected agricultural communities can be supported and encouraged to choose and plan their own futures for adapting well to salinity. Through SERL we have created a mechanism that achieves our key overarching intermediate project outcome: communities are learning from each other in a sustained system of knowledge sharing.

The fundamental principles of SERL are rooted in adult education and the co-production of knowledge. SERL uses participatory research practices to ensure all stakeholders' knowledge and skills are incorporated. Capacity is enhanced among all stakeholders within their contextual environments. The women, men, and youth of rural farming communities are integral researchers along with all stakeholders, be they research academics, government and non-government employees, or agricultural service providers. All stakeholders possess knowledge that, though different, is of equal value. Each stakeholder has an existing capacity worthy of respect. Hence SERL is built on valuing, respecting, and trusting all involved. SERL is also culturally and linguistically sensitive and provides a basis for sustaining change towards improved livelihoods (Heaney-Mustafa et al., 2023).

Those outside the farming communities, such as academics and policymakers, have valuable knowledge, but their knowledge is non-contextualised. Farmers, meanwhile, have lived experience but little scientific or regulatory knowledge about the issues affecting them. To address this, SERL has three iterative and repeating phases: a pre-research phase, a collaborative workshop, and an action and evaluation phase (see Figure 9). In the pre-research phase, all stakeholders need to appreciate that they have incomplete or imprecise knowledge. So, in phase one, data is collected, stakeholder capacity is analysed, and contextual information is gathered. Thus, a rich picture is developed, informing the purpose of the research.

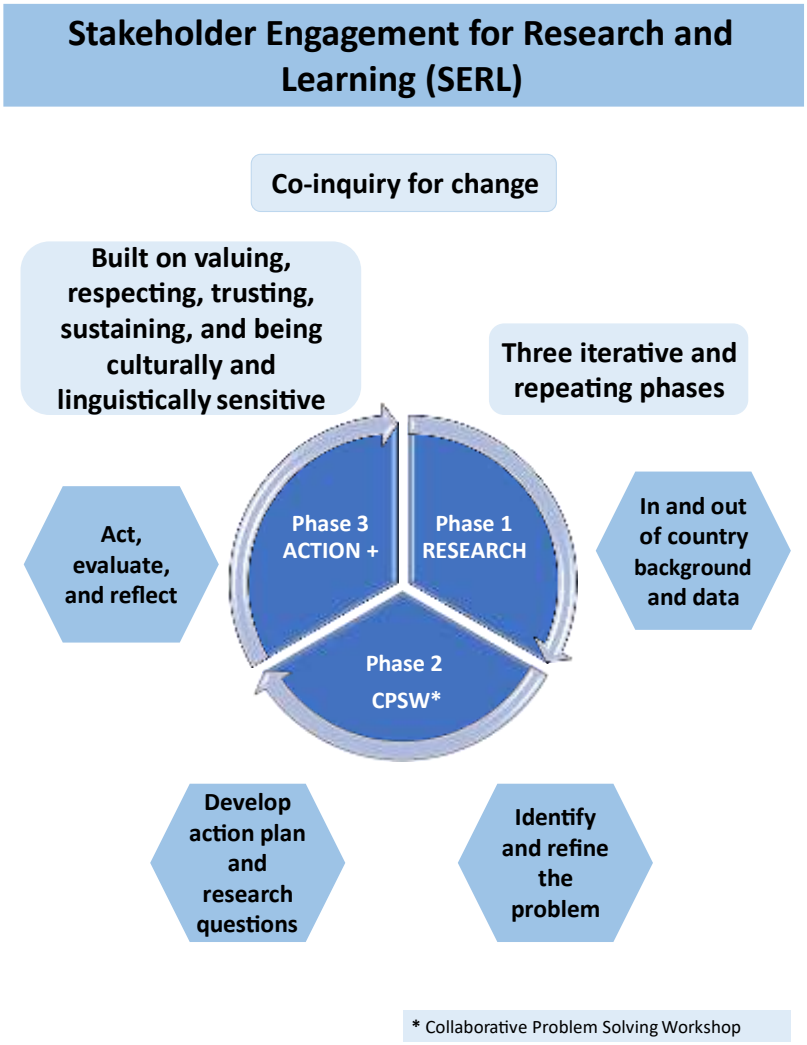


Figure 9: An Abridged Summary of the SERL Approach.
Source: Heaney-Mustafa & Ashraf, 2024

The workshop phase has two parts: convergent, where knowledge is shared, and "wicked" problems are identified from everyone's perspective and then prioritised. In the following divergent phase, ideas for co-inquiry research are identified. Action and evaluation plans are then developed, and research questions are posed. The various stakeholders are assigned relevant responsibilities in the third phase to ensure actions are implemented and evaluations conducted, feeding back into subsequent workshops or discussions that form the basis to launch the phase one activities of the next SERL cycle.

Heaney-Mustafa and Ashraf (2024) explain three key characteristics required of processes like SERL and closely align with the Representative Agricultural Pathways (RAPs) approach outlined below (Ashfaq et al., 2023). First, time is needed for all stakeholders to build a realistic and contextual understanding of the issues to be addressed through co-inquiry. Second, locally relevant and implementable adaptations and solutions need to emerge through discussion with each community and be owned by them. Third, all stakeholders need to be engaged over the longer term to support application of the innovations and adaptations in ways sufficient for sustainable change to occur. Given these principles, what did the women and men farmers think about SERL? The following is a summary of some of the findings presented by Heaney-Mustafa and Ashraf (2024).

After conducting an experiment on sowing wheat on ridges compared to flat wheat sowing, one farmer researcher noted that there was no significant difference in wheat yield. However, there was a timing saving of 25 minutes for each irrigation. He further commented that he "*never applied any fertilizer in the experimental plot; it is totally organic*".

A female farmer researcher in Sindh said of the SERL approach:

… the SOFT and MUET teams taught us, step-by-step, how to present our problems and their solutions on charts. At the conclusion of the activity, we organized our action plans into co-inquiry research goals before beginning our research through various training sessions (Story of Change interview, Allan et al., 2024).

A fish farmer researcher said that he *"felt like a researcher after learning how to take care of the shrimp and doing it well during cycle 2."* He further noted that the SERL method had *"helped him build contact with the experts"* and that he also hopes *"to continue benefiting from the connections he has built in the future*". He also noted when the men go to sea to collect the seed, *"the women and children protect and feed the fish regularly".* Again, the strength of SERL in engaging women and youth in the approach is evident.

When asked if he felt respected and that his opinions were considered by others in the SERL workshops and interactions, he commented that he is "*very satisfied … because every decision is discussed with him and the family members and that their traditional knowledge and opinions are valued*." Smiling, he said, *"Because we are totally involved in the discussion, we know exactly how to properly manage and take care of our seed, and when we face a difficulty, we contact the team, and it helps us overcome that challenge."*

These are a few reflections on SERL from the farming community, but what of other stakeholders?

One academic compared a previous project to ASSIB and commented that even though the prior project had farmers teaching other farmers "*… they only tell others what they have been told, however, our farmers are more creative and have greater thinking power to identify problems and come up with other options".* He then spoke of taking students to the field and the impact of the SERL approach on them saying "*Oh yes, they have changed their attitudes, and that will lead to change in practice."* One of the students told me, *"The farmers are my teachers, so I have to respect them."*

For the farmers, as one of the ASSIB Community Engagement Team members noted, "*the problem is clear – salinity is the main issue and other issues less important" … "there is no one solution to salinity*". She went on to say the farmers realise that there is no one solution and that they are "*more encouraged to engage with the team*". She also noted a fundamental change is that "*farmers are coming to learn from other farmers, so farmer-to-farmer learning is working well*". She said that *"whole villages are talking about mulching and other practices now"*.

From these few comments, it can be seen that SERL has given farmers and others confidence, enhanced knowledge and capacity, built lasting networks, and given women a voice. Further, SERL upskilled men and women in the facilitation of other farmers. SERL is a farmer-led, farmer-facilitated, farmer-to-farmer scaling-out strategy.

Other Related Research

The ASSIB project also developed research in related domains that could be used to reinforce the use of SERL. These include the use of Representative Agricultural Pathways to enhance community-wide long-term planning (Ashfaq et al., 2023; Alam et al., 2024), value chain analysis (Ahsan et al., under review a; b), and a couple of strategies related to community capacity assessment and enhancement (Samoo et al., in preparation; Mitchell & Bond, in preparation).

Representative Agricultural Pathways (RAPs) had been used in the prior LWR/2015/036 'Groundwater' project to integrate diverse sources of information to create scenarios that can inform community-scale decisions involving changed agricultural practices seen as more sustainable options under climate change. Statistical packages are used to quantify projected productivity gains from some of these changed practices. The potential for improved profits can have a significant influence on farmers' decisions to adopt. We took advantage of that project's experience with RAPs to undertake a post-project assessment of outcomes (Ashfaq et al., 2023), and to develop the potential for RAPs to be used as a process with two ASSIB's 'bright spot' communities in South Punjab (Alam et al., 2024).

7.4 Results Related to Outcome 4

Relevant government departments, policy makers, donors and other institutions have engaged with and are supporting locally and collaboratively determined adaptation planning and action, including through co-development of future participatory research projects.

7.4.1 Engagement with ASSIB's Co-inquiry Approach by Research Donors, Government Agencies and Others

Presentations detailing our use of co-inquiry with salinity-affected communities have been a feature throughout our many interactions with research donors, government agencies and others (as detailed in Jabeen et al., 2023). FAO representatives in Pakistan have shown particular interest in this approach, with several meetings held. Some of our project's community engagement team were invited to contribute to a workshop FAO organised on farmer engagement in climate smart agriculture. There is a high likelihood that FAO will adopt use of co-inquiry research with farming communities as part of its ongoing work to support transformation of irrigation and water management practices, especially in Sindh. World Bank and Asian Development Bank representatives were similarly impressed by our demonstrated use of the approach during dedicated meetings with them in September 2022. The Secretary of Sindh Agriculture was especially supportive of the co-inquiry approach we presented to him in August 2023. With a social science background, he held a strong view that farmer participation is a key element to address waterlogging and salinity problems related to irrigated agriculture in Sindh. He was keen for us to personally update him on the outcomes of our co-inquiry work, especially any evidence we could provide on the positive impacts for the farming communities so engaged.

This level of interest by donors and government agencies in the co-inquiry approach we have pursued has inspired our team's effort to make co-inquiry the central component of our future research roadmap for living with salinity (Lashari & Memon, 2024). The concept note included in this report is the Pakistan-based team's rallying call to maintain the work we have started, and to keep the connections among the team intact, alive and productive. ACIAR is also proposing a new Small Research and Development Activity for Pakistan to integrate SERL (Heaney-Mustafa et al., 2023) as part of its proposed research into climate change adaptation and transformation in Pakistan. This and other uptakes of SERL are included in the report by Heaney-Mustafa and Ashraf (2024).

7.5 Discussion

This discussion responds to comments made by ACIAR on a draft version of this report. Among other things, the ACIAR reviewers were interested to understand more about:

1. The role of project partners, including SOFT's role in linking academic team members with the bright spot communities and the role of these networks in general.
2. How the results and impacts related to Research Question 1 fit with the emphasis in this report on our use of co-design and co-inquiry research methods.
3. The project's policy impacts, especially given our comments made in this report's Background section related to the project's intended role to help launch a longer-term 'living with salinity' research agenda.

A theme has emerged for this section in how we have responded to these three requests. We explore how our one time-defined project fits into ACIAR's longer-term research-for-development agenda. We are grateful for the opportunity ACIAR has provided for us to contribute to this longer-term research-for-development agenda but also explore the challenges of delivering such an agenda through time-defined projects (or 'projectification' – see Allan, 2012). An individual ACIAR-funded project leaves an immediate legacy, while also contributing to the ongoing research-for-development agenda delivered by ACIAR, with collaborating in-country partners taking leading roles. As we highlighted in Figure 2, ACIAR's championing of co-design with in-country end users when establishing research-for-development projects has considerable merit. It is an approach that we have been proud to be associated with, and our experience is that it sets ACIAR apart from other funding agencies in a laudatory way.

7.5.1 Legacy of Networks Built through ACIAR Projects

Our demonstration of co-inquiry for delivering research with rural communities built on our in-country project partners' existing networks. These enhanced networks are, in turn, a crucial legacy of the ASSIB project. Our project was co-designed from the outset with these partners, including through their connections with beneficiary communities, and all partners are committed to finding ways to pursue the co-inquiry research approach post-project. In this context, the role of SOFT as a Pakistan-based NGO specialising in facilitating community engagement with project-funded research needs to be highlighted. Time-constrained academics at MUET and MNSUAM, in particular, relied heavily on the SOFT team to support their interaction with their co-inquiry research partners among the bright spot communities. By comparison, IUCN was able to employ their own community mobilisers to facilitate engagement, but were also able to take advantage of the SOFT team who offered further support. The project relied on a bank of such project-funded positions (via SOFT and IUCN) that together formed the project's Community Engagement Team (CET). With support from the ASSIB project leader and other relevant researchers, the CET met regularly online to build on each other's learnings and experience. All CET members were able to enhance their skills to support the project's community engagement efforts, including through dedicated training workshops. This skills enhancement extended to their taking on research responsibilities, most notably to deliver on-property co-inquiry research (Faried et al., 2024; Jarwar et al., 2024; Qureshi et al., 2024; Soomro et al., 2024), develop evidence of the project's overall impacts (Allan et al., 2024; in preparation), and produce research outputs (Kumbhar et al, under review; Malik et al., in preparation; Mohiuddin et al., in preparation a; b; Riaz et al., in preparation; Samoo et al., in preparation). The challenge, of course, is how the longer-term research-for-development agenda can capitalise on ACIAR's investment in these individuals. For the ASSIB project, we benefited from the experiences many of our CET members had in past ACIAR projects (notably the 'Farmer Learning' project LWR/2014/074). We include a recommendation (see Section 9) that future ACIAR projects in Pakistan draw on this acquired expertise to enable co-design and co-inquiry with rural communities to become entrenched practice.

7.5.2 Our Reflections on Integrating across Disciplinary Boundaries

The ASSIB project is an example of an ACIAR-funded project with a research-for-development aim that is primarily people-focused. We approached that aim from an integrating systems-based perspective founded on a recognised social science methodology. We sought to articulate and demonstrate co-design and co-inquiry. The practical implementation of Research Questions 2 and 3 thus became a single research agenda that championed co-design and co-inquiry. Also, there were social-institutional aspects of Research Question 1 that were addressed in ways that contributed to Research Question 3. The results and outcomes related to biophysical aspects of Research Question 1 contribute to the broader systems-based understanding. This improved understanding creates opportunities for people managing and living in salinity-affected landscape to explore more effective adaptation options and strategies.

Integrating science with practice is a long-term agenda that can only partially be addressed within short-term individual projects. Some of the outcomes from the biophysical research methods were available during the project, and were thus able to be used by people engaged during the project. However, much of this new knowledge was only available after local-level multi-stakeholder community planning had occurred. Uptake of that new knowledge is instead likely to be part of future work undertaken as part of the longer-term 'living with salinity' research agenda.

To put it another way, an improved systems-based understanding of what is driving the presence and impacts of salinity in the landscape and their associated trends can contribute to the practice change options to be taken up by people managing and living in salinity-affected landscapes, but this is a longer-term agenda with changes that are likely to be transformational in character for the people involved. Researchers working across disciplinary boundaries can create the basis through which to integrate contributions from science with management and policy outcomes (e.g. Bosch et al., 2003; Lefroy et al., 2012; Maheshwari et al., 2016), but the impacts of these efforts can often come into effect after the end of the project when they were established. This time delay is particularly pertinent to influencing policy, as described in the following section.

7.5.3 How ACIAR Projects are Influencing Policy

It is difficult to attribute specific examples of our project having policy influence, despite all the efforts we have invested to engage with a range of policy influencers (see Jabeen et al., 2023). This is because educating policy makers requires long-term and concerted engagement that is beyond the scope of the current project, and attribution can be difficult in the short term. Influence is best perceived in retrospect. As the ASSIB project is part of the longer-term research-for-development agenda of ACIAR, it is relevant to provide examples of how related past ACIAR projects have influenced policies in Pakistan. Embedding this project's influence in this longer-term narrative is justifiable. The project was established because of the influences and recommendations of past projects. The project was also co-designed with relevant policy influencers through a series of workshops held between 2017 and 2019 (Mitchell et al., 2018; 2020). We also regularly reached out to potential donors and collaborators throughout the project's duration to spark interest and support for our project's approach and our recommendations for the longer-term living with salinity research agenda. We therefore draw some key learnings below from this longer-term narrative on strategies researchers can use to influence policy within the confines of a single time-defined project.

ACIAR's groundwater-related projects (LWR/2005/144 and LWR/2015//036) influenced the increased attention Pakistan's government authorities is now placing on groundwater management. While the need for more effective groundwater policies was evident, the process these projects used to engage relevant government authorities as co-inquirers enabled the policy influence. From the perspectives of those involved, we would argue that trust was built, and the shared purpose and reasons driving the collaboration enabled

improved groundwater monitoring processes. We would also assert that the contribution of technical work and engagement with policy actors supported refinement and adjustment of the new Punjab groundwater policy by the Punjab Irrigation Department in 2018. The second project's engagement of Sindh Irrigation Department (SID) as a partner had a similar effect. In this case, project team members Punthakey and Lashari were consulted with then SID project lead representative and now Secretary Zarif Khero to help shape the Sindh Government's water policy approved in 2023, especially as it related to groundwater. The reports from the ACIAR LWR/2015//036 project contributed to the evidence that a groundwater policy for Sindh was needed.

As part of this longer-term influence on policy, the ASSIB project has prepared several policy briefs, including those emerging from the outcomes of the biophysical component of Research Question 1. In the case of the groundwater-related policy briefs developed for Sindh, the established trust and connection Punthakey and Lashari developed with the Secretary SID meant that SID remained engaged at the highest level. While this is one specific example, the point being made is that value needs to be placed on ongoing connections and trust that emerge from working together on shared challenges requiring emergent policies and practice. For the ASSIB project, representatives from the provincial irrigation and agricultural departments were engaged as stakeholders from local to highest hierarchical levels, and PID in particular saw themselves as collaborators with us. A lesson from our experiences is that greater value needs to be placed on having government departments, as those responsible for policy development, engaged as internal project stakeholders who co-design the project's intended processes and outcomes (as per Figure 2), rather than to merely see the policy influence being exercised through interaction with government departments as external stakeholders.

Experience through sequential projects provide validation and support for our approach to influencing broader policy that recommended salinity-affected communities be engaged as co-inquirers with those responsible for managing salinity across the Pakistan landscape. For example, ACIAR project teams have supported Pakistan Agricultural Research Council (PARC)'s Social Science Research Institute (SSRI) for over a decade. The capacity developed over this period has strengthened the quality of social science research undertaken, and based on the testimony of those involved, has contributed to the development of PARC's policies and practices. The ongoing connection and interaction between ACIAR project team members and the SSRI provides another key learning for how our projects can influence policy. While there is a role for high-level interactions with senior government officials, as we show in the next section, these efforts should not downplay the influence that can be achieved through our interaction with 'lower-level' staff, especially those we can engage in a more day-to-day way on shared research agendas. These staff are better placed to become co-inquirers with us, experiences that can influence their future perspectives and behaviours, which in turn can influence future policy development.

Our final comment on policy influence is to offer an important caveat to the notion that our policy influencing efforts need to be directed at engaging government operatives alone. The discourse on this is now widely established whereby policy influence relates to governance, not just government. As articulated by Stoker (1998), power and authority for directing societal behaviours has become decentralised and devolved beyond government as the formal, centralised policy maker. This offers further justification for our local-level SERL strategy to engage wide-ranging stakeholders as co-inquirers. Civil society is increasingly influencing change in government policies, and this is not limited to Pakistan alone.

7.5.4 The Challenge of Local-Level Stakeholder Engagement

A challenge undermining more effective use of the SERL approach for the delivery of Research Questions 2 and 3 relates to our efforts to engage a broad range of 'bright spot' community stakeholders as genuine co-inquirers. On the positive side, those stakeholders

who lived in these communities and their dedicated ASSIB project partner representatives were in regular and ongoing connection to develop the co-inquiry interventions throughout the project. On the other side, for the most part, such regular and ongoing connections could not be developed with other stakeholders, such as those from agricultural service providers, and especially those from relevant government departments. This challenge was most clearly manifested in the difficulty faced in securing participation from these stakeholder organisations in workshop discussions that helped direct co-design of interventions. Where these involved participation at workshops for men, it was rare to secure consistency with the person representing the organisation in attendance, and even when a replacement departmental representative participated, they were unlikely to have had any briefing about what was involved or the history of the connection. For workshops with women, it was mostly not possible for such stakeholders to identify a woman representative that they could send to participate.

To address this, it can help to at least have key stakeholder organisations formally committed to the project as partners. Such a high-level commitment, however, may not so easily translate into commitments made by those directing the activities of local-level staff who need to be engaged. For this, our project was able to gain inspiration from our field experiences during the International ACIAR Salinity Futures Symposium in Vietnam. We were inspired to the see active engagement of young, often female, local-level extension staff with the research activities being pursued in the field by the ACIAR research team there. Translating this experience to the Pakistan context requires a transformation in thinking towards adoption of more participatory approaches to extension knowledge co-creation. It also means a transformation to enable greater government investment to enable women to be employed as extension officials able to leave the office and be engaged with communities, as well as provision of resources and associated attention on transforming social acceptance to ensure these women can perform their extension duties comfortably and safely. These, of course, are necessarily part of the longer-term delivery of ACIAR's research-for-development agenda. We can remain proud that the work of ACIAR's projects to engage young university female graduates is making a difference, offering a pathway for increased employment of women working in a range of relevant government positions. But continued and heightened attention on delivery of these transformational agendas is an urgent priority.

8 Impacts

8.1 Scientific Impacts

8.1.1 Impacts on the Science of Saline Agriculture

One of the major issues affecting the practice of saline agriculture is that it is not regarded as a scientific discipline in its own right. Its knowledge and skill set extend across the disciplines of soil science, agronomy, plant physiology, agricultural extension, rural sociology, and – increasingly – aquaculture and silviculture. This means that researchers and extension agents need to have an extraordinary breadth of education and experience to provide well-informed advice to farmers and other stakeholders. Unfortunately, young people with this breadth of education are simply not available to take on the range of roles that will be required to disseminate the practice of saline agriculture.

Our team (but especially Dr Barrett-Lennard) has addressed this issue in relation to biophysical knowledge by authoring the new book "*Living with Salinity: how understanding salt, water and soil can help farmers grow better crops*" (Barrett-Lennard, under review). This book has been written with two audiences in mind: (a) extension officers and community engagement facilitators, and (b) new research professionals entering the field of saline agriculture. The book provides both audiences with a grounding in the foundations and practice of saline agriculture. Much of the book's content is based on current knowledge in saline agriculture. The material has been workshopped with community facilitators and project researchers and we are confident of its value to Pakistan.

This includes the penultimate chapter of the book (CRAM), which is entirely novel for the science of saline agriculture. CRAM represents a new method of improving the fit between land, soil, water, plants and soil management by:

1. Defining the capability of saltland in terms of its salinity and water content (from drought through waterlogging to inundation), and thus define a 'risk boundary' for any given site.
2. Defining the impacts of key land management interventions on the risk boundary so defined.
3. Defining the adaptation of plants to land within the risk boundary.

The insights contained in the book, and especially the CRAM chapter, help users to provide more informed advice to farmers about better options for 'living with salinity': the causes of revegetation failures are better understood, and better advice can be provided to farmers by community facilitators.

The book is currently under review by ACIAR and we hope it will be published in 2025. The book and its contents will be highly relevant to many countries in Asia and the Pacific that are experiencing salinity now, or that are expected to experience increased salinity in the future due to climate change impacts. For example, sea-level rise is an existential threat to many island nations in the Pacific. The book could become an increasingly important resource as these communities adapt and transform their agricultural systems to withstand the threat. This uptake would be greatly accelerated by using the book as a resource in face-to-face training courses.

8.1.2 Impacts on the Science Used to Understand Salinity Drivers, Extent and Trends

Establishing the first consistent long-term water balance analysis across the Indus Basin Irrigation System canal commands (Ahmad et al., 2021a) is a significant scientific advance. We used this analysis to inform national and provincial-scale policymakers

about the canal commands we had identified as areas where groundwater use is becoming less sustainable, leading to increased attention and research by these entities on these areas.

Our demonstration of the advanced approach to using remote sensing data to investigate land cover and associated salinity dynamics, especially the use of image blending techniques, opens new avenues for operationalising remote sensing-based irrigation monitoring in Pakistan and elsewhere. These represent significant knowledge improvements for investigating the extent and impacts of salinity (a key intermediate outcome of the ASSIB project's impact pathway analysis).

In addition, the project's future trends analysis related to overall water security has garnered significant high-level policy and research interest in Pakistan. The team involved in this research were invited to give keynote presentations as part of Pakistan's Ministry of Water Resources national water policy implementation conference in Islamabad (Kirby and Ahmad, 2022b) and at the 5th International Conference on Precision and Sustainable Agriculture Under Climate Change at Khwaja Fareed University of Engineering and Information Technology (Ahmad, 2023) attended by senior policy makers, international donors, and national and international researchers.

8.1.3 Impacts to Improve How Science Can Contribute to Climate Change Adaptation and Resilience

Our project's groundwater team has developed an approach termed Climate Change Mitigation, Adaptation and Resilience for Sustainability (C2MARS), which involves the use of modelling to simulate climate change and adaptation scenarios. The approach enables exploration of new adaptation strategies that can moderate the impacts of increased salinity mobilisation from excessive groundwater pumping and projected climate change conditions. The modelled scenarios have been able to articulate different outcomes from taking specific adaptation options as compared with other no-action scenarios: business-as-usual, business-as-usual that assumes increased groundwater pumping, and scenarios that account for impacts of modelled climate change projections.

The scientific advance is to improve application of these findings. In Pakistan, many researchers conclude their publications with broad statements on the need to improve sustainability of groundwater use. There is also broad awareness that climate change poses a significant threat to Pakistan. Quantifying these impacts using modelled scenarios offers practical advice for decision-makers on what they can do next to adapt to projectible future changes and, more importantly, which adaptation options will work best. A key advance is that the models were designed to account for the complexity in how natural systems change in response to stressors, especially given that climate changes is impacting the entire agricultural system across Pakistan through extreme events such as extreme summer temperatures, prolonged droughts, and the 2022 pluvial floods experienced in the Southern Indus Basin. While C2MARS has been developed for the Pakistan context, the same advances can be applied to other contexts. The iterative process of rethinking adaptation options and strategies requires building the capacity to assess how these might evolve over appropriate planning horizons. This includes consideration of key tipping points that can be identified through the modelled scenarios, such as, for South Punjab, the accelerated depletion of groundwater and enhanced salinity transport occurring around 2040 (underscoring the limited time for changed management available there) and similarly with sea level rise for the coastal communities of Sindh.

8.1.4 Impacts on Social Science Methods for Enhancing Community Adaptive Capacity

A side interest explored through the project was the use of an existing Critical Institutional Analysis and Development (CIAD) framework (Whaley, 2018) to develop a deeper

understanding of the socio-political contexts facing our communities. We developed and trialled a new way to use this framework to see if it could operate as a diagnostic tool that would allow our 'bright spot' communities work with the ASSIB team to identify practical improvements in the institutional arrangements impacting the community. As Mitchell and Bond (in preparation) explain, this diagnostic tool draws on characteristics found to be associated with high levels of adaptive capacity (Gupta et al., 2010). We believe this emerging approach offers a way to enhance community-led analysis and aspirations that can evolve into improved policy and practical outcomes, especially in places like Pakistan where marginalised communities like those affected by salinity have not been well engaged in research and development work.

8.2 Capacity Impacts

The ASSIB project's Community Engagement Team, comprising facilitators and mobilisers employed by SOFT and IUCN, have built capacity in the theory and practice of SERL. They have developed an understanding of the principles of adult education, inclusivity, and equity in research and learning. Projects being pursued by IUCN and others that are adopting SERL or similar co-inquiry approaches mean that some of these facilitators and mobilisers are or can be employed to continue their use of SERL as a tool in their work. These individuals have highly sought-after skills with the increased emphasis on genuine rural community participation for research and learning.

The ASSIB project's groundwater modelling research and analysis was undertaken by early career researchers (Abdul Raheem, who had just completed a Masters, and Shahryar Jamali, who completed his Masters while working with the ASSIB project team). They worked under the guidance of Dr Jay Punthakey in collaboration with MUET and MNSUAM researchers with expertise in groundwater. This experience leaves the universities with a legacy of capacity for groundwater research that they can use in the future to support those government agencies responsible for water resource planning and management.

These early career researchers were involved in all aspects of the groundwater modelling including simulations to explore implications on complex groundwater systems of climate change impacts and adaptation options. They built their confidence in model development and more importantly in interpreting model results. They have an improved understanding of how to design and investigate adaptation strategies for improved groundwater resource management. This improved confidence, knowledge and skills allowed them to present their work at the International ACIAR Salinity Futures Symposium in Vietnam and at workshops for key national stakeholders in Pakistan. Abdul Raheem was invited to travel to MUET to give a presentation to Sindh-based water resource managers on the groundwater modelling research undertaken in South Punjab as part of the Groundwater Management and Modelling in Sindh workshop on 17 May 2024. Raheem was also invited to deliver hands-on training in an FAO project workshop on Groundwater Modelling Using MODFLOW on 18-19 April, 2024, and gave a presentation at the International conference on Geo-informatics for Water and Agricultural Resource Management on 24-26 April 2024. Shahryar has also participated in providing training to Sindh Irrigation Department and as assistant instructor on groundwater modelling in a workshop arranged by FAO on 29 February and 1 March 2024. Shahryar also delivered a presentation at the stakeholder workshop on Groundwater Management and Modelling in Sindh.

The development and engagement of early career researchers to engage with irrigation departments and international researchers has been the cornerstone of the approach championed by the CSU team. It would have been far easier to have conducted the modelling studies from Australia, but then this would have deprived researchers from the knowledge sharing opportunities that they have acquired. One MUET Master's student has secured employment as an engineer with the Sindh Government, and is, at the same

time, writing up her Master's based on use of electromagnetic soil salinity field testing to improve crop productivity for publication (Kalhoro et al., in preparation).

On the other hand, Pakistan-based ASSIB project partners were not able to be directly engaged in the remote sensing analyses led by the team from CSIRO as these analyses were run in high-performance computers in Australia. Even so, these partners and other Pakistan-based agencies benefited from direct interactions with the CSIRO team which strengthened their understanding about the usefulness of remote sensing analyses and the process involved. The groundwater models developed by MUET and MNSUAM were able to use the actual evapotranspiration and land cover gridded datasets the CSIRO team had created. In addition, Dr Siyal (Sindh Agriculture University) was involved in the salinity modelling activity which included advanced machine learning techniques, thereby providing a capacity building opportunity for him. There are no impediments for him to take this work forward.

8.3 Community Impacts

A detailed analysis of the project's community impacts is provided by Allan et al. (2024). Based on "story of change" interviews among ASSIB project participants and stakeholders, the report provides many examples of strengthened community through adoption of new 'living with salinity' practices and their outcomes, leading to improved individual and community conditions brought about by their engagement with the ASSIB project.

An overarching theme that emerged from these story of change interviews was evidence of increased adaptive capacity (Allan et al., 2024). This adaptive capacity was built because community members were supported to learn by doing, which led to changed thinking and changed behaviours. Their practices changed because they developed them within a supportive, respectful social setting. They had ownership of the practices they were trialling and were the beneficiaries of improved productivity. Their new perspectives for living with salinity became the catalyst for scaling out (see Figure 10).

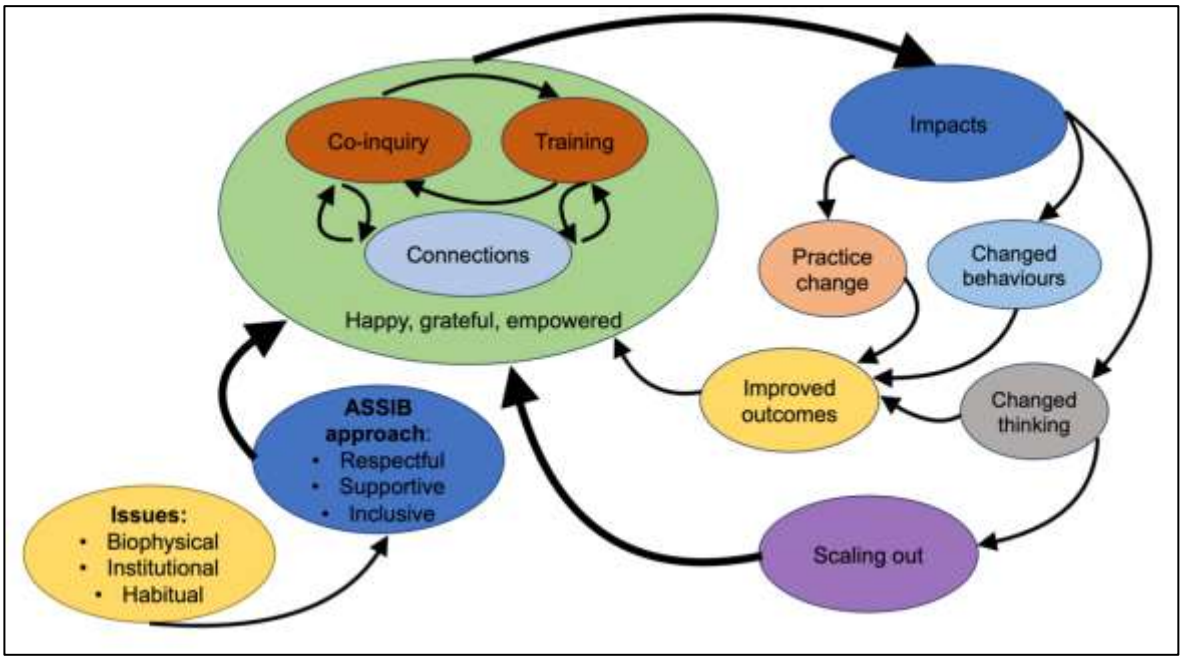


Figure 10: Visual summary of the insights from the stories of change as related to ASSIB farming communities. Source: Allan et al., 2024.

As part of this learning-by-doing experience, men, women and youth in the project's 'bright spot' communities have been upskilled in the use of SERL and are able to teach and guide other farmers within their villages and in neighbouring villages (Heaney-Mustafa & Ashraf, 2024). Women have developed leadership skills as a result of their involvement

with ASSIB and will continue to act as teachers and leaders in their communities (Mohuiddin et al., in preparation). The experience using SERL has also given farmers a means of resolving other agricultural issues as well as non-agricultural issues in their villages in future years. As one fisher commented: *"I hope to continue with the experiment and develop skills and that we will be able to raise our living standards for years to come"* (a farmer cited in Allan et al., 2024).

Remote sensing analysis, while primarily a scientific endeavour, can have significant indirect impacts on communities through the identification of areas facing environmental challenges such as salinity and water management issues. Remote sensing analyses can pinpoint areas where agricultural productivity is hampered by salinity or water supply issues, prompting the adoption of improved farming practices tailored to local conditions. For example, farmers can implement salt-tolerant crop varieties or adopt precision irrigation techniques to mitigate the impacts of salinity on their livelihoods. Since the analyses are conducted systematically for a large area (potentially the entire Indus canal commands) these provide an overview in which governments, NGOs, and other stakeholders can target resources and interventions where they are most needed. This targeted approach ensures that in the future limited resources are directed towards communities that are most vulnerable to these challenges, leading to more effective and equitable distribution of assistance.

8.3.1 Economic Impacts

To demonstrate economic impact, our project has mostly relied on cost-benefit analyses arising from the interventions the community participants have adopted or as graphed presentations of improved incomes. These are presented as appendices in Jarwar et al. (2024) and as tables or graphs included in the reports by Faried et al. (2024) and Soomro et al. (2024). Ahsan et al. (under review b) conducted an analysis demonstrating profitability and value chain improvements arising from salinity adaptation practices among farmers cultivating okra and pomegranate. Mohiuddin et al. (in preparation b) is also developing an analysis to document other profitability gains. Yield improvements have been a characteristic outcome from interventions undertaken and frequently mentioned by farmers interviewed to exemplify how their situation has been improved:

> *We can see that production in mulched rows is better, water requirement is lower, and number of weeds is fewer. We have earned PKR 101,500 net income from okra sales with total expenses of PKR 35,000* (Farmer cited in Allan et al., 2024, p. 26).
>
> *The introduction of cane grass and fruiting trees including guava and pomegranate will help us use our saline agricultural lands more efficiently. When these three newly introduced crops/trees become successful in the area, we will multiply them on a large scale, which will positively help the economic status of the community* (Farmer cited in Allan et al., 2024, p. 26).

The increasing gap between water supply and consumption due to land use shifts towards more water-intensive activities has been quantified by Kirby and Ahmad (2022a) revealing major food security and economic consequences. By pinpointing areas affected by salinity and water management issues, the remote sensing analyses enable farmers to implement targeted interventions to improve soil health and water use efficiency. This can lead to increased agricultural productivity and higher crop yields, resulting in greater income for farming communities. Better targeted investment by governments, NGOs, and other stakeholders in interventions where they are most needed can maximise their effectiveness, translating into cost savings and improved efficiency.

8.3.2 Social Impacts

In the long term, the remote sensing analyses achieved by the CSIRO team can help identify areas disproportionately affected by salinity and water management issues, highlighting disparities in access to resources and environmental risks. By advocating for equitable resource allocation and targeted interventions in marginalised communities, remote sensing promotes social justice and addresses underlying inequalities, thereby fostering a more inclusive and resilient society.

Connections within and among communities, and the networks built among all stakeholders bode well for the future. Famers are learning and teaching each other and sharing this knowledge with other families and friends. Networks built with researchers, extension agents, agricultural service providers and others have increased the trust and reciprocity among them. It has provided them with a source of knowledge into the future.

> *I got information about the institutions, which institution is located where, and what is their work, which officers can help us in which matters* (a farmer cited in Allan et al., 2024).

The impact of the ASSIB project on the social conditions among the 'bright spot' communities has been particularly profound for gender dynamics. Before the ASSIB project, women had little or no involvement in the decision making about farming matters. Now, as Allan et al. (2024) report, the community experience of engagement with the ASSIB project has changed cultural norms with women now seen as important partners:

> *The ASSIB project team is the first to engage both men and women in our village. It is the first time in our life experience that someone has come to discuss agricultural and livestock activities with women and acknowledge our activities* (a farmer cited in Allan et al., 2024).

Women are having opportunities to share their new knowledge and skills with others for the first time:

> *I am feeling very honoured and now realise that my knowledge is equally valuable as that of my husband because, in the SERL workshops, I shared my knowledge with the ASSIB team and with my community women.* (a farmer cited in Allan et al., 2024).

Community engagement with researchers and students is also having a catalysing impact to bolster potential for women's entrepreneurialism within and beyond 'bright spot' communities. As one female researcher commented:

> *I went to the village to show them how to prepare pickles. They were interested in those. Then later they had dates declining in quality pre-harvest, as they didn't know how to save the fruit on the trees. I told them how they can prepare jam, and paste, using their own existing resources. There was a 13-14 year old there watching; he was so interested I am sure he will do something with this. When I visited that date orchard an idea came into my mind. Why don't we work on the pre-harvest protection, with SMART protection? There are now 10 registered projects after that visit. Harvesting premium dates and managing them well post-harvest brings better returns to the smallholders.* (a researcher cited in Allan et al., 2024).

8.3.3 Environmental Impacts

The successful pursuit of aquaculture in an estuarine pond in Tippun Dublo was in part tied to the need re-introduce mangroves in the estuary surrounding the pond. Planting mangroves is inherent to the life of this coastal community and is regularly practised. The community appreciated that the mangroves would serve as a buffer to protect the pond walls from tidal surges and heavy rainfall events. They also valued the broader role the mangroves play in improving water quality and as a haven for sea creatures upon which

the community depend. The work of this community is an exemplary effort – part of IUCN's longer-term strategy of mangrove rehabilitation along the coast of the Indus Delta.

The proposal to establish a green buffer along the coast also represents a potential future game changer for the environment. Our project team has long argued for the need to incorporate interventions that enhance social and ecological aspects of the landscape (Mitchell et al., 2021). The need to for nature-based solutions has become central to the Pakistan-based team's view of how to pursue the 'living with salinity' agenda in the future (Lashari & Memon, 2024).

The project has also been able to quantify the extent of soil and groundwater salinity for the two regional case study areas in South Punjab and Sindh (Gao et al. 2023, Gao et al., under review). Having this knowledge underpins good land management practices and policy initiatives. We are not aware of any immediate policy changes resulting from this information; educating policy makers requires long-term and concerted engagement, and is beyond the scope of the current project.

However, at a practical level, women who have adopted improved land management practices such as mulching for their kitchen gardens have seen that such practices enhance both their family's food nutrition and security and the preservation and protection of their local environment (Mohiuddin et al., in preparation a). The practice of incorporating fruit trees with kitchen gardening has also proved a welcome improvement to the local environment, especially at the Malwah case study site, where the community believes tree removal in the past had led to exacerbated local heatwave conditions.

8.4 Communication and Dissemination Activities

A feature of the ASSIB project has been its efforts to engage with a diverse set of Pakistan-based national and international stakeholders representing government, policy, donor and other interests. This included a series of inception workshops in 2021 as local Covid pandemic restrictions began to lift, and the National Salinity Workshop, which was held during the peak of the 2022 Pakistan Flood National Emergency. These activities have been detailed by Jabeen et al. (2023).

The ASSIB project was inspirational in establishing interaction among ACIAR's other projects engaged with salinity management research and the need to organise a symposium with the two other projects (SLAM/2018/144 in the Mekong Delta of Vietnam and LWR/2014/073 in the coastal zones of the Ganges Delta in Bangladesh and India). This proved to be an effective capacity building event to strengthen the project team's ability to communicate its key research findings and to learn from the other projects. The work to craft abstracts, presentations and posters has laid the groundwork for the project team's current efforts to disseminate research findings in the form of journal articles.

The use of peer-reviewed journal papers and presentations at international conferences has been a key avenue for disseminating outcomes of the project to the international scientific community. This approach was initially championed by the CSIRO team based in Australia working on the project but has since been taken up with fervour by the rest of the team, with most of these papers led by Pakistan-based early career researchers. Dissemination activities with relevant Pakistani agencies has also been achieved through several presentations at key water agencies and national conferences.

English language fact sheets written for an educated but non-specialist audience have also been prepared. It is anticipated that these will have multiple communication uses.

9 Conclusion and Recommendations

9.1 Conclusion

Co-development of knowledge, skills and agency among farming communities, provincial government departments, universities and others was a crucial element of the research-for-development approach adopted by the Adapting to Salinity in the Southern Indus Basin (ASSIB) project (Heaney-Mustafa & Ashraf, 2024). If a change towards sustainable practices for living with salinity is to emerge, those who make a living from salinity-affected areas must develop knowledge, skills, and attitudes to adopt or adapt to existing options. The ASSIB project thus sought to develop a knowledge-sharing approach to enable co-development of adaptation approaches and activities, which is vital for sustaining change. Developing adaptive capacity among women, men and youth farmers is crucial for Pakistan's continued economic growth, food security, environmental biodiversity, climate resistance, and resilience. SERL was the foundation of the co-inquiry approach used in the ASSIB project. SERL is inclusive, and supportive, and can guide communities into developing and owning adaptations to issues of farming or fishing in saline affected areas (Heaney-Mustafa et al., 2023). It enables fishers and farmers to adapt to living with salinity within their resources, and for stakeholders broadly to support the adaptations they wish to make over time.

The capacity for government and non-government agencies seeking to support farmers to adapt and live well with their salinity is greatly enhanced through the production of Barrett-Lennard's (under review) salinity handbook. By becoming familiar with and using the CRAM framework, extension agents, community mobilisers and action researchers can enable communities living in salinity-affected areas pilot adaptation options that are contextually relevant, increasing the potential for initial successes. The use of CRAM as part of the handbook is also backed up with the best available science on saline agriculture.

Decades-long research into the role that trees can play in response to salinity-affected landscapes has also been greatly enhanced by this project's research investigations. Combining the notion of trees as 'pumps' that can act as 'drains' to draw down water levels in waterlogged areas with productive returns makes them doubly attractive to farmers living in the waterlogged type of salinity-affected area. Trees can be a long-term solution and require long-term planning. In some cases, the return-on-investment can take many years (e.g. when the income is based on wood or date sales). Along the coastal belt, trees also serve as a buffer to reduce the impact of seawater intrusion and extreme weather events.

For coastal communities, the successful establishment of various types of community-based aquacultural enterprises represent the kind of transformational change needed for these communities as they face the impacts from climate change. These initiatives stand in strong contrast to the demeaning alternatives associated with artisanal fishing or being labour hire on commercial fishing trawlers (Malik et al., in preparation). The proliferation of fishponds in South Punjab, on the other hand, has represented another kind of transformational change that can appear irreversible. It can be seen as the choice when saline agriculture is not an option. However, the project's work with the Dera Haibat has witnessed the potential for a second transformation. First there was the transformation to reliance on fishponds about a decade ago. Now there are trials involving the integration of aquaculture with agriculture, with promising prospects.

Long-term future planning and action at a range of scales has been strengthened by the research into salinity trends and impacts, including surface water analysis, remote sensing and groundwater modelling. This kind of research and its outputs offer key support to natural resource management agencies and policy makers.

9.2 Recommendations

Farmer-led, farmer-facilitated, farmer-to-farmer strategies have aroused interest in Pakistan and internationally. So, to ensure the spread and sustainability of these approaches, it is recommended that:

1. The knowledge and skills of farmers at all levels, and inclusive of a range of age and genders, be routinely acknowledged and respected by all seeking to become involved with them or influence what they do.
2. Co-design and co-inquiry with rural communities become an entrenched practice among ACIAR projects in Pakistan.
3. Partners and multiple stakeholders (policymakers, non-government and civil society organisations, government departments, etc.) be exposed to co-inquiry and co-design practices at the beginning of future projects.
4. Commitment from those groups be encouraged to enshrine their ongoing participation in co-inquiry and co-design practices to ensure successful interventions are routinely outscaled and upscaled.
5. Champions for change be identified and familiarised with co-inquiry based on SERL so as to encourage those with influence to take up the approach.
6. Future ACIAR project designers and researchers be encouraged to draw on SOFT and other ASSIB team members' experiences with the theory and practice of SERL to strengthen their projects' delivery of co-design and co-inquiry research.
7. Funding be sought to enable SOFT facilitators to train others in institutions and organisations in the theory and practice of SERL.
8. Multiple participating organisations in ACIAR projects form community engagement teams to promote such co-inquiry and co-design.
9. Women and men farmers already skilled to teach others also form peer-to-peer networks to continue to learn from each other, including through the pursuit of a range of other practice change experiments and pursuits.
10. Sharing of knowledge be encouraged through publications, conference presentations and at farmer field days.
11. Peer-to-peer networks be built within and between government, universities and NGOs.
12. The Pakistan Agricultural Research Council (PARC) be encouraged to promote co-inquiry approaches to facilitate the spread of their valuable research.
13. Interdisciplinary approaches be routinely practised to strengthen synergies between the biophysical and social-institutional aspects of ACIAR projects.

The next stage of the longer-term 'living with salinity' research program requires greater involvement of agricultural and other related service providers from government and non-government agencies and the private sector. It is therefore recommended that:

1. The new salinity handbook prepared by Barrett-Lennard be published as soon as possible and widely promoted – not just in Pakistan, but for all countries where salinity impacts agricultural production and natural resources.
2. ACIAR provide support for training in Pakistan in how to use the handbook so that the handbook becomes a foundation for how young Pakistan-based agricultural and other rural service professionals work with those living in salinity-affected areas to support their investigations into adaptation options and development of their adaptive capacity more broadly.

3. The handbook form the basis for further translation of key messages into local languages and as visual materials like those already developed by the ASSIB project to support its farmer-led scaling out strategy.
4. Existing efforts by ACIAR and ASSIB partners to continue research with salinity-affected communities (e.g. ACIAR Trees for Salinity SRA, IUCN's ongoing collaborations with coastal and desert-based communities, MUET and MNSUAM's ongoing action research work with salinity-affected communities) should draw on both SERL and CRAM as the basis for the modes of operation.
5. The proposal for a future "Nature-Based Salinity Management Solutions for the Southern Indus Basin" project be supported.
6. Pakistan's natural resource management and planning agencies need to increasingly take ownership of the research processes and outputs that inform salinity trends and impacts, including by consolidating relevant data and research across the multiple entities involved and by building collective capacity for a long-term salinity management strategy.
7. The recommendations emerging from the surface water trends analysis, remote sensing and groundwater modelling be considered by relevant Pakistan government agencies and adopted.
8. ACIAR take responsibility to reach out to relevant policy makers to follow up on all the above recommendations to ensure their implementation.

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10.2 List of ASSIB Project Publications Produced

10.2.1 Peer reviewed project publications - journal articles

Ahmad, M.-u.-D., Peña-Arancibia, J. L., Stewart, J. P., & Kirby, J. M. (2021a). Water balance trends in irrigated canal commands and its implications for sustainable water management in Pakistan: evidence from 1981 to 2012. *Agricultural Water Management, 245*, 106648. https://doi.org/10.1016/j.agwat.2020.106648

Ahmad, M.-u.-D., Peña-Arancibia, J. L., Yu, Y., Stewart, J. P., Podger, G. M., & Kirby, J. M. (2021a). Climate change and reservoir sedimentation implications for irrigated agriculture in the Indus Basin Irrigation System in Pakistan. *Journal of Hydrology, 603*, 126967. https://doi.org/10.1016/j.jhydrol.2021.126967

Kirby, M., & Ahmad, M.-u.-D. (2022a). Can Pakistan achieve sustainable water security? Climate change, population growth and development impacts to 2100. *Sustainability Science, 17*(2049-2062). https://doi.org/10.1007/s11625-022-01115-0

10.2.2 Peer reviewed project publications - book chapters

Ashraf, M., Imran, S., & Majeed, A. (2023). Water quality and salinity. In M. Ahmad (Ed.), *Water policy in Pakistan: issues and options* (pp. 123-142). Springer. https://doi.org/10.1007/978-3-031-36131-9_5

10.2.3 Peer reviewed project publications - papers in conference proceedings

Ahmad, M.-u.-D., Pena-Arancibia, J., & Yu, Y. (2023). High spatiotemporal resolution remotely sensed timeseries actual evapotranspiration estimates for irrigation management in salinity-affected areas of the southern Indus Basin. In J. Vaze, C. Chilcott, L. Hutley, & S. M. Cuddy (Eds.), *MODSIM2023, 25th International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand, July 2023* (pp. 7-13). https://doi.org/10.36334/modsim.2023.ahmad184

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10.2.4 Project publications - technical reports

Ahmed, W., Punthakey, J. F., Jamali, S., Qureshi, A. L., & Shaik, S. (2024b). *Assessing groundwater monitoring in Sujawal and guidance for strengthening groundwater monitoring across Sindh (Gulbali Report No. 8).* Gulbali Institute, Charles Sturt University. https://www.csu.edu.au/research/gulbali/about-us/publications/

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Ahmad, M.-u.-D., Peña-Arancibia, J. L., & Yu, Y. (2024). Land and water use dynamics in southern Indus basin: implications for sustainable groundwater use and environmental flows. Presentation delivered at the 12th International Congress on Environmental Modelling and Software, Michigan USA, 23-27 June 2024.

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10.2.7 Publications by project team members involved with related ACIAR/ DFAT projects (during ASSIB project)

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10.2.8 Other relevant publications by project team members

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10.2.9 Thesis dissertations

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10.2.10 Media articles

Ahsan, M. B. (2024, September 14). Salinity in agriculture: challenges for farmers. *The Agricultural Economist.* https://agrieconomist.com/salinity-in-agriculture-challenges-for-farmers

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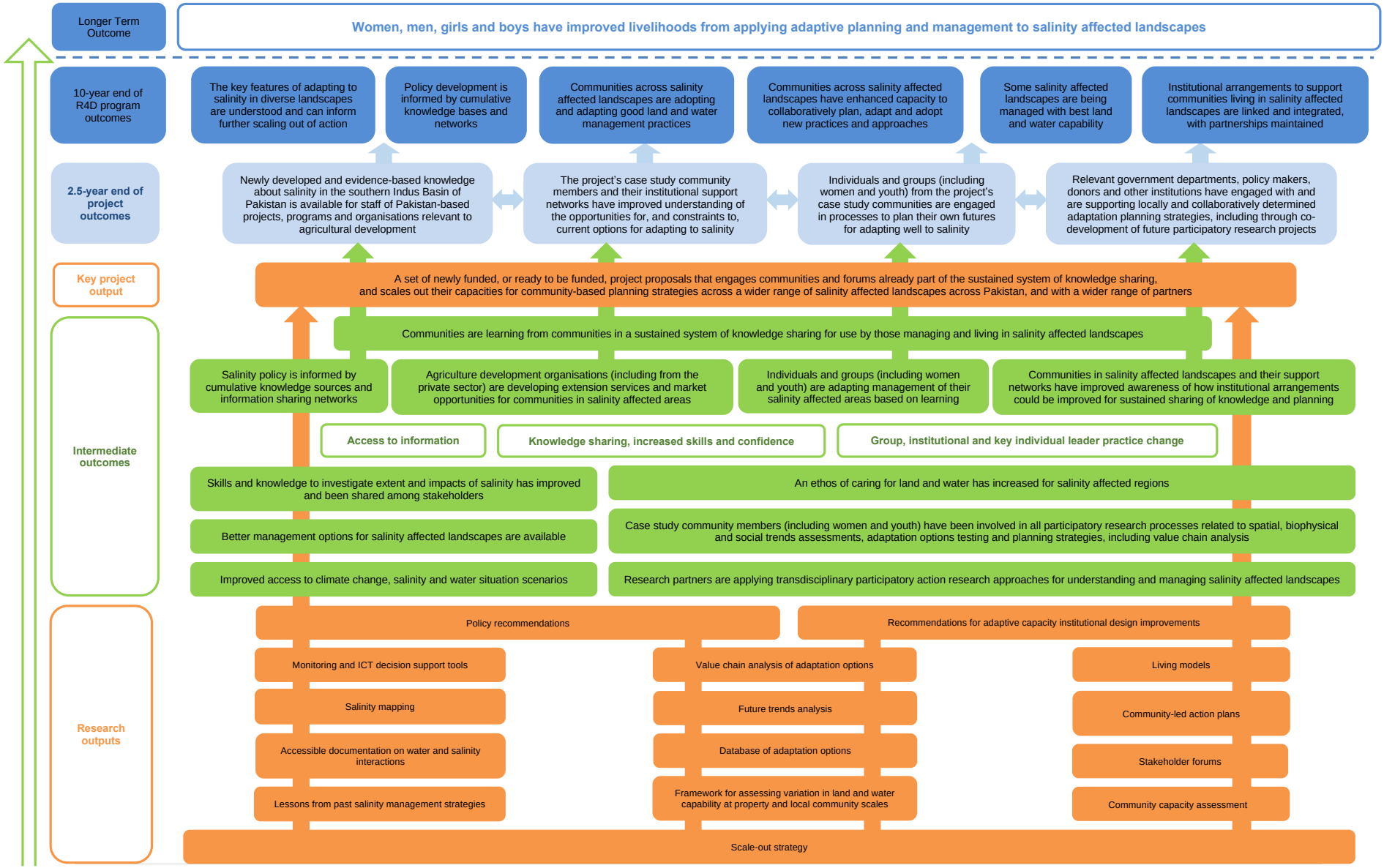
Appendix 1. ASSIB Impact Pathways Analysis



Appendix 2. Criteria Used to Select ASSIB 'Bright Spot' Communities

A portfolio of "bright spot" communities was started as part of the proposal development of the ASSIB project, with eight communities identified (Mitchell et al., 2020).

We adopted the term "bright spots" (cf. Noble et al., 2006) to describe communities living in salinity affected landscapes that are sustaining and perhaps enhancing their livelihoods through active community-driven adaptations.

Those organisations engaged in the project's development, who then became the project's partners, were invited to nominate "bright spot" communities. Five communities were initially selected, and others were subsequently nominated as the project developed.

The following selection criteria were included in the nomination form as the basis for selecting our "bright spot" community case studies:

1. A partner or collaborating organisation willing to champion collaborative research activities with the community (usually the organisation providing the nomination).
2. Convenient distance and logistics for those involved to undertake regular research activities.
3. Well-established interaction by active members of the nominating organisation with key contact persons involved in the adaptation actions being driven by the nominated community.
4. A broad range of different contexts in which communities are adapting to salinity (location, types of salinity impacts being faced, range of severity of impacts, and predominant means of making a livelihood, including at least one community involved in horticulture, one involved in aquaculture, and one involved in livestock).
5. A broad range of different ways in which communities are adapting to living in salinity affected landscapes.
6. A high level of success achieved by the community, or high potential for success if issues identified by the community could be further investigated and addressed.
7. High level of evidence that the adaptation actions are being driven by community members.
8. High potential to engage women and youth in co-inquiry investigations, with at least one community where women are taking a leadership role in community-led adaptation strategies.

Selection criteria 4 and 5 relate to the desire to achieve a broad range of different contexts across our "bright spot" community case studies. Most bright spot communities selected included families with livestock, and we had at least one "bright spot" community whose primary focus was either horticulture or aquaculture.

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