Australian Government

Australian Centre for International Agricultural Research

Trip Report
Jan 28 – Feb 10

Charles Sturt University

ACIAR Program(s) area	Land and Water Resources
Project Titles	Improving groundwater management to enhance agriculture and farming livelihoods in Pakistan Improving Salinity and Agricultural Water Management in the Indus Basin of Pakistan
Project Numbers	LWR-2015-036 & LWR-2017-028
Trip participants	Jan 28 to 10 Feb: Richard Culas, Michael Mitchell, Jay Punthakey; 1-7 Feb: Ed Barrett-Lennard
Research program manager	Dr Robyn Johnston

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Summary table of activities, CSU team visit, 28 January to 10 February

Date	Location	Task/Activities
Sun 28 Jan	Lahore	Richard Culas (RC), Michael Mitchell (MM) & Jay Punthakey (JP) arrive Lahore on TG345 at 10:40 pm
Mon 29 Jan	Lahore to Faisalabad	RC, MM, JP, Dr Ashfaq, Naveed, Kanza & Khurram: meeting with Punjab Agriculture Department on farm water division Dr Ashfaq: return to Islamabad All others plus Saleem (PID): travel to 1-R case study area to identify GW monitoring sites (schools at 3/1-R and 8/1-R), then continue on to Faisalabad
Tue 30 Jan	Faisalabad	RC: meet with socio-economic team to discuss socio-economic survey draft Others: travel to 11-L case study area to identify GW monitoring sites (school at 6/11-L but other sites not suitable – school at 9/11-L too close; piezometer at village 26/11-L not in secure location) Saleem: return to Lahore All others: dinner with Prof Ashfaq and Dr Asghar Ali
Wed 31 Jan	Faisalabad	RC & MM: finalise socio-economic survey design draft, discussion with post-grad students on research topics, and presentation and discussion regarding option of using mobile acquired data (MAD) software for survey Others: work on GW monitoring software Ed Barrett-Lennard (EBL): arrive Faisalabad on FZ343 at 3:25 pm
Thu 1 Feb	Faisalabad to Multan	Kanza: return to Islamabad All others: travel to Multan stop at fish farm near Jhang, salinity affected wheat and canola paddocks on the side of the road, and fish farms between Shorkot and Kabirwala All: dinner with Irfan Baig
Fri 2 Feb	Multan to Karachi	JP, Naveed & Khurram: Skype meeting with GW monitoring equipment provider All: meeting with VC and key academics of MNSUAM then travel to MNSUAM experimental farm at Jalalalpur Pirwala, south of Multan, to see trials of crops etc. suitable for growing in saline affected areas All: fly from Multan to Karachi departing 5:15 pm on PK333; arrive Karachi 6:40 pm MM: meet with Lashari and Fateh
Sat 3 Feb	Karachi to Jamshoro	All: field trip to Thatta (visit Dalda Foods experimental farm south of Gharo; a farm run by an entrepreneur Muhammad Sarwar along Sindh Coastal Highway; sites along the road to Sujawal) then on to MUET, Jamshoro
Sun 4 Feb	Jamshoro & Mirpurkhas	All: Field trip to (1) PCRWR's DRIP experimental station and office at Tando Jam; (2) Mirpurkhas (Nawazabad Farm http://www.nawazabadfarm.com, part of juice company Shezan http://shezan.pk/about-us/, where PCRWR has been collaborating to explore best practice water efficiency and reclamation of saline land); (3) an area north of Mirpurkhas affected by waterlogging

Date	Location	Task/Activities
Mon 5 Feb	Jamshoro	Public holiday – individual work Visit by Dr Tehmina Mangan – discussion with MM and RC; work with RC on socio-economic survey; discussion with farmers (old friends of JP), then lunch with everybody All: dinner with Lashari, Qureshi & Siyal (MUET) Nazir Ahmed Essani (SIDA), Abdul Salam Arain, Dr Ashfaq, Naveed & Kanza (PCRWR)
Tue 6 Feb	Jamshoro to Karachi via Badin	All: field trip to Badin (meeting with FO Chairman and visit to salinity affected farm north of Badin – near piezometer no. 24, then visit piezometer no. 25, lunch in Badin), and then on to Karachi
Wed 7 Feb	Karachi to Jamshoro	All: meeting to discuss project proposal and ecosystem approaches to salinity management with key experts from IUCN and Karachi Uni All: meeting to discuss project proposal with Secretary and DGs from Sindh Agriculture, Supply and Prices Department All: meeting to share project concepts and collaboration opportunities with FAO-ICARDA project in Pakistan related to drought RC, MM & JP: return to MUET, Jamshoro EBL: depart Karachi 11:35 pm on TG342
Thu 8 Feb	Jamshoro & Naushero Feroze	RC, MM & JP: travel to Chiho case study area (head, middle and tail), followed by lunch hosted by SID Naushero Feroz
Fri 9 Feb	Jamshoro, Nawabshah	RC & JP: travel to Malwa case study field site (middle only to introduce MUET & SID to data logger equipment and software) MM: work on SRA report and project proposal
Sat 10 Feb	Jamshoro to Karachi	RC, MM & JP: Meeting with Tehmina and Shabana to discuss proposed PhD research Meeting with Lashari and Qureshi to discuss proposed MUET-CSU GW diploma Travel from Hyderabad to Karachi Meeting with IUCN Country Representative, Dr Cheema, Danish Rashdi and Amjad Siddique RC & MM: depart Karachi 11:35 pm on TG342; JP: stay on in Karachi (private business)

Activities related to Salinity SRA LWR/2017/028 (1-7 Feb)

Dr Ed Barrett-Lennard joined the team for the activities related to the proposed salinity project. The focus of these activities were field visits to saline affected sites that workshop participants had recommended. Visiting these sites in the middle of the Rabi season was helpful for us to observe the extent of salt encrusted surfaces, and understand the difficulties farmers face growing crops. We were also able to observe best practice alternative approaches that farmers could adopt. Another key activity was a set of introductory meetings with the Punjab and Sindh provincial government's agricultural departments. The core group preparing the project proposal had identified these departments as the most important to have involved in the project. We also sought to meet with some of the Sindh-based salinity experts who we had identified should be part of the network to be engaged for the project. We were particularly keen to meet with environmental NGOs, IUCN and WWF.

Meetings

28 January: Meeting with Directorate General Agriculture On-Farm Water Management, Punjab. PCRWR arranged for us to meet with the Directors General of the on-farm water management and extension sections of Punjab's agriculture department. However, the extension staff had to be called away, and we only met with the on-farm water management staff. The director general of the extension section had been at the Faisalabad workshop in November last year, and it was more important for us to meet with the on-farm water management section. After we provided the presentation (see Appendix), the Director General, Malik Muhammad Akram queried whether we were attempting to be too broad in our scope, and suggested we could be more focused. This gave us an opportunity to explain our methods so as to emphasise the nested case study approach. We were all on the same page, and the Director General expressed great enthusiasm for the project, and a willingness to collaborate with us on it.

7 February i: Dr Fateh Marri organised a meeting with the Secretary (Mr Sajid Jamal Abro), Directors General and other senior staff of the Sindh provincial agriculture department, including those responsible for both on farm water management and extension. The following points were discussed:

a) 56% of agricultural land (8 Mha) is affected by salt and waterlogging in Sindh.
b) 30% of water courses have been lined to decrease seepage.
c) RBOD has not yet been completed; LBOD has problems – limited capacity to handle Kharif floods.
d) Agriculture has a focus on agronomy, soil science, climate change adaptation, development of short duration crops, application of gypsum and sulphuric acid to affected soils.
e) They are seeking World Bank support for major large-scale drainage interventions, and would appreciate our support to help make the case.
f) We discussed the locations of case studies. Mustafa Nangraj (current collaborator with us on the GW project) was keen on the idea of slightly, moderately and highly saline areas in Sindh. Jay pointed out that our project needed to have a national focus and that we were considering a zonal classification to help select case studies being: (1) the doabs in the Punjab, (2) southern Punjab, (3) north Sindh, (4) south Sindh, (5) the delta and perhaps also the Cholistan and Thar desert areas.
g) Mustafa subsequently forwarded us a media report on the importance of saline agriculture to food security in Sindh (https://www.thenews.com.pk/print/275386-saline-agriculture-way-forward-to-food-security).

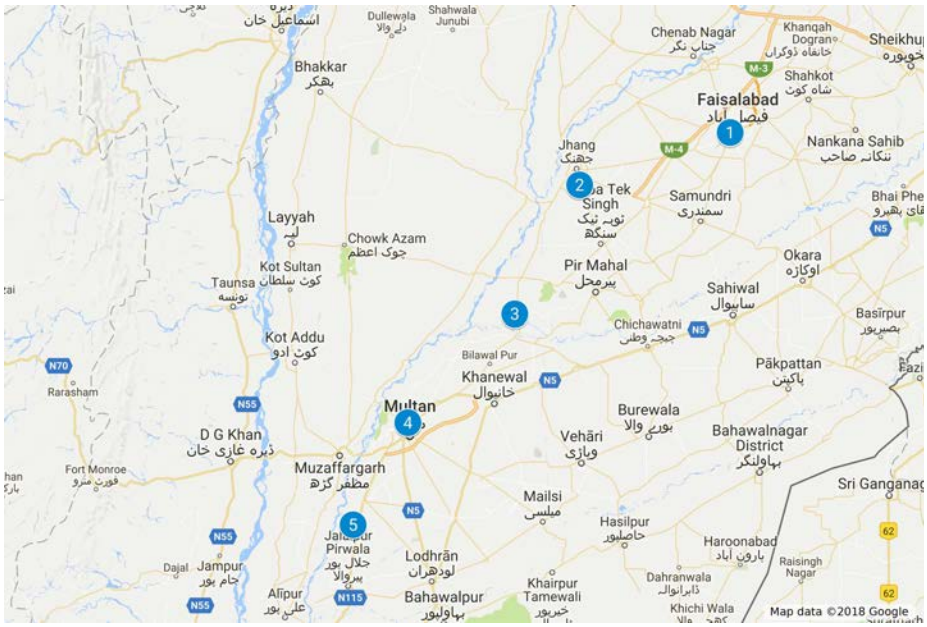
7 February ii: Workshop at PCRWR Karachi office attended by two IUCN representatives, and three University of Karachi academics. A follow up meeting was also organised at the IUCN office on 10 February where we met the country director, Dr Cheema, and two of his staff. WWF had also been invited but were unable to attend. One of the academics is in the final stages of finishing her PhD, and would make an ideal candidate for a research associate for the project. Her PhD is directed at understanding salinity in the delta areas, and she has co-authored a paper currently in press on the topic (Naseem et al. in press). The IUCN staff have also subsequently shared a number of useful reports, including one that has not yet been released on the political economy of agricultural water use in the Indus Basin. All have agreed to become part of the network, and the IUCN mangroves expert has invited us to visit the mangroves area of the delta next time we visit Pakistan.

7 February iii. PCRWR had arranged a meeting with Banaras Khan, from the Pakistan office of FAO and Dr Richard Soppe (a consultant with ICARDA, formerly with CSIRO and member of the Australian team on the ACIAR Iraq Salinity Project). FAO is developing a drought mitigation policy for the Provincial Government. The plan is to develop implementation strategies for the short, medium and long term. Unfortunately, Jay, Michael and Richard had to return to MUET, but Ed had the opportunity to continue the conversation after they left. FAO has done extensive work into the development of alternative cropping strategies for the Kharif – okra, onions and tomatoes can be high value alternatives to rice in water limited environments. In addition, they have done extensive work into intercropping as a means of intensifying cropping and ensuring more continuous land use. FAO should be members of our network. I asked the FAO rep to email me citable publications about their work.

Field trips – Punjab:

Sites visited Feb 1-2

1. Faisalabad (Feb 1 start)
2. First fish pond near Jhang
3. Fish ponds
4. Multan (Feb 1 end)
5. MNSUAM farm (Feb 2)



Thu 1 Feb – Drive from Faisalabad to Multan

We stopped at three spots on our drive from Faisalabad to Multan. The site that had been recommended was a set of fish ponds occupying saline affected land that we would encounter on the way. As we thought we had missed this site, our first site was a fish pond some distance from the main road. It was located by a canal with old brick lining that was clearly leaking. All land within close vicinity of the canal was severely waterlogged, mostly abandoned, with large swathes of reeds suggesting long-term inundation. The fisherfolk we

met worked for the landowner, and had some malnourished livestock feeding on rice straw and some green pick that had been brought to the site. There was a tiny ponded residue of water still containing fish. We understood that the adjacent fish pond had been fished out. Fish are grown here during the summer floods, and we saw fish nets on the bank.

The second site was a striking example of a salt affected landscape (see photo 1). It provided an opportunity for Ed to introduce issues related to saline affected agricultural landscapes, and how salt residues form. The snowy white colour of the salt suggests sulphate crusting on the soil surface. A field of pasture legume (probably berseem) was the most affected, a wheat field less affected and canola least affected. The canola crop we saw had been recently irrigated. At the edges of the wet soil, the formation of salt was clearly visible, as well as the way that salt forms on the ridges as these are the first to dry (see photo 2). On our journey we also saw evidence that green canola is being cut as animal fodder. This makes sense if this is the most salt tolerant crop, and farmers can use urea as their main source of nitrogen.

Photo 1: Impacts of salinity on wheat crops between Faisalabad and Multan

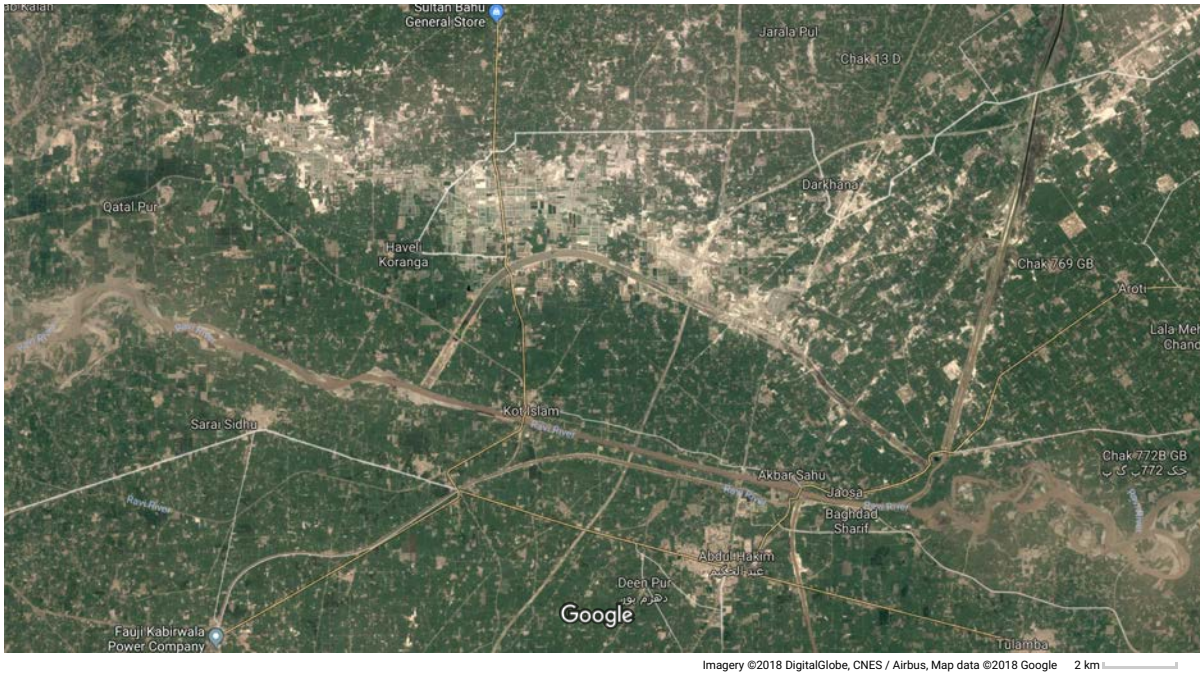
Photo 2: Formation of salt crusts on a recently irrigated field of canola

The third site was the set of fish ponds that had been recommended, located near to the Ravi river, between Sharkot and Kabirwala, on what appeared to be a river course (we stopped near a bridge). The fish ponds were extensive and well established (see photo 3), and the ones closest to us received water through groundwater pumping.

Photo 3: Fish ponds on the side of the road between Sharkot and Kabirwala

The surrounding land was barren, and on the sides of the pond there was a narrow ring of vegetation, with species grading from those preferring inundation to salt tolerant plants below a line of salt crust. The extent of fish ponds showed that adaptation to a different

business model is already taking place. Identifying this site via Google maps satellite imagery showed the extent of the fish ponds, and how they appeared to follow a line that was probably a dry river bed, perhaps a former course of the Ravi (see Google Maps image).



Google Maps image of fish ponds between Sharkot and Kabirwala

Fri 2 Feb – Visit to MNSUAM demonstration farm

One of our purposes for visiting Multan was to arrange a trip to Bahawalpur, and to meet with PARC's Arid Zone Research Institute. However, we were advised against making the trip because of the travel time involved. Instead, we were fortunate to have made prior contact with Dr Irfan Baig, recently appointed to a newly established agricultural university in Multan, MNSUAM. He arranged a meeting with the Vice Chancellor, Dr Asif Ali (a former UAF Director of Research), and several other senior members of staff. The VC gave a presentation regarding the foundation of the university and his (impressive) vision for the university (a copy of his presentation is available). The university is agricultural focused, and has a very forward looking approach for its students, and to engaging with and supporting the surrounding community. The University has 2,000 students, which will double next year. The campus is co-located with a range of relevant provincial agricultural authorities.
The team provided a brief overview of the proposed salinity project, and the VC and his team were very keen to be able to collaborate on the project. One issue that came up was the possibility of looking at boron toxicity. We were told that soil and plant analyses conducted around the Punjab indicated that B-toxicity was not an issue (a report on this was subsequently received by email). The team also met briefly with the Punjab Secretary of Agriculture who was at the university to discuss its construction.

Dr Baig invited us to the university's demonstration farm in a severely salt-affected area beyond the reaches of the canal system. For this trip we were accompanied by Dr Tanveer ul Haq and Mr Nabeel Ahmed. The area is affected by drought induced salinity. The contrast between the intensive lush farms serviced by the irrigation system and the land beyond was stark. A range of techniques were being trialled at the demonstration site, and we observed how saline affected land can be reclaimed for agriculture using salt tolerant crops and techniques such as planting in hollows (see photo 4, with agronomist, Mr Nabeel Ahmed). Unfortunately, due to road works, we did not have much time to inspect the facilities, and

missed out on seeing their fish ponds (containing tilapia). The fields we saw were largely desolate because of recent levelling, low/no rainfall, and their dry condition. This would be an excellent place to study the effects of salinity with drought on crop growth. The EC of the groundwater here is 5-6 dS/m and canal water is only available for ~6 months each year. The staff accumulate canal water in large ponds during the summer for use in winter.

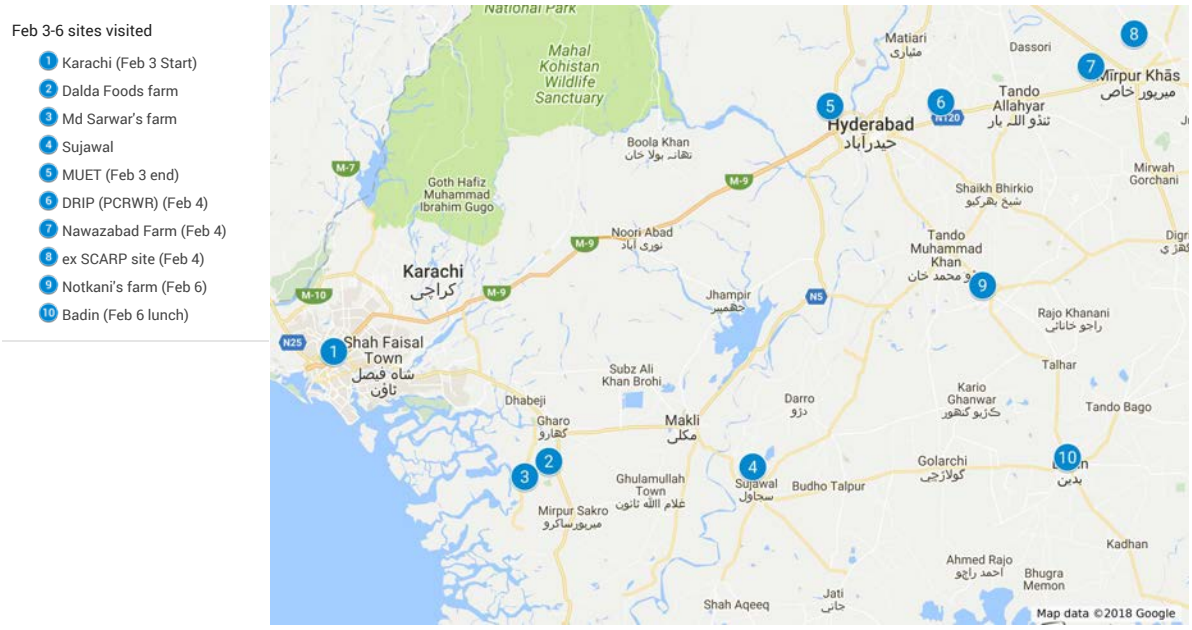
Photo 4: MNSUAM farm fields; pictured is MNSUAM agronomist, Mr Nabeel Ahmed

The farm originally had highly saline soils (EC_e values 20-57 dS/m) and has grown crops of cotton, barley, oats, alfalfa, ispaghol (a medicinal plant) and chia, but the soils were too saline for chickpea, berseem and castor bean. The staff expressed interested in growing Salicornia. Ed advised against this, as this species, while salt tolerant, will require large amounts of irrigation water, and would only survive with frequent irrigation with groundwater (cf. Glenn et al. 2013). The farm would be a useful area to test the growth of the saltbush that being introduced to Pakistan by Ed and CSIRO. There are staff to water the plants and interested researchers. Dr Tanveer is a serious player in saline agricultural research with a nice CV (https://scholar.google.com.pk/citations?user=X6ydOh0AAAAJ&hl=en). He has been added to our network.

This farm could also be a good place to test the value of the revised APSIM being developed in Ed's Bangladesh project to determine different scenarios for salt and drought tolerant crops. If so, we would require a good modeller to collaborate with us on the team.

On the way back to the airport, Ed and Michael discussed the possibility of exploring gender ratio (as determined from the recent census) as an index of poverty (cf. Haq 1997) and the opportunity to express this spatially. From Ed's past experience with the Satiana project, there are significantly more men than women in the villages they surveyed. Reasons for disparities in gender ratios in salinity affected areas could be explored by women researchers interviewing women in selected villages. This would not only address a research question on a significant sociological phenomenon, but could also give voice to women's experiences that have not previously been documented.

Field trips – Sindh:



Sat 3 Feb - Drive from Karachi to Jamshoro via Thatta and Sujawal

The coastal areas of Sindh are very different to the rest of the Indus Basin. The land is typically flat and is underlain by very high salinity. We were accompanied by a range of people including PCRWR Regional Director Karachi, Eng. Abdul Salam Arain and other PCRWR officers. The two farms we visited in the coastal district of Thatta had sought assistance from PCRWR, and are used as demonstrations (quarterly).

The first farm was run by Dalda Foods, and was located in a severely saline area with shallow groundwater. We first inspected the wasteland area adjacent to the farm. The wasteland was so seriously affected that it was mostly bare, with just a few halophytic shrubs. The floor of an abandoned fish pond was salt scalded.

The project manager, Mr Virender Kumar (the person in the middle of photo 5), showed us the difficulties of farming in this landscape. Although efforts are being made to grow sunflower crops it has had mixed success. His best result was with sunflower (Hysun 33) about 2/3 through their growth cycle located in the highest part of the landscape and grown without irrigation. This area had a subsoil pH around 7.5, and it looked as if the plants were accessing the shallow groundwater. Further downslope the soils had a clay surface, silty subsoil, high ECe in the subsoil (~20 dS/m) and alkaline pH (~9) and a water-table of ~1.2 m (all made visible with a nice soil pit). Here the sunflowers had poor establishment. An adjacent field (growing nothing) had been treated with dilute sulphuric soil, which had lowered the pH by 0.2. This manager had also tried growing a legume (field peas) with no success. High pH seems to be an impediment for establishing good crop cover. Ed made

suggestions for using mulching to retain soil moisture and decrease the accumulation of salt at the soil surface. Research in his ACIAR Bangladesh/West Bengal project shows that mulching of sunflowers with rice straw can increase yields and decrease the salinity of the soil solution[1]. During the course of our travels we saw the leaves of sugar cane laid out on the soil surface. While it would be nice to imagine this was for mulching, it was apparent that it was being laid out to be burnt. 'Black urea', instead of 'white urea' – except that through burning all the nitrogen is lost.

Photo 5: Jay, Virender Kumar and Ed in a field of sunflowers grown in salt affected soils, planted in soil still moist from a prior Kharif crop (vegetables)

We were all impressed by the manager of the Dalda Foods farm. He was prepared to try new things. In addition to Hysun 33, he was conducting his own trial into better sunflower varieties (3 other cultivars tested). Ed spoke about his contacts with ICBA in Dubai and the opportunities to conduct trials with a wider range of germplasm.[2] The manager was clearly using scientific approaches to solve his problems. He was able to show us data sheets of soil analyses and we asked for copies of these to be emailed.

The second site was closer to the delta on a farm managed by Mr Muhammad Sarwar, an entrepreneur who also owns Pak Windenergy. This was an impressive farm within the severely affected area of the delta, and they have been more successful in their approach to

[1] Ed's notes: Contrary to widespread opinion, it is actually the salinity of the soil solution (not the soil) that adversely affects plant growth. For NaCl based salinity systems, the salinity of the soil solution (mM) can be calculated approximately as $EC_{1:5}$ (dS/m) x 5000/ Soil water content (% DM). This means that the salinity of the soil solution will double if the concentration of salt in the soil doubles; however, it will also double if the water concentration in the soil halves.

[2] Ed's notes: In July 2015 I emailed Dr Shoaib Ismail (ICBA's Director of Research and Innovation) about the availability of a broader range of sunflower germplasm at ICBA that could be pulled into trials in Bangladesh. He indicated that the appropriate person to contact in ICBA would be Dr. Nanduri Rao, who had been working on the screening and evaluation of sunflower for salinity tolerance. I did not follow this up at the time as I had no funds to develop an activity. Richard Soppe (formerly of ICBA) informed me that new contact to talk with in ICBA is Mohammad Shideed.

establish chilli and mixed cropping with bananas and other vegetable crops (such as eggplant). Their trick was to conserve excess canal irrigation water from the Kharif season by injecting it into the soil profile and then pumping this out again in the Rabi season. It is doubtful whether this water conservation technology would be applicable to large areas of the Indus Delta. Its success here was probably due to: (a) the farm being located on a slightly elevated sandy dune capable of containing a lens of fresh water, and (b) the availability of fresh water in the Kharif through the canal water distribution system.
Both these farms are owned by large enterprises. They are not suitable for sites as our intention is to focus on small farmers. However, it was a good learning experience to see the issues and some possible solutions. Also it would be good to include the Dalda farm manager on the network as his team are attempting to show that sunflower production can be successful, and this may be useful for tapping CSR funds to help small farmers. They have been actively encouraging all farmers in the surrounding areas to learn from their demonstrations. Their incentive for this (see http://daldafoods.com/sustainability/) is that they would like to encourage increased sunflower production across the landscape, which Dalda Foods could then access for their oil products.

The delta areas are close to these sites and on our journey we saw several tidal creeks. We need better knowledge of the delta areas, including through the work done by IUCN and researchers at the University of Karachi.

Sun Feb 4: Travel to Mirpurkhas

We first inspected the experimental farm of PCRWR's Drainage and Reclamation Institute of Pakistan (DRIP) station at Tando Jam. We met the farm manager who is planning a PhD. He showed us their experiments into the use of bedding systems being used with wheat and bananas to decrease water use (instead of flood irrigation). With bananas, water use has gone down from 5000 to 2000 mm/year. We noted that the soils are also being mulched (see Photo 5).

The DRIP station also has an impressive lysimeter facility being used to determine crop water requirements and WUE at three water-table depths. The results from this facility were used to produce a booklet "*Water requirements of Major Crops in Sindh*" (Rao et al. 2016).

On the road to Mirpurkhas, we stopped to see farms in Tando Allahyar touted as one of the most productive in Sindh. We saw extensive evidence of bedding systems being used by farmers to grow Rabi crops and women cutting an adjacent field of sugar cane (see Photo 6).

As we approached our main destination, Nawazabad Farm, we saw an excellent example of previously highly waterlogged area now drying up because of the concrete lining of an adjacent canal (Photo 7). The lining occurs during the six-week layoff period in November/December when the canals are emptied of water for repairs and maintenance.

Nawazabad is a large farm that Jay had visited in 2007. Much of it has been reclaimed from salt affected land by pumping and draining to lower the water table. It is probably the best managed farm as the owners have good resources. They also hire a lot of local workers from the minority Hindu community. They demonstrated good social responsibility towards their farm workers (which is also highlighted on their website http://www.nawazabadfarm.com). For us it was instructive to see the breadth of cropping diversity on the farm. They are very innovative and have introduced new crops like bhel giri (wood apple) purported to have health benefits, a large variety of mangoes, and other fruits like papaya, banana, guava, jujube, citrus and even (notoriously salt sensitive) grapes. It was particularly interesting to see bananas being planted in between the raised beds of a

wheat field. They have also allowed the workers to grow fodder crops for the workers' livestock under large fruit trees (see Photo 8).

Photo 5: DRIP experimental farm manager in a mulched, bedded field of bananas

Photo 6: Bedding systems being used on a farm in Tando Allahyar between Tando Jam and Mirpurkhas. Women were also observed harvesting a cane field on the right.

Photo 7: Recent concrete lining of this canal is helping to dry out seepage areas either side.

Photo 8: Fodder crops grown by Nawazabad workers under fruit trees and harvested for their livestock

Mon Feb 5 (public holiday): Discussion between Dr Tehmina Mangan, Ed and Michael

A major challenge our projects face in scaling up is the inadequacy of agricultural extension resources relative to the scale of the farmer population. Typically, one agricultural extension worker might need to service up to 6,000 farmers. However, this might be achieved far more effectively using mobile phones (analogue and smartphone). Yesterday we saw Dr Ashfaq show us the way in which PCRWR is sending out simple extension messages that can be received on both analogue and smartphones (see photo). Our discussion with Tehmina explored this further. She noted that many farmers are illiterate, and would therefore benefit from receiving oral messages through their devices. The languages would not only need to extend beyond English and Urdu, but also to local languages, and presented in a way consistent with local idioms and technical terms.

Clearly, we need to be developing extension systems capable of delivering extension messages to hundreds of thousands of farmers. Getting access to the right people in the agricultural extension agencies will be critical to success.

Mon Feb 5 (public holiday): Meeting with farmers from Framabad village, Nawabshah District

We met with farmers Mr Shamsdin Laghari and Mr Sarang Ali Leghari from Framabad village in Nawabshah District. The discussion revolved around the current problems being faced by smallholder farmers in Sindh. These farmers are growing sugarcane and wheat (Rabi season). The price set by the government is Rs 182 per maund, however sugar mill owners are colluding to offer low prices to farmers. Some are getting as low as Rs 70 and

the usual excuse for the low price is on the grounds of variety or crop quality. The best price they are getting is Rs 130 per maund in some cases. In most cases the smallholder farmers are forced to accept the low prices. All through Sindh and Punjab we observed lines of trucks and tractor trolleys for several kilometers waiting for sugar mill owners to purchase their crops. Farmers from Sajawal, Badin, Nawabshah and Naushero Feroze all complain that most of the sugar mills are owned by powerful politicians who offer small farmers little recourse to justice. A class action was brought against the mill owners and the high court set an interim price of Rs 162 per maund yet even this price is not being offered by sugar mill owners. Smallfarmers do not have the holding capacity to wait for the case which is now in the supreme court.

One solution would be to develop processing opportunities/ alternative supply chain for their products.

Similar conversations were voiced by farmers about wheat. The price set by the government is meaningless as small farmers seldom get the set price. The price they get is usually 30% less. There is also a scam with wheat bags where small farmers cannot get the approved bags for the wheat. Again this is controlled by vested interests.

Other issues voiced by farmers is that when they purchase land – even if only a few acres – they do no get the papers to prove ownership, making their tenure insecure. As a consequence of all these challenges, many smallfarmer families have one or more members working in cities or overseas in Dubai or other Gulf countries. We would like to emphasise that these are not isolated views of one or two farmers, the same complaints were heard throughout our field trip, including from the Darejo family at Malwa.

Tue Feb 6: Visit to MUET lab and field trip to Badin district

In the early morning we had a brief inspection of MUET's soils lab and library accompanied by Prof Bakhshal Lashari, Director of MUET's Institute of Water Resources. The whole building has been provided with US funding. The lab has seen little use yet but their equipment is world class. They have two EM38 machines. The only piece of equipment that failed to impress was their fairly small soil ovens. They air dry most soils outside before bringing subsamples into the lab for analysis. If we have equipment funding in a new project, it is suggested that we hold over a few thousand dollars for more oven space.

Our field trip involved examining the extent of salinity impacts in the delta areas of Badin district. We first inspected a site on an old river course used as an irrigation distributary. At the time the water course was full, but we were advised that that was just the level of the water table. The site was at a junction offtake, and was being lined on a corner with stone. The purpose was to decrease erosion rather than to reduce seepage.

We then spoke extensively with a local farmer, Majid Khan Notkani, the chair of a local farmers' organisation. Clearly displaying wealth, he wore a crisp white shalwa kameez and a pork pie hat. We inspected land that had been in his family for a while. Land that his grandfather had been able to get useful production from was now becoming too saline, even to grow rice in the Kharif. The water level in an open pond showed that the water table in the area was ~1.3 m deep. He had a dilemma: he knows that if the land is not tilled then it will be lost; however, the productivity of the Kharif rice is now not sufficient to cover his costs. There is variation in the landscape: nearby land was still sufficiently non-saline to grow sugar cane. Nevertheless, we were left with the clear impression that this was a landscape poised on the edge of ruin. Ironically, the burning of sugar cane trash (a potential mulch that could save this land from the capillary rise of salt) was clearly visible, just a few hundred meters away (Photo 9).

Photo 9: The land on this side of the pond has not seen a crop for several seasons and is very saline affected. The adjacent wheat plot had seen sugar cane (residue being burnt)

We also visited PCRWR piezometers to see the extent of seawater intrusion. The impacts are noticeable with EC recordings of shallow groundwater in excess of 45,000 μS/cm. Drinking water is also in short supply in these regions as the shallow groundwater is undrinkable. Mapping salinity in the districts of Thatta, Sujawal and Badin is required to develop a better understanding of salinity dynamics in this region. In some areas of Badin sunflower crops are thriving, this may be because of pockets of freshwater. Also sunflower is not irrigated in some areas as residual moisture is used to grow the crop. Our initial assessment is that over irrigation may result in shallow water tables rising bringing salts to the surface and reducing crop productivity.

Reflections and learnings from salinity related activities

In the areas we visited, the impact of salinity is very prominent. In many salt affected areas farmers do not know what to do or lack the capital to deal with this problem. There is a tendency for small farmers to give up farming and seek another job while larger farmers are better able to manage this problem by accessing enough canal water and/or use groundwater. Many small farmers have left affected areas, or are changing crops grown (such as sunflower which can tolerate salt/ use less water). Some are practising ridge and furrow irrigation method to save water losses from lateral seepage into soil. Wealthier farmers are investing in high-value crops (such as chilli), often intercropped with others (banana or brinjal) to maintain a steady income. Some farmers reported problems of marketing these crops at the guaranteed price, as such farmers are unable to sell their harvest on time and with the guaranteed price (which was set by government). This is a serious issue for sugarcane growers in particular who are unable to sell their harvest to mill owners, faced with delays and lower prices. This implies that there is a severe marketing problem, though farmers are producing their crops efficiently. Many farmers have livestock, but it was reported that government veterinary officers do not provide proper services affecting the development of livestock/poultry industries.

Some opportunities:

1. Agronomy practices:
Improving technical skills of the farmers to adopt to saline conditions through practices such as:

- Conservation agriculture and for growing salt/ drought tolerant varieties;
- Producing high value and water saving crops such as canola/sunflower, horticultural crops;
- Application of low cost land reclamation practices such as use of farm yard manure, crop residuals as mulching (for example from sugar cane), fallow land with fodder/legumes

2. Irrigation improvement:
Improving water conservation methods/irrigation practices to save water and reduce salinity:

- Addressing head-tail equity through proper water distribution scenario and policies;
- Canal lining and high tech irrigation methods that are practical and affordable by farmers;
- Installing loggers to monitor groundwater use and quality and solar to reduce the pumping costs

3. Socioeconomic and policy context:

- Ensuring that farmers get guaranteed price for their crops, formulating collective action for selling/marketing of products, to make them economically efficient and reduce groundwater use;
- Developing processing opportunities/ alternative supply chain for their products;
- Capacity building of farmers, enhancing access to input/out markets and credit facilities;
- Facilitating PPP for investing in innovative methods to enhance farming livelihood in long run

There appear to be a range of crops that have potential for Rabi cropping but farmers have little idea about their relative salt tolerance. Our project could run adaptation trials of different crops relating yield to salinity. MUET (Dr Altaf Ali Siyal) has an EM38 that would be essential to analysing the variation in soil data in such trials. Comparisons could be made between the salt tolerance of crops (sunflower, mustard, wheat) and forages (barley, berseem, cowpea, sesbania, messina)[3]. A link with ICBA in Dubai might be useful in helping us access a range of germplasm.

We could use the special salinity modifications to APSIM-SWIM (being undertaken in the ACIAR Bangladesh project (by Gaydon and Barrett-Lennard) to model the impacts of different scenarios (e.g. decreased water availability, climate change) on the production of the major Rabi crops in Pakistan. Doing this would require the services of a good modeller.

Salinity causes: Pakistan faces three critical causes of salinity. The most important cause is seepage from canals, water courses, and over-irrigated fields (especially in the rice phase Kharif season), which is causing the rise of groundwater, bringing salt to the soil surface. This is the salinity/waterlogging combination that is widely recognised. Gradual improvements are occurring through the lining of water courses, but this can occur during the relatively brief period in mid-Rabi season when the canals are emptied for maintenance. Progress is therefore slow. Far more rapid progress might be possible if farmers were able to diversify from growing rice to more water efficient Kharif crops.

[3] Ed's notes: In our trials in Iraq, sesbania and cowpea produced biomass yields of 15-30 t/ha under irrigated conditions (Salman et al. 2013). Messina has proven to be an exceptionally salt tolerant fodder legume in Australia (Nichols et al. 2008), although it does need inoculation with an especially salt tolerant rhizobium to persist (Bonython et al. 2011).

The second cause of salinization is irrigation itself. Because of the salt in the canal water, and more particularly in the groundwater, irrigation ends up adding 1 ton/ha of salt to all irrigated land every year. Most of this stays on the affected land and there doesn't appear to be anything we can do about this.

The third cause of salinity is seawater intrusion into the Indus Delta. This appears to be focused especially in the old distributaries of the ancient delta. Research to map these would assist us in giving better strategic and tactical advice to farmers.

Our project needs to have a stronger focus on adaptation to salinity than mitigation. Although farmers and government agencies would like to drain affected landscapes, the truth is that there will never be sufficient funds to achieve this on the scale required.

Use of project time: The four-year term of the project provides us with the opportunity employ a 1-year/3-year strategy, carefully evaluating a range of possible options in an initial 'project design' year (year-1), and then implementing this strategy in years 2-4.

New extension methods: One regret from Ed's previous ACIAR Pakistan projects was that there was little if any long-term adoption of our technologies. A figure quoted to us, is that there are about 6000 farmers for every agricultural extension officer. Many poor farmers will only speak Urdu or local languages, and many may also be illiterate. Fortunately, nearly all farmers (or members of their families) now have mobile phones. Conversations with Tehmina Mangan and PCRWR lead me to believe that it may be possible to deliver information through combinations of android, smart-phone and internet. It should be possible to generate a wide range of information products (text, photograph, video, audio) for these platforms, and for this material to be all harvested to deliver a successor to the Qureshi & Barrett-Lennard book – an Encyclopaedia of Saline Agriculture for Pakistan. To achieve change on the scale required, our proposed project will need to deliver relevant information to hundreds of thousands of poor farmers. This may now be achievable.

Land and water capability:
We need a strong focus on land and water capability and its implications for social and economic value. As land and water become more saline, the capability of the land and water to grow crops and forages will decrease, which will result in a loss of socio-economic value (Fig. 1). As land and water lose capability the optimal cropping strategy will change. For example, in the Rabi season, high utility crops like wheat may give way to the growth of more salt tolerant, but lower utility canola and sunflower, and with higher salinity, these may in turn give way to even more salt tolerant, but lower utility forages. A substantial effort will be required to identify the best options and management

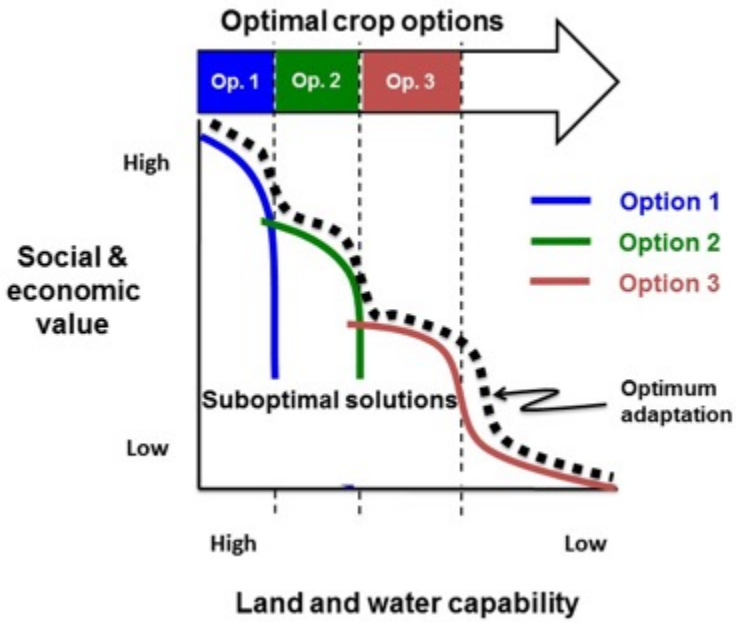


Figure 1. Conceptualisation of adaptation need for crop diversification due to system degradation (after Condon et al. 2017).

strategies to ensure that farmer performance presses against the optimal performance boundary – the dotted line in Fig. 1. In order to identify the optimal cropping system adaptations, it will be necessary to conduct research to define the interaction between land and water capability for diverse crop options, and the socio-economic value of crop product and supply chains.

Crop salt tolerance: There is little useful information about the relative salt tolerance of the major crops under Pakistan conditions. Our field observations in this Rabi season suggest that farmers recognise that sunflower, canola and barley are more salt tolerant than there Rabi season alternatives. It would be useful to establish crop adaptation trials in which the salt tolerance of these species are compared in field trials with other prospective options (e.g. sesbania, cowpea, messina). These trials have been difficult to conduct in the past because of site variation, however many Pakistan groups have the EM38 which enables us to measure 'apparent electrical conductivity' as a covariate of salinity. These kinds of statistical analyses may therefore enable us to derive 'adjusted yields' removing the effects of site variation. A recent published example where this has been done with wheat and barleys trials is the work of Setter et al. (2016).

Land management options: There appear to be three innovative management options that could make a considerable impact on future salinity options in Pakistan.

1. Mulches. One of the principal causes of soil salinity is evaporation of groundwater at the soil surface. The use of mulches is a well understood means of decreasing such evaporation. They break the capillary pathway for water movement to the soil surface. A range of practices such as tillage, the shading of soil by crops and application of crop residues to the soil surface can have mulching effects. It was surprising to see mulches not being applied to the soil surface even though farmers with shallow watertables appeared to be desperate for production. It was particularly ironic to see saw sugar cane trash being burnt in fields, and there was considerable transport of rice straw off farm – presumably for some other low value application. These seem like enormous wastes of potential soil-saving resources. There is an urgent need to trial the effects of mulches on soil salinity and crop performance, perhaps with some supplemental nitrogen to offset the nitrogen losses associated with the microbial degradation of the mulches.

2. Use of bedding systems in the Rabi season. The major cause of most local field-based salinity is the development of shallow groundwater caused by over-irrigation. We saw that innovative bedding systems are decreasing the application of irrigation water. The over-watering is due to most crops being relatively shallow rooted, and farmers using frequent flood irrigations to keep the surface of the soil wet. Deeper recharge over the entire surface of the field is inevitable under these conditions. On the other hand, if free flowing water was confined to smaller proportions of the field surface (focused in furrows between beds), then deep percolation would also be confined to these smaller proportions of the total field surface.

3. Alternative Kharif crops. Most of Pakistan has a rice/wheat system. Rice needs to be puddled to grow, and this puddling causes huge basin-wide Kharif season increases in groundwater. I had always been under the impression that Kharif rice was an essential part of the Pakistan cropping system, but the conversation that Ed had with the FAO rep in Karachi after the rest of the team departed suggests that this might not be the case. Any diversification of cropping systems away from rice in the Kharif would have significantly positive impacts on depth to groundwater and therefore salinity, potentially throughout the country.

Livestock: Everywhere we travelled we saw extensive use of livestock (goats, cattle, sheep, buffalos) in the farming systems. It is quite clear that we cannot ignore the importance of forages in our work. Livestock specialists could be useful additions to the team.

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