Annual report

Project

Optimising Canal and Groundwater Management to Assist Water User Associations in Maximizing Crop Production and Managing Salinisation in Australia and Pakistan

project number LWR/2005/144

period of report Jun 1, 2010 - May 31, 2011

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prepared by Mohsin Hafeez

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approved by Mohsin Hafeez
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1 Progress summary

The project activities from June 1, 2010 - May 31, 2011 are given in this report. The project builds on the strong track record of different federal and provincial organizations in participatory irrigation management, particularly, the current initiatives by the Government of Punjab through Punjab Irrigation and Drainage Authority (PIDA), Punjab-Pakistan. PIDA is working closely with the Farmer Organisations (FOs) under the ongoing institutional reforms in the command area of Lower Chenab Canal (LCC) in Pakistan. This project thus link to different federal and provincial organizations responsible for irrigation management, and the extension services for participatory demonstration, evaluation and exploration of adoption pathways regarding promising on-farm water saving technologies already developed (e.g. laser-levelling; raised beds; zero-till planting etc.) elsewhere by the project team.

This project will develop and use, for the first time in the history of canal and groundwater management in Pakistan, the hydrologic-economic modelling tools capable of scenario analysis of water distribution as a function of crop-groundwater-soil mix at farm and "distributary" and "minor" canal levels both in the LCC and Coleambally Irrigation Area (CIA), Australia. More importantly, the project will couple Remote Sensing and hydrological data with socioeconomic data for developing the surface and ground water supply and demand management options at various spatial scales, for tailoring water sectors adaptations to climate change.

As per project proposal, three distributaries (one each in head "Bhalak", middle "Tarkhani", and tail reach "Khikhi") have been selected in the LCC East system where other major research and development initiative relevant to water management is already in progress. In order to get new and reliable hydrological data, the project team has installed 54 new piezometers, 3 soil moisture probes (provided by CSU team) and an automatic weather station at selective locations within the distributaries in the LCC. Other hydrological parameters including water quality and groundwater extraction has been collected on fortnightly basis at selective distributaries in the LCC and is being processed by partner country (PC) team. PIDA staff is involved in continuous calibration of the gauges at critical canal water delivery points to ensure accurate flow data availability to the project team. Historical data on canal flows across the LCC system have also been collected. This data is being used for water accounting analysis at selective distributaries and for the development of regional surface and groundwater interaction model using MODFLOW. In May 2011, the project team has carried out an extensive ground truthing campaign over two weeks to get information about land use and land cover classification. The project team has developed spatio-temporal maps of actual evapotranspiration and soil moisture using remote sensing based energy balance model for selective distributaries and minor canal levels in the LCC.

The project team has analysed the collected (December 2009-January 2010) socio-economic data of the project distributaries in the LCC system. A multistage stratified random sampling method was used to select a sample of watercourses within the study area. Data about the socio-economic aspects was collected through a structured questionnaire by trained and qualified field enumerators from the University of Agriculture Faisalabad (UAF). The sample included 2 watercourses in the head, middle, and tail sections each of the 3 distributaries covering both the left and right side, giving a total of 18 watercourses. A total of 265 respondents in 21 villages were interviewed. The data collection modules included household basic information, agricultural production, agricultural practices, income and expenditure, groundwater, energy and climate change. The results of the survey are included in a separate technical report on socio-economic component of the project.

The CSU team has developed a database of irrigated crops, water distribution, groundwater uses, aquifer characteristics, and cropping pattern for the CIA. The project team is
continuously collecting data including hydrological, meteorological and flux tower for spatial water accounting analysis and irrigation demand forecasting at system level and sub-system level in the CIA. The developed database was used for irrigation demand forecasting and spatial water accounting analysis in the CIA. The project team has completed remote sensing modelling to develop spatio-temporal maps of land use and land cover classes, actual evapotranspiration and soil moisture at sub-systems and system levels for 2008-09, 2009-10 and 2010-11. In addition, GIS analysis was used to develop ground water use and level maps for the same years in the CIA. Water accounting analysis has already been completed at selective farms, sub-systems and system level in the CIA for 2008-09 and 2009-10.

The CSU and PC project teams also conducted field visits on 30-31 May 2011 in the LCC system and held extensive discussions with members of FOs and farmers in the command area of Bhalak, Tarkhani and Khikhi distributaries to have a better understanding of the major issues and to devise a suitable strategy for addressing the issues falling within the scope of the project.

The third Annual project workshop was held on 01 June 2011 at UAF, Pakistan. Around 70 key stakeholders participated in the workshop including technical experts, CSU team, PC project team, irrigation and agriculture departments, farmers and members of FOs from the study area. The CSU and PC project team gave detailed presentations on ACIAR project activities during 2010-11 in Australia and Pakistan. The workshop also included three focus groups discussion namely surface and groundwater modelling, functioning of FOs and their role in Irrigation Management Transfer, and irrigation policy issues. The focus groups provided practical suggestions and way forward to address major issues affecting FOs performance in successful operation and maintenance of secondary canals under Irrigation Management Transfer agreement with PIDA.

The ACIAR project has thus been instrumental in mobilising resources and high-level stakeholder networking and engagement.
## 2 Achievements against activities and outputs/milestones

### Objective 1: To develop tools capable of analysing hydrological and economic water management trade-off scenarios using spatial crop, soil, water availability and water quality data

<table>
<thead>
<tr>
<th>No.</th>
<th>Activity</th>
<th>Tasks</th>
<th>Completion date</th>
<th>Outputs / Comments</th>
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<tbody>
<tr>
<td>1.1</td>
<td>Collect and synthesise data regarding irrigated crops, water distribution, groundwater uses, soil physiography, aquifer characteristics, and cropping pattern in the command area of the LCC in Pakistan and CIA in Australia</td>
<td>Literature review regarding canal, groundwater, soil and crop issues at farm and &quot;distributary&quot; and &quot;minor&quot; canal levels both in the LCC and CIA.</td>
<td>Jan 2010</td>
<td>Discussion paper about the canal, groundwater, soil and crop issues was finalised for the CIA and the LCC system. Two papers on the LCC and the CIA were presented at international conferences: Wu, J., Hafeez, M.M., Ullah, K., Bodla, H.U. and Ahmad, R.N. (2011) A Groundwater Model for Canal and Ground Water Management to Enhance Crop Production in Indus River System of Pakistan, EGU General Assembly 2011, Vienna, Austria. Ullah, K., Hafeez, M., Chemin, Y., Faux, R. and Sixsmith, J. (2011). Real Time Water Demand Forecasting by Integrating Remote Sensing derived Actual Evapotranspiration with Meteorological Data for an Irrigation System. 34th International Symposium for Remote Sensing of Environment 10 – 15 April 2011, Sydney Convention &amp; Exhibition Centre, Sydney, Australia.</td>
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<td></td>
<td>Collect and synthesise facts and figures from existing data sources and available reports for the LCC and CIA.</td>
<td></td>
<td>Jan 2010</td>
<td>Historical data including hydrological, meteorological, satellite imagery, aquifer characteristics, cropping patterns and socio-economic has been synthesized from existing data sources and available reports for the LCC and CIA. In addition, data on groundwater levels and other hydrological parameters is being collected at 54 locations since the inception of the project. For the calibration and validation of remote sensing derived ET and soil moisture, the project team is also continuously collecting data from three soil moisture probes and an automatic weather station installed in the LCC. PIDA staff is continuously calibrating the gauges at critical canal water delivery points to ensure accurate flow data availability to the project team. Historical data on canal flows in the LCC system have also been collected. This data is being used for spatial water accounting analysis at selective farms as well as distributaries and for the development of surface and groundwater interaction model using MODFLOW.</td>
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<td>1.2</td>
<td>Explore major issues associated with water distribution; identify gaps in the existing knowledge, planning and implementation; and articulate real aspirations for the future of the region for a sustainable irrigated agricultural base and healthy catchments.</td>
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<td>Jul. 2010</td>
<td>The project team had several meetings with selected scientists and regulation agency staff from different disciplines, and community members to discuss major issues associated with irrigated agriculture in the LCC system. Since 2008, A/Prof. Mohsin Hafeez and the team met with key group of experts and scientists working within the water management sector in Pakistan to get better clarification in canal and groundwater management issues in the LCC. The expert groups include Dr. Zafar Altaf (Ex-Chairman Pakistan Agricultural Research Council 'PARC'), Dr. Shahid Ahmad (Member, Natural Resources Management, PARC), Mr. Rabnawaz (Secretary Irrigation and Power Department), Dr. Madar Samad (Director, International Water Management Institute (IWMI) South Asia), Mr. Hakeem Khan (Ex-Director, IWMI Pakistan), Dr Sadiq Shafique, (Ex) Irrigation Management Specialist at IWMI, Mushtaq A Gill (T.I) Director General (Ex), Water Management, Punjab; Executive Director South Asian Conservation Agriculture Network (SACAN), Mr Tsutomu Shimuzu (Japan Bank of International Cooperation &quot;JICA&quot;), Shafiq Ahmed (Director, Space...</td>
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<td>Document findings on: (i) major issues associated with water distribution, (ii) gaps in the existing knowledge, planning and implementation of on-farm water management, and (iii) important features that constitute resilient irrigation communities and environments for better on-farm water management.</td>
<td>Dec. 2010</td>
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For the LCC, the major issues associated with water distributions are;
(i) Irrigation system constraint;
(ii) Unreliable and inadequate water supply at the farm level;
(iii) Lack of rationalization of water allowances on the scientific basis;
(iv) Inequitable water distribution especially at the tail reaches;
(v) Inaccurate discharge measurement at secondary and tertiary canal head regulators; and
(vi) Deferred maintenance of the system
(vii) Substantial increase in the cropping intensity and inappropriate cropping pattern;
(viii) Over exploitation of groundwater;
(ix) Deterioration of groundwater quality;
(x) Water logging and salinity;

The major gaps in the existing knowledge, planning and implementation of on-farm water management are;
(i) Poor irrigation practices;
(ii) Poor maintenance of the water courses;
(iii) Use of marginal and poor quality groundwater on the farms;
(iv) Lack of adoption of resource conservation technologies at the farm scale; and
(v) Small farm sizes

The important features that constitute resilient irrigation communities and environments for better on-farm water management are providing enabling environment to the farmers for their effective participation in the water management.
Undertake spatial and temporal hydrological analysis as a function of crop-groundwater-soil mix at farm and "distributary" and "minor" canal levels both in the LCC and CIA.

Update the developed database of irrigated crops, water distribution, groundwater uses, soil physiography, aquifer characteristics, and cropping pattern in the LCC and CIA.

Prepare spatial and temporal hydrological maps of water distribution as a function of crop-groundwater-soil mix at "distributary" and "minor" canal level both in the LCC and CIA.

May 2011

To address the equity issues in the distribution of canal water, PIDA has established surface irrigation water monitoring unit. PIDA has a complaint management system for the farmers to lodge complaints about water distribution. Figure 1 shows registered complaints about inequity in water distribution in the LCC (E) during last three years.

The developed database of irrigated crops, water distribution, groundwater use, groundwater water levels and quality, and aquifer characteristics has been updated on continuous basis in the LCC and the CIA. In addition, the project team is acquiring optical-thermal satellite imagery (MODIS and Landsat) on continuous basis to model actual crop water consumption and soil moisture, and mapping of irrigated crops in the LCC and the CIA.

For the CIA, the project team has completed remote sensing modelling to develop spatio-temporal maps of land use and land cover classes, actual evapotranspiration and soil moisture at sub-systems and system levels for 2008-09, 2009-10 and 2010-11 (Figure 2). In addition, GIS analysis was used to develop ground water use and level maps for the same years.

For the LCC system, the project team has developed spatio-temporal maps of actual evapotranspiration and soil moisture using remote sensing based energy balance model for selective distributaries and minor canal levels in the LCC. Similarly, the project team has also developed ground water level maps for selected seasons.
| 1.4 | Develop a hydrologic economic framework capable of scenario analysis for more equitable, economically efficient and hydrologically sustainable distribution of canal and groundwater at farm and “distributary” and “minor” canal levels both in the LCC and CIA. | Develop a hydrologic economic framework capable of trade-off scenario analysis of optimising canal and groundwater management given the crop-groundwater-soil mix as a function of distance to canal and socio-economic parameters. | Mar 2011 | The project team has completed salt and water balance analysis at selective farms using the SWAGMAN farm model, a farm scale salt, water and groundwater management model linked with economics. The project team is working on finalization of groundwater model using MODFLOW by dividing the area into ten administrative units in the LCC (E). The west part of the LCC was taken as a whole irrigation area. The model grid consists of 450 columns x 450 rows and four layers. The model was developed for the period from 2003 onwards. Based on an initial analysis of ground water flow, the river Chenab, the river Ravi and Qadirabad-Balloki link canal were taken as the boundary of the simulation model because of their huge discharges and close connection with the groundwater system (Figure 3). The project team has discussed various viable scenarios with the stakeholders and experts including reallocation of surface water supplies from fresh groundwater areas to marginal and poor quality groundwater areas, and prediction of long-term impact of overexploitation of groundwater in areas of already stressed aquifer in the LCC system. Based on socio-economic survey of December 2009-January 2010, an optimal water allocation and optimization model entailing improved canal and groundwater management is being developed. At this stage, the effects of conjunctive use of canal and groundwater on wheat productivity and profitability are being investigated by using the yield function (Figure 4). Several scenarios will be developed to meet the objectives. The hydrologic economic framework capable of trade-off scenario analysis of optimising canal and groundwater management is being developed. |

$PC = \text{partner country}, \ A = \text{Australia}$
Objectives:

Objective 2: To use the developed optimisation tools in a participatory mode with Farmer Organisations in Pakistan and stakeholder groups in Australia to help determine possible improved (more equitable, economically efficient, and hydrologically sustainable) canal and groundwater management options acceptable to the irrigators.

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<thead>
<tr>
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<tr>
<td>2.1</td>
<td>Conduct a preliminary analysis using hydrologic economic models for canal and groundwater management in consultation with different stakeholders.</td>
<td>Conduct a preliminary analysis for canal and groundwater management in the CIA and LCC. Consult different stakeholder for feedback on the preliminary analysis results.</td>
<td>Sep 2011</td>
<td>The preliminary analysis for canal and groundwater management is being finalized using SWAGMAN farm model, groundwater model, and water allocation and optimization model coupled with economic data. The project team has also shared initial results with the wide group of stakeholders and experts during the annual project workshop on 01 June 2011. Three focus groups were established to provide a feedback and suggestions on the following technical areas relevant to the project area: 1- Surface and groundwater modelling 2- Functioning of FOs and their role in irrigation management transfer 3- Irrigation policy issues. The project team has already completed water accounting at seven farms, sub-systems and system level in the CIA for 2008-09 and 2009-10. For the LCC system, the water accounting at three selective distributaries and at the system has also been completed for 2009-10 and 2010-11.</td>
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<td>This task will be assisted by field studies for water accounting at farm and &quot;distributary&quot; and &quot;minor&quot; canal levels both in the LCC and CIA.</td>
<td>Dec 2011</td>
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Objective 3: To support PIDA and Farmer Organisations in the implementation of more equitable, economically efficient and hydrologically sustainable canal and groundwater management options in the study areas.

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<tr>
<td>3.1</td>
<td>Conduct separate interviews and workshops with community participants and groups of ‘experts’ to better clarify the major issues in canal and groundwater management.</td>
<td>Organise interviews and workshops with community participants and groups of ‘experts’ to better clarify the major issues in canal and groundwater management.</td>
<td>May 2010</td>
<td>This activity has been fully achieved. A/Prof. Mohsin Hafeez and Munir A. Hanjra visited the project area and held interviews and workshops involving discussions with community participants and groups of ‘experts’ in January 2010. During a follow up visit by the project team, led by A/Prof. Mohsin Hafeez, they also held further discussion with key experts in March 2010. The project leader met with key group of experts working within the water management sector in Pakistan to brief them about the ACIAR project, to learn about other ongoing projects and to get better clarification of canal and groundwater management projects. The project workshop held on January 11, 2010 was inaugurated by Professor Iqrar Khan, Vice Chancellor, UAF, Pakistan. A/Prof. Mohsin Hafeez, Habib Ullah Bodla and Professor Rai Niaz gave detailed presentations on ACIAR project activities during 2009-10 in Australia and Pakistan in the morning session where as focus group discussions and synthesis presentations thereof were held in the afternoon session, including: Socio-economic Analysis Group: synthesis presented by Munir A. Hanjra, CSU Hydrological Modelling Group: synthesis presented by Professor Zulfiqar Ahmad, Quaid-i-Azam University, Islamabad Irrigation Management Group: synthesis presented by Dr Sadiq Shafique, (Ex) Irrigation Management Specialist at IWMI Up-scaling and Extension Group: synthesis presented by Professor Bakhshal Lashari, Mehran UET, Sindh Policy Implications Group: synthesis presented by Mushtaq A Gill (T.I) Director General (Ex), Water Management, Punjab; Executive Director South Asian Conservation Agriculture Network (SACAN) Similarly, the annual project workshop for 2010-11 was held on June 1, 2011 at UAF and more than 70 participants including FOs, PIDA officials, experts and farmers attended the workshop.</td>
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</table>
To better clarify the major issues in canal and groundwater management, data on socio-economic factors was collected in the command area of three project distributaries (PC). The sample size was calculated randomly taking into account variations such as location of watercourses in head, middle and tail reaches of the three distributaries under the project. A total of 265 respondents in 21 villages, served by 18 watercourses in the head, middle and tail sections of three selective distributaries were interviewed by trained and qualified field enumerators from the UAF. The comprehensive survey was carried out from December 2009-January 2010.

The project intends to conduct another survey of the same sample size for the selective distributaries in December 2011 and January 2012.

This data on baseline socioeconomic conditions and end-of-project conditions will enable impact assessment of the project. This activity will successfully demonstrate, evaluate and explore adoption pathways regarding promising on-farm canal and groundwater management strategies, and water saving technologies.

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<th>Activity</th>
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<tr>
<td>Organise a joint year-end workshop to resolve differences between the ‘experts’ and farmers.</td>
<td>Dec. 2009/ Jun. 2011</td>
<td>This activity has been fully achieved through series of interviews of the experts and FOs representatives through three annual project workshops (October 2008, January 2010 and June 2011). Findings from previous interviews and workshops have been used to re-select one irrigation distributary as project site (PC) and better plan the year-end workshop. For assessing the stakeholders’ perceptions regarding the major issues in canal and groundwater management, a joint year-end workshop was conducted in June 2011 (PC).</td>
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<tr>
<td>Analyse and synthesise findings from interviews and workshops.</td>
<td>May 2010</td>
<td>Report prepared on the findings from interviews and workshops. This activity has been fully achieved. Findings from previous interviews and workshops have been synthesised. Findings from a joint year-end workshop and survey data from 265 respondents has been synthesised.</td>
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</table>
The age of the respondents in the selective distributaries (PC) ranged from 18 to 75 years with an average age of 50 years. The average schooling year was 6.56. Disinterest of parents and requirements to work at the farm were stated as major reasons by most of the respondents for not attending school.

According to the survey results, household members spent most of their time on farm activities followed by paid work and education. Households in Khiki command area have the highest income from various sources including remittance and Bhalak has the lowest income. Major contributor towards this income for the three distributaries is selling of animals.

The major crops are wheat, maize, sugar cane, fodder (barseem & lucerne), gram, onion and chilly. Regarding present status of improved watercourses within the study area, majority of the respondents on Bhalak and Tarkhani distributaries reported that they have rehabilitated watercourses. Overall, farmers rated poor embankments of the canal as the main problem, followed by absence of water measuring devices and illegal water use.

The farmers reported that maximum canal water shortage occurred during the months of December-February, which are critical months for planting and initial growth of the wheat. Most of the farmers reported that they only receive 21-60% of their total water demand during the whole year. The farmers in the head and middle reaches of the distributaries were more satisfied with the quantity of irrigation water received as compared to tail end farmers. Majority of the farmers responded that current Abiana (water charges) are moderate and needs revisions. However, majority of the farmers demanded to double the increase irrigation water supplies from current irrigation levels.

Groundwater is not only being used as a source of domestic water supply but it augments the canal water supplies to meet crop water requirements of irrigated agriculture. Tubewells are mainly running on diesel which has high operational cost. The pumping cost of the groundwater varied not only from distributary to distributary but the cost also varied within each of the distributary.
### 3.2 Training workshops to assist Farmer Organisations in participatory demonstrating, evaluating and exploring adoption pathways regarding promising on-farm canal and groundwater management strategies, and water saving technologies.

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<tr>
<th>Prepare training modules, and conduct training year-end workshop in LCC.</th>
<th>December 2010-11</th>
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The major problems ranked by the majority of farmers are the shortage of irrigation water, purchase of fertilizers and agro-chemicals from the market. Significant numbers of the farmers in Khiki distributary also advise that poor irrigation facilities are the main factor affecting crop production.

There was significant yield difference among the head, middle and tail reaches along the distributaries. Results show that yields are generally higher in head reaches, followed by middle and tail except Khiki distributary.

The project team had meetings with FOs representatives and a group of farmers in Khiki and Turkhani distributaries on May 30th and in Bhalak distributary on May 31st to assess the training needs for an efficient irrigation water management at the farm scale. The project team has prepared the training modules in Urdu on:

1. Flow measurement and calibration of the gauges by PIDA
2. Introduction to water savings by UAF
3. Resource conservation technologies by UAF
4. Improved Irrigation practices by UAF

The project team plans to conduct training in November-December 2011. In addition, the project team agreed with FOs in PC to produce a video demonstrating efficient irrigation management and best-bet irrigation management practices used by the farmers in Australia.

*PC = partner country, A = Australia*
Figure 1 Farmer's complaint about the inequity in water distribution in the selective distributaries and in the LCC (E) system during 2008-2010

Figure 2 Spatial distribution of monthly and seasonal actual ET using Landsat 5 TM satellite for summer 2009-10 in the CIA
Figure 3 Groundwater Level and flow vector in the LCC system (Left: Jun 2003, Right: Jun 2008) using MODFLOW

Figure 4 Water Allocation and Optimization Model for the wheat crop in the LCC (E) system
Field Visit of the Project Team, comprising CSU staff and PC staff, to Data Collection sites specifically soil moisture probe locations and piezometers monitoring during May - June 2011
Consultation and discussions with FOs, farmers and irrigation officials in Tarkhani, Bhalak and Khiki distributaries during May-June 2011 visit
Project Annual Workshop held at University of Agriculture, Faisalabad (UAF) – Pakistan on June 01, 2011. It was attended by FOs Representatives, CSU Team, PMIU-Punjab Irrigation Department, PIDA, and academia from UAF, Quaid-e-Azam University Islamabad, National University of Science and Technology, Islamabad.
3 Impacts

3.1 Scientific impacts

This project will develop and use, for the first time in the history of canal and groundwater management in Pakistan, the hydrologic-economic modelling tools capable of scenario analysis of water distribution as a function of crop-groundwater-soil mix at farm and "distributary" and "minor" canal levels both in the LCC and CIA. More importantly, the project will couple Remote Sensing and hydrological data with socioeconomic data for developing the surface and groundwater supply and demand management options at various spatial scales, for tailoring water sectors adaptations to climate change.

Using participatory approaches, the project is also assisting FOs and PIDA staff for demonstrating and evaluating adoption pathways as listed below:

(i) promising on-farm canal and groundwater management strategies that would ensure more equitable, economically efficient and hydrologically sustainable distribution; and

(ii) on-farm water saving technologies already developed elsewhere (e.g. precision land levelling; raised beds; and zero-till planting etc.). Four training modules in Urdu are being developed in consultation with FOs and hands-on training will be provided in the near future.

This project has the potential to highlight the tradeoffs in canal and groundwater management in terms of the impacts on resource quality, income and livelihoods, socioeconomic impacts. This will need integration of Remote Sensing data with baseline socioeconomic data, to be collected through in-person interviews using a questionnaire data for socioeconomic impact assessment. The coupling of household level socioeconomic with the remote sensing and biophysical data is scientifically innovative in data sparse environment like LCC system. This will have significant scientific impacts by advancing the academic and scientific capacity of the PC team.

The project is also making use of the existing models (e.g. SWAGMAN) for optimising land and water management decisions at farm level. For regional groundwater management, MODFLOW/MT3D (a 3-dimensional ground water flow and solute transport model) is being developed for understanding the sub-regional supply (canal) surface and groundwater interactions. Simulations for various viable scenarios will be carried out for all administrative units to understand groundwater dynamics. Water allocation and optimization model entailing improved canal and groundwater management is being developed. The effects of conjunctive use of canal and groundwater on major crops productivity and profitability will be explored by using the crop specific yield functions for the LCC (E) system.

3.2 Capacity impacts

CSU team has provided training to PC team on the use of GPS for the collection of geo-referenced data and the ground truthing for Remote Sensing analysis, as well on the use of Electrical Conductivity (EC) meters for collecting data on water quality. In addition, the CSU team has provided tailored training on the installation, use and analysis of soil moisture probes used in the project area. The CSU team has also taken the lead on developing a questionnaire for the collection of socioeconomic data, and provided necessary training to PC staff in Pakistan.

The Annual project workshop for 2010-11 was held on June 1, 2011 at University of Agriculture, Faisalabad - Pakistan. Around 70 key stakeholders participated in the workshop including technical experts, CSU team, PC project team, farmers, PIDA officials and members of FOs from the study area. A/Prof. Mohsin Hafeez, Habib Ullah Bodla and
Professor Rai Niaz gave detailed presentations on ACIAR project activities for 2010-11 in Australia and Pakistan during the morning session (June 1, 2011) where as focus group discussions and synthesis presentations thereof were held in the afternoon session, including:

Surface and Groundwater Modelling Group: synthesis presented by Professor Zulfiqar Ahmad, Quaid-i-Azam University, Islamabad

Functioning of FOs and their role in Irrigation Management Transfer Group: synthesis presented by Choudhary Karamat Ali, General Manager PIDA, Lahore

Irrigation Policy Group: synthesis presented by Syed Aquil, Superintendent Engineer of Irrigation and Power Department, LCC Circle.

Focus groups and their synthesis findings were highly welcomed by the stakeholders, including farmers from the PC project area. The focus groups discussed the problems faced by FOs and policy issues effecting FOs performance in successful operation and maintenance of secondary canals under Irrigation Management Transfer agreement with PIDA. The PIDA officials reassured the FOs representatives, addressing their grievances and making necessary adjustments in existing regulations for strengthening the coordination to improve irrigation water management at the farm scale. In addition, A/Prof. Hamza Farooq Gabriel from National University of Science and Technology (NUST) covered the climate change perspectives and its impact on water management in the Indus Basin, Pakistan.

Mr. Habib Ullah Bodla, Team Leader (Pakistan) visited USA during February 2011 for 3 weeks under “International Visitor’s Leadership Program.” During his stay, he briefed the Georgia Technical University, Atlanta Georgia about the interventions of the project including scientific data collection and the development of various surface and groundwater models for the LCC. In addition, he also discussed the various real time data transfer techniques including the installation of Rubicon developed Hydraulic Structure gates at the pilot sites and monitoring of the soil moisture using Aquaspy probes installed in the project sites. Dr. Muhammad Riaz, Team Member from PIDA, participated in the 2nd Istanbul International Water Symposium in May 2011 in Turkey. In the Symposium, he presented the initiatives being taken under the Project by development of database in pilot site of the project regarding surface and groundwater uses, cropping pattern and soil lithography.

Lastly, Mr. Azeem Khan, UAF team member, was awarded John Allright Fellowship to pursue PhD degree at CSU. Apart from the above high-level capacity building for the PC team members, a number of students have been linked with the project as listed below:

Mr. Azeem Khan - PhD thesis on Irrigation scheduling using Remote Sensing and GIS Modelling (CSU Candidate)

Mr Saif-ur-Rehman- PhD thesis on Irrigation Management Transfer in Punjab, Pakistan: A Case study of the LCC Area Water Board (CSU Candidate)

Mr A Waqas - MSc thesis on Assessing the Performance of Large Irrigation System through Remote Sensing and Participatory Approaches (UAF Candidate)

Ms Sadaf Majeed - PhD thesis on Remote Sensing for Actual Evapotranspiration Modelling (UAF Candidate)

Mr M Adnan - PhD thesis on Remote Sensing for Land Use and Land Cover Classification (already secured an admission at CSU and will apply again for John Alright Fellowship)

Miss Sumaira Ashfaq - M.Sc. thesis on a groundwater potential for agriculture in LCC system (awarded M.Sc. degree from UAF in 2010)
3.3 Community impacts

Increasing water scarcity threatens the sustainability of irrigated agriculture and hence the food security. Groundwater use has contributed significantly to food security and reduction in poverty in Pakistan. Due to rapid population growth there has been a dramatic increase of groundwater exploitation leading to declining groundwater tables and deteriorating groundwater quality. In such prevailing conditions, the hydrologic and economic assessment of escalating groundwater exploitation have become of paramount importance. Keeping this in view modelling conjunctive use of surface and groundwater to assess future groundwater trends in the LCC system which is a food bowl of Indus River Basin, Pakistan is of vital importance for sustainability of the irrigated agriculture.

The ongoing reforms in Murray-Darling Basin aim to reduce water diversions from irrigated agriculture to enhance the water availability for the environment. The proposed reduction in water availability to the irrigated sector is threatening the wellbeing and sustainability of rural communities and irrigated agriculture. There is a strong need to scientifically investigate the impacts of water reallocation from irrigation to environment.

In addition, there is a need to understand the costs associated with climate change adaptation and their impacts on farm water management decisions as well as the costs and potential benefits of water management at sub-system and system level. The profitability of farming and the value or market price of water into the future remains uncertain. This project aims to develop science-based information for understanding the impacts of changes in irrigation technology and cropping decisions.

3.3.1 Economic impacts

In Pakistan, the economic payoffs of applying optimising canal and groundwater management options will accrue from three main pathways:

Firstly, where economic optimisation is an implicit outcome, the aggregate value of crop production is likely to be higher than the current aggregate production. On an individual farmer basis, this might result in a few privileged farmers close to the canal not necessarily making gains or even losing some of their productivity and income, but proportionally more farmers standing to benefit through increased crop productivity and incomes further away from the canal - improved equity.

The second mechanism by which economic gains will be generated is by enabling a better return on the Government of Pakistan's current investment in infrastructure rehabilitation and the lining of watercourses, as the improved delivery of water can be coupled to increased crop water productivity.

Thirdly, as the improved distribution of water is also explicitly designed to address the issue of salinisation, economic benefits are also likely to accrue through cost reductions arising out of a reduced need to rehabilitate or reclaim salt-affect irrigation lands. The order of magnitude of these economic benefits will be determined by comparing the "before Project" condition with "after Project" situation by using the socioeconomic panel data collected through household level survey, twice through the project life.

3.3.2 Social impacts

The key community impacts will be reduced social tensions among different stakeholder through equitable water distribution and reduced impacts on the environment. This will result in improved irrigator behaviour towards efficient irrigation water management. The more rational, flexible and equitable distribution of water within FOs is also expected to increase overall food production in the command areas, thus increasing food security. Improved management and surface water supplies in canal system can reduce inequity in water distribution between head, middle and tail-reaches of the system, and contribute to improved social relations and reduced litigation among water users in Pakistan.
The key Australian economic benefit will be reduced non-beneficial water use by matching irrigation demand and supply in the near real time environment. The policy options developed under the project could lead to optimisation of economic returns from limited surface and ground water supplies, while improving the environmental quality.

3.3.3 Environmental impacts

The environmental impacts of this research in both countries are anticipated to be reduced incidence of land and water salinisation and the potential to rehabilitate salinity-affected areas in the longer term, as well as improved equity in terms access to water particularly in Pakistan. The more efficient use of water and land resources is also likely to reduce adverse downstream impacts due to enhanced quality of return flows. Conjunctive use of surface and groundwater can minimise the adverse impacts on the environment due to escalating ground water demand in Pakistan.

3.4 Communication and dissemination activities

The project activities and outcomes are being communicated widely among the stakeholders through FOs field days and demonstration and training components of the project, as well as workshops, conferences, briefing, technical notes, public seminars. The Annual project workshop for 2010-11 was held on June 1, 2011 at University of Agriculture, Faisalabad - Pakistan. Around 70 key stakeholders participated in the workshop including technical experts, CSU team, PC project team, farmers, PIDA officials and members of FOs from the study area. In addition, the project information and achievements was widely disseminated through national, regional and local newspapers in English and Urdu.
CALL TO SAVE GROUNDWATER

Speakers at a seminar have called for adopting latest water management trends to save groundwater and agricultural water to fight water crisis being faced by the country.

They were addressing a seminar on the project of optimising canal and groundwater management to assist water user associations in maximising crop production and managing salinisation with Australian assistance.

Speaking on the occasion, UAF Faculty of Agriculture Engineering Dean Prof. Rai Niaz said that a mechanism was being devised to provide water to farmers as per to their needs, preventing its wastage and theft.

He said that machines would be installed at various points that would analyse water extracted from the ground. PDA General Manager (Operations) Khurram Ali said that the project would help farmers to have a check on water. He said that the PDA was doing its best to redress the irrigation problems. Prof. Mohsin Haider of the Charles Stuart University also spoke on the occasion.
4 Training activities

Key training activities conducted by the CSU team under this project include:

1. Training to PC team on the use of GPS for the collection of geo-referenced data and the ground truthing of Remote Sensing and satellite data.

2. Training on the use of Electrical Conductivity (EC) meters for collecting data on water quality.

3. The development of questionnaire for the collection of socioeconomic data, and training to PC staff in Pakistan on data collection, collation, and analysis.

4. Training on remote sensing for modelling of actual ET in data sparse environments to PC team. Future trainings on this component are planned during late 2011.

5. Training on the protocol and format for database development and sharing the project data among the team members in PC and Australia.

6. Training on installation, use and data analysis from soil moisture probes used in the study area.

In addition, there is a strong demand from PC team (UAF and PIDA) to provide two week intensive hands-on training on remote sensing and GIS application for hydrology.
5 Intellectual property

There are no intellectual property and other regulatory compliance concerns in the project, at this stage. Information generated, technologies tested and model developed will be handed over to the respective stakeholders to facilitate their implementation and adoption.

All intellectual property issues will be subject to the standard clause under the Australian state and territory regulations.
6 Variations to future activities

There are no major variations to year 4 activities at this stage. However, there are some minor variations to personnel's time allocation given their skill-set and the future needs of the project from Australian and PC. The detail of these changes in the available scientific team of CSU is given in the next section.
7 Variations to personnel

The following personnel are available for ACIAR Project.

<table>
<thead>
<tr>
<th>Contract Named Person</th>
<th>Role</th>
<th>% of Time</th>
<th>Agency</th>
</tr>
</thead>
<tbody>
<tr>
<td>A/Prof. Mohsin Hafeez</td>
<td>Spatial hydrology, water management, Project Leader</td>
<td>30%</td>
<td>CSU</td>
</tr>
<tr>
<td>Mr. Syed Khair.</td>
<td>Socio-economic and water policy analysis, stakeholder engagement</td>
<td>20%</td>
<td>CSU</td>
</tr>
<tr>
<td>Mr. Dharma Dassanyke</td>
<td>Water System Analyst</td>
<td>10%</td>
<td>CSU</td>
</tr>
<tr>
<td>Dr. Richard Claus</td>
<td>Economics, economic analysis and resource use optimisation</td>
<td>30%</td>
<td>CSU</td>
</tr>
<tr>
<td>Dr. Kaleem Ullah</td>
<td>Ground water hydrology, system dynamics modelling, system optimisation</td>
<td>80%</td>
<td>CSU</td>
</tr>
<tr>
<td>Mr. Umair Rabbani</td>
<td>Remote Sensing and GIS, and spatial Hydrology</td>
<td>40%</td>
<td>CSU</td>
</tr>
<tr>
<td>Professor John Blackwell</td>
<td>Water management</td>
<td>10%</td>
<td>CSU</td>
</tr>
<tr>
<td>Mr. Habib Ullah Bodla</td>
<td>Canal operations, Head PMIU, Project Coordinator</td>
<td>30%</td>
<td>PIDA</td>
</tr>
<tr>
<td>Dr. Muhammad Javaid</td>
<td>Hydrology, Groundwater data provisions and conjunctive management scenarios</td>
<td>50%</td>
<td>PIDA</td>
</tr>
<tr>
<td>Dr. Muhammad Riaz</td>
<td>Irrigation modeller, Decision support system</td>
<td>30%</td>
<td>PIDA</td>
</tr>
<tr>
<td>Mr. Azhar Javaid</td>
<td>Salinity and groundwater management, data provisions and modelling</td>
<td>50%</td>
<td>PIDA</td>
</tr>
<tr>
<td>Mr. Basharat Ullah</td>
<td>Agronomy, crop database development</td>
<td>50%</td>
<td>PIDA</td>
</tr>
<tr>
<td>Mr. Abdul Shakoor</td>
<td>IT and irrigation database development</td>
<td>30%</td>
<td>PIDA</td>
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<tr>
<td>Mr. Tauseef Ahmed</td>
<td>IT Professional and</td>
<td>20%</td>
<td>PIDA</td>
</tr>
<tr>
<td>Name</td>
<td>Position</td>
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<td>Project</td>
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<tr>
<td>Mr. Ali Zeb</td>
<td>Irrigation Engineer</td>
<td>30%</td>
<td>PIDA</td>
</tr>
<tr>
<td>Mr. Usman Tehsin Shah</td>
<td>Assistant Director Monitoring, Discharge</td>
<td>30%</td>
<td>PIDA</td>
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<tr>
<td>M. Khurram Ilyas</td>
<td>Software developer, database development</td>
<td>30%</td>
<td>PIDA</td>
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<tr>
<td>Prof Dr. Rai Niaz Ahmad</td>
<td>Project Co-Coordinator</td>
<td>30%</td>
<td>UAF</td>
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<tr>
<td>Mr. Azeem Ahmed Khan</td>
<td>Water Management</td>
<td>20%</td>
<td>UAF</td>
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<tr>
<td>Mr. Amir Saeed</td>
<td>Agricultural Economist, Farmer interviews</td>
<td>15%</td>
<td>UAF</td>
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<tr>
<td>M. Waseem Ahmad</td>
<td>Interviews with scientists and regulation</td>
<td>15%</td>
<td>UAF</td>
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<td>agencies staff to identify issues</td>
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<tr>
<td>Mr. Umer Draz Khan</td>
<td>Farmer interviews to identify their concerns</td>
<td>50%</td>
<td>UAF</td>
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<td></td>
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<tr>
<td>Dr. Sher Muhammad</td>
<td>Agricultural extension, technology transfer</td>
<td>25%</td>
<td>UAF</td>
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<tr>
<td></td>
<td>and demonstration to farmers</td>
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</tr>
<tr>
<td>Dr. Muhammad Arshad</td>
<td>Irrigation and groundwater database development</td>
<td>40%</td>
<td>UAF</td>
</tr>
<tr>
<td></td>
<td>and scenarios development</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dr Abdul Nasir Awan</td>
<td>Spatial hydrology, GIS, database development</td>
<td>50%</td>
<td>UAF</td>
</tr>
<tr>
<td></td>
<td>and water accounting</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mr. Ahmad Waqas</td>
<td>Technical support for water accounting at</td>
<td>50%</td>
<td>UAF</td>
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<tr>
<td></td>
<td>farm, distributary and minor</td>
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</tr>
<tr>
<td>Mr. Aamir Khan</td>
<td>Sociology, Farmer interviews</td>
<td>50%</td>
<td>UAF</td>
</tr>
<tr>
<td>Mr. Arif Manzoor</td>
<td>Agriculture, crop varieties and crop water</td>
<td>50%</td>
<td>UAF</td>
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<tr>
<td>Khan</td>
<td>demand</td>
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</tbody>
</table>
8 Problems and opportunities

No major problems are identified at this stage.

New opportunities include:

1. New training opportunities for PC staff and students to use Remote Sensing tools for modelling the conjunctive use of surface and groundwater, and its coupling with socioeconomic data and analytical tools. Such training facilities are currently not available in Pakistan.

2. Training of UAF staff in template development for data collation, and use of statistical and econometric packages for data analysis.

3. Training of PC team in writing and publishing papers in Australian and other international journals.

4. Training of PC team in writing a Book for joint publication, with Australian team members as Editors and lead authors.
9 Budget

There is no significant variation from the approved budget during the reporting period. A summary of expenditure is given below:

<table>
<thead>
<tr>
<th>Description</th>
<th>Expenses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milestone 1-6: Payment to Pakistan-Punjab Irrigation and Drainage Authority as per Contract</td>
<td>$100,941</td>
</tr>
<tr>
<td>Milestone 1-6: Payment to Pakistan-University of Agriculture, Faisalabad as per Contract</td>
<td>$126,600</td>
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<tr>
<td>CSU Expenses including PC members travel</td>
<td>$320,732</td>
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<tr>
<td>Total</td>
<td>$548,273</td>
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