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Final report

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List of acronyms and abbreviations

ACCA	ACIAR Climate Change Adaptation project
ACIAR	Australian Centre for International Agricultural Research
AgMIP	Agricultural Model Intercomparison and Improvement Program
APN	Asia Pacific Network
APSIM	Agricultural Production Systems Simulator
AusAID	Australian Agency for International Development
BARC	Bangladesh Agricultural Research Council
BRRI	Bangladesh Rice Research Institute
CGIAR	Consultative Group for International Agricultural Research
CLL	Crop Lower Limit
CRIDA	Central Research Institute for Dryland Agriculture
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CSISA	Cereal System Initiative South Asia
CSSRI	Central Soil and Salinity Research Institute
DDG	Deputy Director General
DOA	Department of Agriculture (Bhutan)
DSSAT	Decision Support System for Agrotechnology Transfer
DUL	Drained Upper Limit
EC	Executive Chairman
ED	Executive Director
GB	Governing Board (of SAC)
GYGA	Global Yield Gap Analysis Project
IARI	Indian Agricultural Research Institute
ICAR	Indian Council for Agricultural Research
ICAR-NEH	ICAR Research Complex for Northeast Hills Tract
IGP	Indo-Gangetic Plains
IRRI	International Rice Research Institute
IWMI	International Water Management Institute
NARC	Nepal Agricultural Research Council
NARS	National Agricultural Research System
NRM	Natural resource management
NRMC	Natural Resource Management Center (Sri Lanka)
NW	Northwest
ORYZA	IRRI rice crop model
PARC	Pakistan Agricultural Research Council
PDSFR	Project Directorate for Farming Systems Research (India)
RNR-RDC	Renewable Natural Resources Research and Development Centre (Bhutan)
SAARC	South Asian Association for Regional Cooperation
SAC	SAARC Agriculture Centre
VMC	Volumetric moisture content

Executive summary

One of the major emerging threats to food security in South Asia is the decreasing availability of water for agriculture and the need for improved water productivity in both rainfed and irrigated agriculture. However despite several decades of agricultural research into water productivity, the impact of past research has not reached the level required to safeguard future food production against likely reductions in water availability. In part this can be attributed to the traditional research and extension approaches in South Asia which are mostly organised along disciplinary boundaries or on a commodity basis. This precludes, or at least makes it harder for a holistic approach to farming systems research to take place effectively. Yet a systems approach is a prerequisite to addressing issues such as water scarcity or climate change, as well as being better equipped to reflect farming reality.

Cropping systems models are key research tools for effective systems research. The historical use of cropping systems models in SAARC countries has been fragmented or absent, with little residual capacity to address many of the major agricultural challenges facing the region (climate change, adapting to changing water supplies etc). Worldwide, there is a long-documented history of successes and failures with cropping systems modelling groups – the demonstrated key factors for long-term success, growth, and sustainability of skills include (i) co-ordinated training; (ii) the creation and maintenance of a critical mass of networked practitioners and (iii) functional structures for sharing network resources (particularly model-related data – climate, soils, crops etc). This project offered Australia's expertise in establishing and maintaining such networks to build capacity within SAARC agricultural research organisations to undertake more effective research using modelling-supported systems approaches to future food security and water use research issues. The cropping systems model, APSIM (http://www.apsim.info/), was the model of focus in this project.

In the two years since its commencement, this project has been successful in laying the groundwork for a future functional network of cropping systems modellers using APSIM in the SAARC countries. Key project achievements include:

- Training a cohort of 20 scientists from Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka in the use of the APSIM model; including field data collection requirements and techniques for high-quality model input and validation data.
- Linking several of the trainees into wider on-going modelling initiatives in the region.
- Establishment of an on-line modelling database for the SAARC countries, containing soil, crop, climate and a range of other key APSIM-model related data, linked with a Google-Earth interface and easily accessible by all current and future regional modellers (part of the wider global APSIM-World initiative).
- Establishment of an institutionalised modelling support role within the SAARC Agriculture Centre (SAC) to coordinate and support the growing network of modellers.
- Improved visibility of modelling as a vital research discipline with SAARC country stakeholders and the national agricultural research organisations.
- Obtained critical learnings on how best to conduct future training of this type in the SAARC countries
- Production of a 200+ page SAC Monograph detailing learnings from the project and providing a repository of modelling results obtained by trainees during the project. Preliminary scientific insights detailed in the monograph include things like (i) the suggestion that a reduction of two irrigations (200 mm) in Bangladeshi boro rice or a reduction of one irrigation (100 mm) in T. Aus or in boro, respectively, will

not significantly affect the total system productivity, and will enhance the likelihood of increased gross margins; (ii) In Indian and Sri Lankan rainfed agriculture, adjustment in transplanting dates of paddy can significantly improve crop water productivity. Simulation studies revealed that introduction of one to two life-saving irrigations in the post anthesis period could lead to an increase in yield by over 25% in rainfed systems, or (iii) In high-rainfall North East India, the optimisation of fertiliser-N from present 90 kg/ha to 60 kg/ha improved the N-use efficiency without yield penalty.

It is planned to build on the momentum and significant achievements of this project via a SAARC-Australia follow-on project funded by AusAID. It is anticipated that such a project consolidates a self-sustaining network of cropping systems modellers by building upon the successes and lessons learnt of this first project. It is planned that such a follow-on project will:-

- Include the most promising trainees from the first project as “Assistant Trainers” in the next phase project – recognising this as an intermediate step on their path to becoming “Master Trainers” for their home countries.
- Continue to build, structure, and publicise the SAC APSIM-World modelling database.
- Continue to strengthen SAC’s role as supporting institution of the growing modeller network, by establishing communication processes (blogs, online user groups, email groups, conferences etc).
- Improve the selection process for the next cohort of SAARC country trainees – specifically to seek younger early-career scientists with appropriate career plans, institutional support, and are already involved in other modelling initiatives or projects.
- Implement a course-work focus to the training, involving the university sector which must ultimately become the source of young modellers in the SAARC countries.
- Continue work to build awareness and demonstrate the value of modelling in agricultural research to institutional stakeholders through the use of relevant examples on important issues (eg climate change, increasing water-use efficiency, etc.).
- Continue to link strongly with other international modelling initiatives and projects in South Asia, ideally by sharing trainees.

The main envisaged pathway to community and policy impacts is the assumption that use of modelling to underpin experimentally based choices of improved crop water and nutrient management options will shorten the time required to evaluate promising techniques. This happens because modelling allows a more rapid temporal and spatial extrapolation of feasible technology compared to field experimentation alone, via virtual experiments using a well-tested model, which take minutes rather than years. This will in turn shorten the time to dissemination and impact, as well as more efficiently and effectively deploying resources used in agricultural research.

1 Background

This project originated from an initiative by the Australian Government to support the South Asian Association for Regional Cooperation (SAARC) through a $1M project funded by AusAID and managed by the Australian Centre for International Agricultural Research (ACIAR). It is a two year project that effectively commenced in February 2011. The project was undertaken by CSIRO's Sustainable Agriculture Flagship, in collaboration with the International Rice Research Institute (IRRI). The main interface with SAARC was through the SAARC Agriculture Centre (SAC).

The overarching objective of this project was to improve water productivity in rainfed and irrigated smallholder rice-based farming systems in South Asia to enhance agricultural production and food security. The project has contributed to this aim through the following objectives:

1. Establishing a network of agricultural research scientists in SAARC Member States collaborating on cropping systems analysis and modelling.
2. Applying the APSIM-ORYZA model to identify a suite of improved crop and water management practices that increase water productivity of representative rainfed and irrigated rice-based cropping systems.
3. Strengthening institutional support in SAC and in SAARC Member States for systems analysis and farming systems modelling as a means of enhancing research impact in addressing water scarcity and other future cross-sectoral issues.

Given the resources available and considering the 2-year project timeframe, as well as recognising that SAC's mandate is primarily one of facilitation and networking rather than direct execution of research, a key consideration for the design of this project was to focus on capacity building and to capitalise on previous ACIAR investments by utilising previous or existing trial sites as potential research hubs for this project, avoiding the need for substantial new investments in new trials and associated data acquisition. It was thought that the strong capacity building focus of the project also allows us to capitalise on SAC's core capability in convening and executing multi-country training courses and workshops, as well as fostering multilateral collaboration across SAARC Member States.

2 Objectives

The overarching objective of this project was to improve water productivity in rainfed and irrigated smallholder rice-based farming systems in South Asia to enhance agricultural production and food security. The project contributed to achieving this aim through the following objectives and activities:

1. Establishing a network of agricultural research scientists in SAARC Member States collaborating on rice-based cropping systems analysis and modelling.
    - 1.1. Identifying suitable participating scientists from SAARC Member States from research hubs working on key rice-based cropping systems
    - 1.2. Conducting workshops to train selected scientists in APSIM-ORYZA and its application.
    - 1.3. Conducting field courses to train selected scientists in sampling and monitoring techniques to acquire supplementary climate, soil and crop phenology datasets from their ongoing research trials for APSIM-ORYZA parameterisation and validation.
    - 1.4. Conducting training in acquisition of location specific farming practices and farmer-defined crop and water management scenarios for evaluation using APSIM-ORYZA.
    - 1.5. Utilising the data generated in activities 1.3 and 1.4 to parameterise and validate APSIM-ORYZA for major rice-based cropping systems for selected locations in SAARC Member States.
2. Applying APSIM-ORYZA to identify a suite of improved crop and water management practices that increase water productivity (WP) of representative rainfed and irrigated rice-based cropping systems.
    - 2.1. Using the first set of modelling training workshops to perform a gap-analysis to determine potential options to increase WP of rice-based cropping systems.
    - 2.2. Using the second set of modelling training workshops to perform scenario analysis to test improved crop and water management scenarios.
    - 2.3. Integrating the outcome of the gap-analysis with results of the scenario analysis to identify feasible crop and water management practices that will improve WP.
3. Strengthening institutional support in SAC and in SAARC Member States for systems analysis and cropping systems modelling as a means of enhancing research impact in addressing water scarcity and other future cross-sectoral issues.
    - 3.1. Strengthening SAC's role by including modelling support to SAARC Member States and by establishing a resident APSIM-ORYZA modelling support capacity within SAC.
    - 3.2. Developing a database with comprehensive model parameterisation and validation datasets to be maintained by SAC and made accessible to the modelling network established in SAARC Member States.
    - 3.3. Conducting workshops to expose NARS research managers and policy makers to the scope and value of systems modelling in order to foster greater institutional support.

3 Methodology

3.1 Brief review of past attempts to build modelling capacity

Developing capacity in modelling in South Asia is in itself not a new concept, and there have been many attempts in the past. Generally however, these have not been very successful. Some of the limitations reported by previous review studies (Ten Berge 1993; Carberry, 2005) include:

- Past capacity building has been too narrowly focussed on training in the use of modelling software, with insufficient effort on providing a broader theoretical background in systems analysis and participatory action research approaches.
- There often was a lack of institutional support to maintain a critical mass in modelling capacity and to avoid transferring trainees out of roles requiring modelling into new roles where the modelling skills were no longer required and languished or were lost. In part this lack of institutional support arises out of a lack of perceived benefits from modelling through to explicit scepticism that models can approximate reality.
- Trainees were not able to apply the models to their local situation because of lack of data and lack of knowledge on how to acquire missing data. This reduces the relevance of the model to trainees and diminishes their motivation and commitment to go through with the training of to maintain their acquired modelling skills. It also explains the ongoing scepticism by non-modellers towards modelling, as the models will not have been sufficiently well parameterised to credibly reproduce observed results.
- Candidates selected for training did not have a strong enough grounding in computer literacy, mathematics and university-based modelling courses to readily adopt modelling. Therefore, selecting collaborators for modelling activities needs to account for their affinity for modelling rather than accepting candidates with only a general interest in modelling. In addition, the few who do become proficient, thus demonstrating talent, are poached into other jobs and careers.

3.2 General approach

Mindful of the shortcomings in earlier attempts at building capacity in systems modelling, the design of this project attempted to broaden the training strategy to overcome some of the constraints mentioned in the previous section by integrating the following elements into a more comprehensive package:

- Exposure to modern concepts of systems and integration science.
- Training in modelling rice-based cropping systems using cropping systems models based on the 'learning by doing' principle, i.e. by using existing or past trial sites as core parameterisation or validation cases, allowing trainees to use the models to explore and extrapolate their own trial data.
- Training in the acquisition of high quality data. In the past this has been neglected, and here we propose to use existing trials to demonstrate key climate and soil characterisation techniques, as well as demonstrating cost-effective crop, nutrient and soil water monitoring techniques. The emphasis thus was on using existing trials to obtain supplementary data, rather than establishing new, dedicated trials.
- Training in parameterisation of models conducted in a way that the models better reflect farming reality rather than being based on researcher assumptions, making the models more credible and locally relevant.

- Awareness raising and exposure workshops for senior research managers in key institutions to demonstrate how systems approaches and modelling can be used for strategic research direction setting as a means of fostering stronger institutional support for retaining modelling capability. Consultations during the project design with research leaders in ICAR (DDG NRM Dr AK Singh), BARC (EC Dr Wais Kabir, Member-Director NRM Dr Ghulam Hussain) and NARC (ED Bhartendu Mishra, Dr Renuku Shreshta) confirmed that these institutions have recognised the urgent need to build strategic capability in the field of systems analysis and simulation modelling and hence were strongly supportive of this project.
- Institutionalisation of modelling support. This was to be attempted by building a resident capacity for modelling and database support within SAC, complemented by 4-5 master trainers / modellers who will serve as key resource persons in each SAARC Member State, working in a virtual team with the SAC-based modelling and training support person. Institutionalisation was further supported by the establishment of a Project Advisory Committee in August 2010.

3.3 Selection of trainees

A key challenge for the project was to identify appropriate candidates from each partner country. In consultation with the Project Advisory Committee it was agreed that selection of participating scientists needed to be based on a mutually agreed selection process based on a suite of agreed criteria.

Calls for nominations were made through SAARC procedures in December 2010, i.e. the initial request for nominations was conveyed by a letter from the SAARC Secretariat to NARS heads through SAARC Member State Foreign Ministries and Agriculture Ministries. Each NARS in each SAARC Member State nominated candidates from within their system following their respective procedures. Selection of candidates was then carried out against the below selection criteria:

Essential criteria for individual candidates

- Evidence of the candidate’s ability to think in a systems approach (to be assessed on the candidate’s ability to address questions on systems conceptualisation and a brief *exposé* on how and what for they would use modelling skills in their future research)
- Background in quantitative / process based research, with at least a MSc in soil science, water / irrigation management / engineering, crop physiology, agronomy or, agro-meteorology
- High level of computer literacy (to be assessed on the candidate’s responses to questions relating to problem solving using a range of software products)
- Hands-on experience and access to ongoing experimental trial(s) with comprehensive climate, soil and crop data (to be assessed on current involvement in experimental trials)
- Evidence of working in multidisciplinary teams and networks (to be assessed on the basis of authorship on publications, membership in interdisciplinary programs etc.)

Highly desirable criteria for individual candidates

- English language proficiency (to be assessed based on quality of English in addressing criteria 1 and 3 above)
- Preference to be given to candidates with a strong publication record (commensurate with their age and career level)
- Preference given to researchers younger than 45 years of age
- – Commitment to see through a 2-year training process (through supervisor endorsement)

In total, 32 nominees out of a total of 51 applications were selected to participate in an initial APSIM exposure workshop in August 2011. Here they were further assessed with respect to their aptitude for modelling, based on their performance during the exposure workshop. This resulted in a core team of project participating scientists of 21 being selected after their successful participation in the exposure workshop (see list of collaborating trainees in Acknowledgements section).

3.4 Choice of APSIM

APSIM (**A**gricultural **P**roduction Systems **Sim**ulator) is a modelling framework designed to simulate the production and resource consequences of agricultural systems (Keating et al., 2003). Today, APSIM is one of the leading simulation platforms in the world for modelling agricultural production systems and, in the aspects of breadth of science coverage, software engineering and IP management, it is arguably the world's most advanced agricultural systems model.

APSIM has been widely used in Australia as well in a number of African (Kenya, Malawi, Zimbabwe, South Africa) and Asian cases studies (India, Bangladesh, Indonesia). APSIM has proven its versatility in participatory farming systems research in Australia (e.g. FARMSCAPE – Carberry et al., 2002; YieldProphet – Hochman et al., 2009), as well as in a range of mainly ACIAR-funded projects in Africa and Asia. The main strength is its ability to simulate long time sequences of multiple cropping sequences. Another differentiating feature is its versatility in programming farmer decision making through the use of a unique programming language in its management module. However, to date exposure to APSIM within South Asia has been limited, mainly because until comparatively recently, APSIM did not have the capability to model rice systems. In the past four years, significant effort has been put into enabling APSIM to also reliably model rice systems (Gaydon et al., 2012a; 2012b). This was achieved in partnership with IRRI, by coupling APSIM to IRRI's rice model ORYZA.

3.5 Design and conduct of workshops

A prerequisite for SAC being able to host and conduct the APSIM training workshops was a prior refurbishment of its training room. This was upgraded with project funds to accommodate up to 32 trainees, working in pairs around shared laptops acquired by SAC for the workshop. A total of 20 laptops were acquired, so that in future SAC can conduct computer-based training workshops independently of the project or trainees bringing their own laptops. The latest APSIM software was installed on all laptops.

Over the course of the project, the APSIM software was also installed on collaborating trainees' laptops, and they were all issued with individual APSIM licences. However, as not all trainees have access to laptops, where required, APSIM was also installed on desktops in the trainees' parent institutions.

While drawing on the past experience of the APSIM Joint Venture in delivering APSIM training primarily in Australia, the actual APSIM training workshops were customised to suit the needs of the SAARC project.

3.5.1 Exposure workshop

The APSIM-ORYZA exposure workshop was held at SAC in Dhaka from the 8 – 10 August 2011. It involved 31 SAARC trainees from Bangladesh (5), Bhutan (3), India (9), Nepal (3), Pakistan (4) and Sri Lanka (7) and three trainers from CSIRO (Dr Don Gaydon, Perry Poulton) and IRRI (Dr Balwinder Singh). Whilst the structure of the workshop followed the standard 2 ½ day APSIM exposure training workshop format, the workbooks provided were completely redeveloped to contain simulation exercises and results using datasets and simulations pertinent to South Asian cropping systems. These were sourced from modelling results obtained in a predecessor ACIAR project (LWR/2005/146 - *Expanding the area for Rabi-season cropping in southern Bangladesh*). The objective of the exposure workshop was to familiarise trainees with concepts of farming systems analysis and the basic logic and use of the various APSIM modules. This was achieved by the trainees working through a number of sequential exercises, following the APSIM training workbook. Each trainer supported about 10 working pairs.

In preparation for the parameterisation training workshop, trainees were given a set of tasks to perform between the exposure and the parameterisation workshops:

- Select a past or ongoing experiment with an as complete dataset as possible and that the trainee intended to use as the training dataset throughout the course of the project;
- Compile all available climate, crop soil and management data of that experiment in order to use that for initial APSIM parameterisation during the parameterisation training workshop;
- Continue to work on APSIM by repeating the step-by-step exercises in the ASPIM training manual provided during the exposure workshop.

3.5.2 Parameterisation training workshop

The APSIM parameterisation training workshop was held in Dhaka on during the 20 – 24 November 2011. This was the second in the planned series of four farming systems research and APSIM training workshops (exposure – August 2011; parameterisation – November 2011; scenario analysis – May 2012; yield gap analysis – March 2013). Again, the workshop was held in the training premises of SAC. This time it involved the core team of collaborating trainees from Bangladesh (3), Bhutan (1), India (8), Nepal (1), Pakistan (2) and Sri Lanka (4) and three trainers from CSIRO (Dr Don Gaydon, Perry Poulton) and IRRI (Dr Balwinder Singh). Workshop logistics were organised by Dr Ibrahim Saiyed and SAC.

The objective of this workshop was to bring collaborating trainees to a level where they were capable of going through iterations of APSIM parameter modification until they achieved a best fit between modelled and observed data using Excel Pivot Tables. In the process, they also experimented with sensitivity of key crop and soil parameters, and through that process identified key data gaps. This enabled them to formulate an action plan to acquire missing data, either through supplementary data acquisition from the trials they had selected, or in the case of meteorological data, sourcing long term climate records from close by met stations.

To achieve the above workshop objectives, workshop participants progressed through a number of prepared APSIM exercises over the 5 days, interspersed with a field demonstration day at Gazipur, where trainees were shown ongoing farming systems trials (CSISA hub experiment; ACCA farming systems trial) and where they received training in soil sampling techniques, in crop growth stage monitoring and in the setting up of small climate stations. Topics covered in the workshop included:

1. Data compilation and sensibility analysis
2. Setting up APSIM with own datasets
3. Introduction to and use of Excel Pivot tables
4. Methods of acquiring climate, crop and soil data (field demonstrations)
5. Running simulations and comparing model output with observed data
6. Optimisation of APSIM parameterisation
7. Planning of field and modelling activities in the lead up to the next workshop

3.5.3 Scenario analysis workshop

The scenario analysis workshop was conducted in conjunction with the project mid-term review on 28-31 May 2012, at the University of Peradeniya, Kandy, Sri Lanka. Local arrangements this time were made by the Sri Lankan partners, with logistical oversight and support from SAC. Once again it involved the core team of collaborating trainees from Bangladesh (3), Bhutan (1), India (8), Nepal (1), Pakistan (2) and Sri Lanka (4) and three trainers from CSIRO (Dr Don Gaydon, Perry Poulton) and IRRI (Dr Balwinder Singh). Workshop logistics were organised by Dr Ibrahim Saiyed and SAC, with close collaboration with Dr Wickramasinghe (Sri Lankan Department of Agriculture) and Dr Buddhi Marambe (University of Peradeniya).

Since the previous workshop, trainees had invested considerable effort in collecting additional field data and finalising the parameterisation, calibration, and validation of the APSIM model for their specific locations, often with the on-hand assistance of visiting trainers. The objective for this third workshop was now to extend the trainees' experience in model parameterisation, calibration, and validation into the realm of scenario analysis and actual use of the model for investigating research questions. Trainees were split into groups along country lines (Sri Lanka 2 groups, India 4 groups, all other countries 1 group each) to conduct this workshop. Each group decided upon a key region and relevant research question, and with the assistance of the trainers, the APSIM model was configured to conduct long-term scenario analysis relevant to investigating the research question. Different potential on-farm management options (changed sowing dates, irrigation practices, crop varieties or sowing densities) were envisaged and specified within the model, before APSIM was run using long-term climate data to provide insight into the effect of climate variability on the management systems envisaged. A wide range of technical skills for analysing model output were shared with the trainees, including concepts such as cumulative distribution functions (CDF's) for comparing simulated results of different management scenarios. The trainees spent a significant proportion of the workshop investigating different methods of comparing their research scenarios. The final component was preparation of presentations on their research, which were presented to the project mid-term review on the final day.

Topics covered in the workshop included:

1. Defining research questions
2. Envisaging potential management scenarios to investigate using the model
3. Techniques for specifying those scenarios into the model
4. Providing long-term climate data to the model
5. Running APSIM simulations and production of scenario output files.
6. Methods of analysing and comparing scenarios.
7. Planning of trainee chapters for proposed SAC Monograph (see 5.7) for detailing the complete process of model parameterisation/calibration, validation, and scenario analysis.

3.5.4 Yield Gap analysis workshop

This workshop was conducted in conjunction with the project final review on 10-14 March 2013, at the SAARC Agriculture Centre, Dhaka, Bangladesh. The focus of this final workshop was for trainees to learn techniques for using the APSIM model to explore yield gaps in their home cropping systems. Yield Gap, for the purposes of this workshop, was defined as the difference between the grain yields which farmers achieve, (and/or which regional on-station research trials achieve) and what is agronomically possible (ie *potential* or *unlimited* yields). This exploration consisted of two components: (i) firstly, using the model to understand the existing yield gaps. What were the driving mechanisms between discrepancies? Was it water stress, N stress, or some combination of both? Did it vary between seasons, or was it generally always the same story; followed by (ii) using the model to explore ways of closing the revealed yield gaps through agronomic and management changes.

Since the previous workshop (section 3.5.3), the trainees collected pertinent information for undertaking this model-based exploration. This included detailed data on regional farmer practices and yields, together with any available information on recommended regional practices and yields. The trainees then proceeded to configure the APSIM model for each of the following scenarios: (i) farmer practice; (ii) recommended practice; (iii) potential production (unlimited by water and nutrient constraints, limited only by local environment (climate and soils)). The model was then run over a long time period for each scenario. Model outputs were assessed against regional yield figures and expected potential yields, and adjustments made to parameterisations if necessary. Once the model performance was as expected (this did not take long at all sites, since model had been locally parameterised and calibrated by trainees for their own regions in previous workshops), the trainees were then taught how to use modelled outputs for variables such as N-stress and water-stress (which are not readily measured) to examine why farmers were achieving less yield than was physiologically possible at their location. Armed with this knowledge, the trainees then conducted additional APSIM simulations to explore the impact of (for example) additional N or supplementary irrigation at various stages of crop growth in closing the yield gap. Other agronomic measures were also explored, including variations to sowing dates, varieties, effect of delay in transplanting, retaining crop residues, etc.. It was the assessment of the project team that the trainees learnt a lot about their own farming system research priorities from this exercise – for example, it may not be productive focussing on N-management improvements if crop are fundamentally water-stressed at key growth stages. Maybe in that situation, the application of supplementary irrigation, followed by a reassessment of the new ‘best practice’ N management, would be prudent.

During the final ACIAR review meeting at the conclusion of the workshop, trainees gave oral presentations on their discoveries and learnings during the workshop. All trainees provided evidence that they were now able to use the model to help understand facets of their own regional cropping system constraints, and also to explore management adaptation options to reduce the yield gap. Some of the more advanced trainees undertook quite detailed assessments, fed by modelled outputs, on the economics of reducing the yield gaps in their local regions. The hypothesis that improvements to yields which are agronomically possible, may not necessarily be economically feasible, was explored by several trainees. An example of the analysis from Drs Choudhury, Das, and Mohapatra (Meghalaya, India) illustrated that in their high rainfall environment, the amount of N required to reach potential yields was so high (due to leaching and runoff losses) that the maximum *economic* yield for local farmers was lower than potential yield, hence it made no sense for farmers, under current pricing structures, to aim for potential yield. Rather, they should aim for an increased, but slightly lower yield target. This is important information for extension services, and provided an excellent example of how modelling can be used to extend the information gained from experiments, to make vital contributions to extension programs.

The project team is continuing to assist trainees in developing their analyses from these workshops into journal papers, either in-country or international. The assessment of the project team is that two of these papers will be well-targeted for high-impact international journals; the remainder for in-country or regional journals. Another option to be explored in the future AusAID extension of this project, is the publication of a further SAC Monograph on Yield Gap Analysis in addition to the monograph from this current project (discussed below).

3.6 Technical backstopping

Additional training and technical backstopping support was provided after the parameterisation workshop during several follow-up visits by project team members to nearly all institutions where trainees are based:

- India (CSSRI, PDSFR in Karnal and Modipuram): November/December 2011, B Singh
- Philippines (IRRI, Los Banos): January 2012, additional training for I Saiyed by B Singh
- Sri Lanka (all three institutions in Kandy, Mahailluppallama, Batalagoda): January/February 2012, B. Singh and I. Saiyed
- India (CRIDA, ICAR NEH, PDFSR - during AgMIP workshop in Hyderabad): February 2012, P. Poulton
- Nepal (NARC, Nepalgunj): March 2012, P. Poulton
- Bhutan (RNR-RDC, Timphu and regional centres): March 2012, I. Saiyed
- Pakistan (PARC, Islamabad): April 2012, I. Saiyed
- Bangladesh (BRRI, BARI, Gazipur): monthly modelling team meetings in conjunction with modellers from the ACIAR climate change adaptation project (LWR/2008/019), I. Saiyed

This support consisted in visiting the trials selected by trainees from which they intended acquiring their datasets and assisting them with the implementation of appropriate soil sampling and crop monitoring regimes to supplement their datasets. Furthermore, project team members reviewed data compilation and APSIM parameterisation progress during the visits, fixed any software bugs and ensured that the most up-to-date APSIM software was running smoothly on all trainees' computers.

Support of trainees (and involvement in other regional modelling initiatives) continued following the scenario workshop in Kandy, Sri Lanka (June 2012):

- Bangladesh (July 2012) – D. Gaydon visited the Bangladesh modelling group and Gazipur and conducted a two day workshop where a range of topics from the scenarios workshop were revisited, and trainees continued to develop their simulations leading to their SAC monograph chapters.
- Bangladesh (September 2012) – D. Gaydon hosted Dr Ibrahim Saiyed for 2 weeks in Brisbane for intensive model training.
- India (June 2012) – B. Singh visited IRRI office, New Delhi, India to deliver a seminar on APSIM and general modelling approaches and worked with Dr Varinder and Dr Sheetal on CSISA Karnal platform datasets. APSIM has been calibrated for the two years data from rice-wheat and mungbean system and potential yield simulations have been completed.
- Sri Lanka (Nov 2012) – B. Singh attended South Asia AgMIP meeting as APSIM resource person held in Colombo, Sri Lanka from 12-16 November 2012.
- Attended AgMIP rice pilot team meeting at Los Banos, Philippines from 3-5 December 2012 – B. Singh.
- India – P. Poulton - AgMIP workshop in Hyderabad in Feb 2012 that was attend by a number of our trainees. Perry's role was training participants in using APSIM with both wheat and rice, climate change analysis (increased temperature and CO_2) and basic yield gap analysis.
- India (April 2013) – B. Singh - upcoming AgMIP workshop in Hyderabad where there will be a number of our trainees. This group (Dr Subash et al.) have undertaken to deliver on significant modelling outcomes under an AgMIP funded project over the next 12-18 months with Dr Kenneth Cassman.
- Nepal (March 2013) – P. Poulton – AgMIP workshop in Kathmandu, March 2013 - will involve trainees Dr Subash (India) and Rajendra Darai (Nepal).

- All countries – D. Gaydon, P. Poulton and B. Singh - Continuous support to SAARC trainees through email/skype for simulation issues associated with final preparation of their SAC Monograph chapters (section 3.6)

4 Achievements against activities and outputs/milestones

Objective 1: To establish a network of agricultural research scientists in SAARC Member States collaborating on rice-based cropping systems analysis and modelling

No.	Activity	Outputs/ milestones	Completion Date	Comments
1.1	Identify suitable participating scientists from SAARC Member States from research hubs working on key rice-based cropping systems	32 candidates identified for initial exposure workshop	Jan 2011	Selection process implemented by NARS partners and coordinated by the project officer in SAC.
		20 candidates for core training identified	Mar 2011	The evaluation of participants in the “Exposure workshop” by the trainers yielded 20 core trainees for the remaining workshops. As recommended following the mid-term review, selection of trainees in any follow-on project will include more female participants, younger staff, staff who have commitment to modelling and have time available for hands-on modelling work between training workshops. Potential participants (in any future project) with modelling deliverables as part of their home institution work-plan (for example, required to produce some modelling outputs as part of other project- or research-related commitments) will be given particular preference in pre-selection.
1.2	Conduct workshops to train selected scientists in APSIM-ORYZA and its application	Exposure workshop conducted	Aug 2011	Enabled selection of core trainee group; exposed all to APSIM and modelling
		1st training workshop conducted (Model parameterisation, calibration, and validation)	Nov 2011	Developed a deeper understanding of model parameterisation, calibration and validation requirements. Trainees were also trained in field data collection techniques and practices during this workshop (see milestone 1.3)
		2nd training workshop conducted (Scenarios)	Jun 2012	Trainees capable of using the validated model in research applications (Scenario analysis)
		Additional 3rd training workshop conducted (Yield Gap Analysis)	Mar 2013	Trainees knowledgeable in the concepts of Yield Gap Analysis and the role which modelling can play in defining constraints and opportunities.

1.3	Conduct field courses to train selected scientists in sampling and monitoring techniques to acquire supplementary climate, soil and crop phenology datasets from their ongoing research trials for APSIM-ORYZA parameterisation and validation	Development of and training in data acquisition and monitoring protocols Sampling and analysis of supplementary data Supplementary data compiled in APSIM format	Nov 2011 Nov 2011 - Jun 2012 Jun 2012	The field techniques training which was conducted during the 1st training workshop in Bangladesh was very successful and enjoyed by all trainees. This was demonstrated by the way all subsequent in-country data collection and lab analyses were conducted in timely manner, successfully demonstrating developed capacity in data acquisition. Low cost soil monitoring and climate monitoring equipment were made available to trainees from Pakistan, Sri-Lanka, Nepal and Bhutan. In-country visits by project trainers were also undertaken. All input data required for scenario analysis workshop was collected successfully, illustrating the success of this process.
1.4	Conduct training in acquisition of location specific farming practices and farmer-defined crop and water management scenarios for evaluation using APSIM-ORYZA	Survey templates and protocols developed and training in survey methods completed Farmer surveys and farmer group discussion notes documented		Activity abandoned as per recommendation from mid-term review,
1.5	Utilise the data generated in activities 1.3 and 1.4 to parameterise and validate APSIM-ORYZA for major rice-based cropping systems for selected locations in SAARC Member States	Initial parameterisation of APSIM carried out for all trainee's sites	Jun 2012	Required data was collected by all participants, and the model parameterised, calibrated and validated prior to the scenarios workshop in June 2012.

Objective 2: To apply APSIM-ORYZA to identify a suite of improved crop and water management practices that increase water productivity (WP) of representative rainfed and irrigated rice-based cropping systems

No.	Activity	Outputs/ milestones	Completion date	Comments
2.1	Use the first set of modelling training workshops to perform a gap-analysis to determine potential options to increase WP of rice-based cropping systems	Proceedings documenting results of gap -analysis published as SAC publication Draft journal paper	Mar 2013	Yield gap analysis was undertaken through a structured set of tasks and through remote support (Skype) as necessary. This was supported by a third training workshop in Dhaka in Mar 2013. Rather than through another SAC monograph, we propose to publish these results in the SAC Agriculture Journal.
2.2	Use the second set of modelling training workshops to perform scenario analysis to test farmer-defined crop and water management scenarios	Proceedings documenting results of scenario-analysis published as SAC publication Draft journal paper	Aug 2012 Sep 2012	Data from activities 1.3 - 1.5 was of sufficient quality and consistency to allow robust parameterisation for scenario analysis. All trainees performed scenario analysis on relevant research questions related to water-use efficiency in their home countries. Participants have worked in teams to produce 10 chapters for a monograph, detailing their scenario analyses and conclusions (see Gaydon et al. 2013). The monograph will be produced by SAC, with an expected publication date of October 2013. Depending on quality of monograph chapters, some will be published in SAC Agriculture Journal, others in international journals. Results against these milestones are also input to activities 2.3 and 3.3
2.3	Integrate the outcome of the gap-analysis with results of the scenario analysis to identify feasible crop and water management practices that will improve WP	Series of in-country farmer-researcher forum discussions held Report documenting farmer -preferred suite of crop and water management practices Policy briefs for NARS leaders and key stakeholders	Sep 2012 Oct 2012 Nov 2012	This milestone was abandoned (see 1.4). A synthesis of the results has been compiled as a chapter in the SAC monograph and will be available in October 2013. Following recommendations from the Midterm Review, formal Policy Briefs will only be prepared once tangible results worthy of wider dissemination to a broader range of stakeholders have materialised. This is likely to occur at the end of the project.

Objective 3: To strengthen institutional support in SAC and in SAARC Member States for systems analysis and cropping systems modelling as a means of enhancing research impact in addressing water scarcity and other future cross-sectoral issues

No.	Activity	Outputs/ milestones	Completion date	Comments
3.1	Strengthen SAC's role by including modelling support to SAARC Member States and by establishing a resident APSIM-ORYZA modelling support capacity within SAC	Suitable SAC modelling support person appointed	Nov 2011	Dr Ibrahim Saiyed performed this role for the current project.
		SAC modelling support person fully trained in APSIM-ORYZA and database management	Sep 2012	Dr Saiyed visited Australia for 2 weeks in Sep 2012 for intensive APSIM and database management training.
		Institutionalisation of modelling support person within SAC. Approval from SAARC Standing Committee obtained to establish ongoing modelling support position in SAC	Nov 2012	The SAC GB has approved the institutionalisation of a modelling support position. SAC has commenced proceedings to employ a permanent modelling support officer to service the growing network of APSIM modellers created by the SAARC-Australia project initiative. This person will be based at SAC, Dhaka. Dr Ibrahim Saiyed will remain with SAC as required, and will train the new appointee, as part of the SAARC-Australia follow-on project planned for 2013-2015. The SAC modelling support person will co-facilitate future training workshops and supplementary data acquisition, as well as being responsible for the provision of ongoing modelling support to SAARC Member State researchers.
3.2	Develop a database with comprehensive model parameterisation and validation datasets to be maintained by SAC and made accessible to the modelling network established in SAARC Member States	Appropriate database format selected	Apr 2011	APSIM World, a new database developed by the APSIM Consortium to facilitate worldwide access to model parameters and APSIM parameterisations has been chosen as the repository for the data generated by this project. A dedicated data structure has been incorporated into APSIM World to accommodate this data.
		Data from trainee research trials and additional trial data sets (CSISA, ACIAR) entered into database	Mar 2013	Data used by SAARC Member State researchers in this SAARC-Australia project is being successfully entered into the database.
		SAC data access website operational	Mar 2013	The SAC database website shows promise for becoming a model for other data sharing arrangements between SAARC research institutions.

3.3	Conduct workshops to expose NARS research managers and policy makers to the scope and value of systems modelling in order to foster greater institutional support	Annual project review workshop including NARS stakeholders Design and conduct SAARC stakeholder and NARS decision maker workshops	Mar 2013	Key stakeholders from India, Nepal, Bangladesh, Sri Lanka and Bhutan were briefed on results of the scenario analysis during the midterm review workshop. In March 2013 a modelling awareness seminar was held in Dhaka involving the Bangladesh Secretary of Agriculture, NARS chiefs and BARC Chairman, for the purposes of strengthening institutional support for modelling in Bangladesh. Trainees attended as a training exercise to enable them to undertake similar awareness seminars upon return to their home countries.
		Policy briefings to SAARC Intergovernmental Core Group and Technical Committee on Agriculture and Rural Development	Ongoing	An opportunity to brief the SAARC Intergovernmental Core Group and Technical Committee on Agriculture and Rural Development has not yet presented itself. However, the incoming Secretary General of SAARC, and the Director of Agriculture and Rural Development have been routinely briefed about the SAARC project. In the last briefing in Dec 2012 the SG SAARC expressed a strong desire to see the SAARC project continue into a second, consolidation phase.

5 Key results and discussion

5.1 Increased capacity amongst individual trainees

Some of the trainees started this project without any prior exposure to modelling; others had limited experience. Some were experienced practitioners in hydrological and other types of models, yet beginners with cropping systems modelling. All of the trainees made significant progress throughout this project, regardless of their background, evidenced by the completion of SAC Monograph chapters by all (section 5.6). From the perspective of individuals, this project has resulted in increased personal capacity as scientists, and opened up several new modelling opportunities for some trainees.

New skills, new experience

1. Understanding of systems modelling philosophy
   - The concept of a "system" and the range of interacting processes in soils, atmosphere, and crops.
   - Importance of careful model calibration/parameterisation followed by model testing/validation before the model can be confidently used to answer "what if?" questions in scenario analysis.
   - The potential contribution of cropping systems models to agricultural research – not replacing experiments, but augmenting them by adding value and understanding, particularly in relation to climate-driven risk and climate change.
   - The philosophy of always questioning model outputs, never blindly accepting what the model says.
2. Understanding model data needs and techniques for obtaining high quality data
3. Framing research questions leading to scenario analysis
4. Understanding of ways of presenting scenario analysis information and its limitations

Trainees have done more than just learn about these concepts – each one of them has investigated a research question related to water use efficiency in their home country, starting from first principles data collection for the model (soil/crop information, climate etc.), parameterised/calibrated APSIM for their home site, validated the model using either existing datasets or specially-collected field datasets, then envisaged research questions and used the model for scenario analysis to investigate the long-term characteristics of various scenario management options aimed at increasing water-use efficiency. Results of their analyses were presented to their peers at the mid-term review (Kandy, Sri Lanka, June 2012) and since then they have all prepared chapters detailing their modelling efforts for publication in the proposed SAC Monograph (section 5.6) on this project. This has been a comprehensive and challenging undertaking for all of the trainees – taking a research question from first-principles to final analysis using the APSIM model – and has resulted in significant personal and professional development as modellers for all trainees.

Additional opportunities created

Trainees with long-term career aspirations in farming systems research have received further entry into the international modelling community via participation in a range of workshops and projects, additional to this project (various AgMIP initiatives, and an APN project led by Dr Holger Meinke). Their participation in these initiatives resulted directly from their involvement in this SAARC-Australia project – it was the justification for their being selected as part of those further initiatives. This has doubtlessly resulted in consolidation of their confidence, extension of their modeller networks, and general increased capacity as model practitioners, as each of these additional projects/workshops. Examples of trainees and associated additional workshop activities are listed below:

5. *AgMIP South Asia Regional Project*: Dr Subash, Dr Choudhury, Dr Das, Dr Mohapatra (India); Dr Rajendra Darai (Nepal), as well as project trainer and post-doc Dr Balwinder Singh.
6. *APN Project on Developing Rice Modelling Capacity in South Asia (led by Professor Holger Meinke, University of Tasmania)*; Dr Puppala Vijaya Kumar (India); Dr Lalith Suriyagoda, Dr Laknath Perris (Sri Lanka)
7. *DSSAT model training initiative in Thailand.* Dr Balwinder Singh.
8. *Global Yield Gap Analysis Project (led by Prof Ken Cassman):* Dr Balwinder Singh; Dr Subash

5.2 Creation of an incipient network of APSIM modellers in SAARC countries

This project has created a fledgling network of 19 APSIM modellers from across the SAARC countries. Their experience, skills, modelling achievements, institutional support, and access to resources vary. However they have provided a test-case for evaluating interaction, cooperation, and communication issues within the future planned network. This is built on a strong spirit of collaboration and shared sense of purpose evident within the group. First and foremost has been an endeavour to perform as a group of agricultural scientists who want to contribute to a future productive and sustainable world, and they see cropping systems modelling as one of the tools of their future work. It has become clear to the project trainers also that this group recognises the value of their small network, and the value of having other people with whom they can share their successes, problems, and ideas. This is the major supportive role which a network can offer to an isolated modeller – not leaving someone struggling with a modelling problem alone and trying to “re-invent the wheel” with their efforts.

As this network grows, co-ordination and management of shared infrastructure and resources (for example, the APSIM database (see 5.2.1 below)), together with the ability to link people with other people across the network with whom they may share common research interests or problems, or organise training workshops, distribute training materials or updates/news etc., becomes a critical aspect to plan and implement. Otherwise the risk is that all the good intentions in the world will result in an unworkable and fragmented collection of scientists who, despite sharing and collaborating well within project workshops, soon split off into their own worlds as project initiatives like this come to completion.

For a modeller network in the SAARC countries, such a co-ordination role is custom-made for the SAARC Agriculture Centre (SAC) and this project has explored options for this to happen. Commitment to accepting this role from SAC, based on the demonstration of possibilities which this project has offered, has been important. One of the key results of this project has been the initiation of a process to institutionalise a modeller-network coordination and support position within SAC.

Several trainees from this project have subsequently become involved in other modelling networks in South Asia as a direct result of their involvement in this SAARC-Australia project (see section 5.1 above). Additionally, trainees and any other future APSIM modellers have access to the world-wide APSIM help forum (https://groups.google.com/forum/?fromgroups#!forum/apsim). This support group is monitored by APSIM experts in Australia and world-wide, and successfully offers APSIM support to isolated scientists working worldwide.

5.2.1 Creation of an information database for future modelling efforts in the region

One of the largest barriers for commonplace use of models by SAARC regional scientists is the lack of accessibility of model-suitable data on soils, crops and climates. This same issue was recognised a long time ago in Australia, leading to such valuable initiatives as the SILO climate resource (http://www.longpaddock.qld.gov.au/silo/), the ASRIS soils database (http://www.asris.csiro.au/index_ie.html) and the APSOIL database (http://www.apsim.info/Wiki/APSoil.ashx), where modelling scientists can access model-ready data on soils and daily long-term climate for sites across the country . These resources make the data-sourcing task much easier for Australian modellers, but they have not always existed, having originally arisen from the same problems which now confront scientists wishing to use models in the SAARC countries. Given this history, an early initiative of this project was the establishement and initial population of a database for APSIM-ready information for locations throughout the SAARC countries – aimed to be easily accessible for regional modelling scientists, both current and future. In addition to model input data on soils, crops, and climate, the database stores complete validated APSIM simulations which can be used as examples by new users

The project team has taken the initiative to collect and store quality data from the experimental fields of the trainees associated with the project. Despite the challenges associated with obtaining quality data, SAC has obtained sets of quality data (APSIM simulations, soil, climate) from experimental plots originating from the six SAARC countries (Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka), as well as IRRI datasets from South Asia.

The data have been stored as a special SAARC component in the “APSIM-World” database. APSIM-World is a community driven portal to facilitate the sharing and distribution of APSIM simulations and related data (www.apsim.info/THESTACK.). It consists of two main components:- (i) a data management tool that allows to upload, download and management of data; and (ii) a Google earth interface that provides a geographical view of all data in the database. From this view you are able to focus in on a global region you are interested in and download data related to that specific site. New tools are being planned to be included in the future. Specific details on accessing and using this database are contained in Appendix 1.

SAC will link the APSIM-World interface with its website so that users not only from SAARC countries but also from around the world may use the required datasets for their own parameterization, validation and simulations.

5.2.2 Institutionalisation of modelling (within SAC and within NARS)

Permanent modelling support and co-ordination of network and database. Broadening the current mandate of SAC to include a SAARC-wide support role in farming systems analysis and modelling was seen to constitute a significant capacity building outcome of this project. This was seen as an opportunity to significantly boost the relevance and effectiveness of SAC in SAARC Member States, in turn strengthening SAARC's ability to foster regional cooperation. In order to build this capacity within SAC, the project funded a dedicated project officer based within SAC, who was trained to become the nodal point of contact for ongoing technical backstopping in modelling and future training of other scientists from SAARC Member States. In addition this resource person also established, and is maintaining and expanding the database described above (section 5.2.1).

For this arrangement to be effective in the long-term, it was clear that the SAARC Secretariat needed to continue supporting this position beyond the life of the current project, thereby broadening the scope of SAC activities and strengthening its institutional relevance within

SAARC. This required a formal approval process within SAARC involving the SAC Governing Board, which met on 3-4 September 2012 and approved the appointment of a Senior Project Officer (NRM) for this purpose. SAC has initiated the recruitment process for the new position, and it is ongoing.

Master trainers. In the initial consultation meetings for this project it was planned that a dedicated researcher should be selected from each country to become a master trainer and to act as a country liaison person for the SAC modelling support person. This has proved a more difficult goal to achieve across all countries than anticipated, but depending on the final outcome of the training workshops, it is possible that several potential master trainers will be identified. Indeed two of the SAARC project trainees involved in the AgMIP South Asia Regional Project have assumed a training role to train other modellers in the project in APSIM-ORYZA. These NARS master trainers together with the SAC modelling support person may be offered further in-depth training in Australia during the second phase SAARC-Australia project. It is planned that they would take on role of assistant trainers in that project, for the new cohort of trainees. Whether this is feasible depends on final funding availability, the performance of potential master trainers during the final training and the level of support from their home institutions. Dr Ibrahim Saiyed (current project co-ordinator and SAC support person) visited Australia in September 2012 and undertook intensive training in APSIM-ORYZA to achieve master trainer status, as well as in database management. He has since focussed on establishing the SAC modelling database and populating it with the datasets generated as part of this project.

Additional evidence of impact and institutionalisation of modelling within NARS. Institutions such as BARC (Bangladesh Agricultural Research Council) have demonstrated a commitment to institutionalise modelling as part of their core business, no doubt influenced by this project and other ACIAR modelling projects such as ACIAR's Climate Change Adaptation project (ACCA;LWR/2008/019). In June 2012 the BARC instigated BARI and BRRI to establish and support modelling teams, particularly for future climate change research. As part of this process, BARC has requested that modelling become a standard part of BRRI and BARI's annual program, and we understand that this will be supported by funds and resources through BARC.

In India, modelling as core research activity is much more established, particularly in some of the ICAR institutes (e.g. CRIDA, PDFSR). In this case, exposure of trainees from these institutions to APSIM has strengthened the debate for the use of integrated systems research, contributing to the ICAR internal discussions to progress from the use of mere crop models to farming systems models. This has also triggered a request from PDFSR for assistance by CSIRO in training Indian modellers in farming systems modelling, currently under consideration by ICAR.

5.2.3 Post-project activities of trainees

The trainees of the SAARC-Australia project have become involved in a wide range of national and international modelling initiatives as a result of their involvement in this project. Many have also taken their APSIM skills back to their home institutions and countries and initiated PhD students and junior staff using APSIM modelling in their research. Examples of this are listed below:-

Dr Vijaya P Kumar (India): conducted training on the topic "An Introduction to APSIM model" to 30 scientists/teachers of different research institutes/agricultural universities in a course entitled "Crop Weather Modeling" organised at CRIDA, Hyderabad. Work on parameterisation of the APSIM model for pigeon pea varieties grown under Indian conditions is being taken up in an ongoing CRIDA research project led by Dr Kumar. He is also engaged in continuing efforts to study the effect of sowing dates on yield of rice varieties at five or six locations of India using APSIM Oryza model.

Dr M Sharmim (India): conducting an experiment to collect data for APSIM model calibration and validation. Dr Shamim is now a participant in a regional AgMIP project lead by Dr Subash (DSSAT introduction course). He is planning to compare APSIM, DSSAT and Info-Crop.

Dr N Subash (India): initiated a project with AgMIP using APSIM (Strengthening simulation approaches for understanding, projecting and managing climate risks in stress-prone environments across the central and eastern Indo-Gangetic Basin). He is collecting data from 15 farmers (eco---agronomic) for modelling use, and is interested in downscaling GCM data for modelling He is also planning to undertake whole system analysis under climate change scenario using IAT. Dr Subash is also progressing his work under the Global Yield Gap Analysis project (GYGA – led by Dr Ken Cassman, University of Nebraska, US) in which he is now using APSIM.

Dr Rajender Yadav (India): is undertaking a rice---wheat experiment for data collection for use with modelling. He has collected data from 3 villages over 3 years, and is communicating with Dr Sena on APSIM to explore the potential for in-house experiments for data collection.

Dr Dipak Sena (India): has continued the development of a preliminary research proposal (PRP) on use of models (RothC, APSIM, WEPP), has sourced further funding (Austria), has calibrated APSIM using parameter estimation software (PEST), and has developed Visual Basic code to compare predicted vs observed.

Dr Burhan U Choudhury (India): is a district level partner in the regional AgMIP project with Dr Subash (Strengthening simulation approaches for understanding, projecting and managing climate risks in stress-prone environments across the central and eastern Indo-Gangetic Basin). He presented a symposium paper (including use of APSIM) with a full journal paper planned for Jan 2014. He has also developed PRP using models, and a National Information Center project has been approved (on coordinating crops with simulation (water productivity focus), and he is planning district level data collection on soils, crops (15---30 years).

Dr KP Mohapatra (India): is carrying out project work with Dr Choudhury and Dr Das.

Dr Anup Das (India): is a co-author with Dr Choudhury on various Indian journal papers. His field data collection now includes a full data set for modelling use, but more work required to parameterising local varieties.

Dr Faruque Ahmed (Bangladesh): presented introduction workshop to institute staff on APSIM, InfoCrop training, is undertaking a maize experiment with Dr Akhter for model data collection, and is collecting yield gap data for Gazipur. Acted as key trainer in unsupported APSIM training for the Bangladesh Modelling Group (initiative of this SAARC project and also ACCA project), which held its first APSIM training workshop in Bangladesh in August 2013.

Dr Sohela Akhter (Bangladesh): established maize variety and nitrogen experiment at BARI, is training young scientists in data collection, provided AgMIP workshop data on wheat, InfoCrop training, and is involved in collection of yield gap data in Gazipur. Acted as key trainer in unsupported APSIM training for the Bangladesh Modelling Group (initiative of this SAARC project and also ACCA project), which held its first APSIM training workshop in Bangladesh in August 2013.

Dr Md. Abdul Muttaleb (Bangladesh): conducted InfoCrop training and runs a field trial in Khulna (model data collection) for the ACCA project (ACIAR LWR-2008-019). Key trainer in unsupported APSIM training for the Bangladesh Modelling Group (initiative of this SAARC project and also ACCA project), which held its first APSIM training workshop in Bangladesh in August 2013.

Dr Bashir Ahmed (Pakistan): continuing to work on yield gap analysis (data collection), harvest of trial data in April 2013 for paper, future focus on maize (WUE under climate change), ongoing data collection from farmers; improving the availability of soil water data. Additional activities: AgMIP-Pakistan inception workshop and International Seminar on Climate Change was held in University of Agriculture Faisalabad – Pakistan from June 4-6, 2013. It had various sessions on modelling. There were five presentations from APSIM crop modelling researchers and one hands-on APSIM training session.

Bashir is presently finalizing the 2nd year trials of wheat yield modelling in NARC, and has also provided 3 days hands-on training to four internees of final year BSc Engineering at WRRI, NARC.

Mr Irfan Ali (Pakistan): Supervising a MD student (some APSIM focus), organised Phd student for training in APSIM, presented APSIM exposure training to NARS staff.

Mr Rajendra Darai (Nepal): is working with Nepal University staff to develop APSIM course – this work is at a quite advanced stage with training material prepared and students being instructed Rajendra is a participant in the AgMIP (India-Nepal) project lead by Dr Subash (Strengthening simulation approaches for understanding, projecting and managing climate risks in stress-prone environments across the central and eastern Indo-Gangetic Basin). Rajendra is also engaged in ongoing data collection (socio---economic and agronomic), and a soybean experiment targeting data for APSIM. A significant range of new modelling-based activities have been initiated in Nepal, of which Rajendra is a central player.

Mr Ganja Singh Rai (Bhutan): is continuing data analysis, contributing to SAC program on vegetables. Plans to collect long-term weather data (10 years) and farm field data, and would like to be able to simulate fruit crops.

Dr B Laknath Peiris (Sri Lanka): continuing data collection for use with APSIM, discussion around including crop modelling in course work at university level (University of Peradeniya, Sri Lanka).

Dr Lalith Suriyagoda (Sri Lanka): has become the key modeller on an AusAID project (Food Security in Indian Ocean Rim Countries in a Variable and Changing Climate) working with CSIRO on long-term rice system production and use of seasonal climate forecasts in farmers decision-making. He is conducting new maize-mungbean experiment and actively working with the APSIM model on a continuing basis.

Ms. U Rathnayake (Sri Lanka): continuing existing experimental program into this wet season, plans to explore 3 climatic zones with APSIM, conduct rainfed cropping area evaluation, and is involved in AusAID Climate Adaptation Farming project (Food Security in Indian Ocean Rim Countries in a Variable and Changing Climate) using APSIM with climate forecasting. Upul has now also commenced a PhD study (plans to include modelling component).

Mr Wasantha Malaviarachchi (Sri Lanka): continuing work with APSIM in rice based cropping systems, next crops - green gram and cowpea, trials in rainfed farmer fields, time of sowing trials for data collection. Wasantha has also commenced a PhD study with the University of Peradeniya (includes modelling component).

5.3 Increased testing and validation of APSIM

The APSIM model has a dryland heritage (Keating et al. 2003) and whereas it has been widely tested and validated in Australia, Africa, and some other countries, prior to this project the degree to which it had been tested in major rice-growing areas of South Asia was limited. The relatively new capacity within APSIM to simulated rice-based farming systems (Gaydon et al., 2012a, 2012b) had largely been tested in more tropical environments (Philippines, Indonesia). This project has provided unprecedented access to experimental datasets from across the broad range of environments present in the SAARC countries; from the cooler highlands of Bhutan, to the hot tropics in Sri Lanka, from the irrigated lands of Punjab (India), Pakistan, and Bangladesh, to the rainfed farming systems of southern India and Sri Lanka. The use of such datasets by trainees in their model training has allowed for a concurrent evaluation of the APSIM model in these new environments.

The performance of a model depends on a range of factors. The most important ones include:

1. Skill of the modeller and knowledge about the agriculture system
2. Quality and completeness of the input data
3. Ability of the model to represent the key processes being modelled, and their interactions.

All three factors to varying degrees affected the quality of the modelling performed in the 10 case studies of this project. The ability of trainees to parameterise the model, to query it and to run the simulations varied quite widely, reflecting a range of disciplinary backgrounds, whether trainees had already been exposed to modelling before joining the project, and the amount of time they were able to dedicate to learning and using APSIM.

The quality and completeness of the data showed significant variation (Table 1). In terms of length of the climate record, only four cases had datasets that were in excess of 20 years (case studies 1, 3, 5, 7 and 11), the length generally recommended to ensure long term climate variability is fully captured. In four cases, the climate datasets were probably too short (case studies 2, 4, 8 and 10) to be able to come to fully conclusive results. Only one dataset provided radiation rather than sunshine hours, while in the case of the Bhutan and Nepal datasets (2, 8 in Table 1), no climate data representing the case study location could be sourced. In these cases, data from other sources (e.g. NOAA - National Oceanic and Atmospheric Administration) had to be used. In summary, obtaining good long-term climate datasets still presents a constraint to modelling location specific conditions in South Asia. However, collaborating trainees were exposed to, and in some cases equipped, with low cost radiation and temperature sensors and trained in their use. It is now possible to set up comparatively low cost climate stations for about 1000 USD that can automatically record all the climate variables required for APSIM.

The completeness of soil data, in particular critical parameters such as the Drained Upper Limit (DUL) and the Crop Lower Limit (CLL) was only partial at best. Of the 11 case studies, only four had complete soil datasets (1, 3, 5 and 11 in Table 1), including some NO_3 and NH_4 as well as soil moisture measurements during the crop growth cycle (not shown). If texture, or preferably particle size distribution, and bulk density are known, DUL and CLL can be estimated using pedotransfer functions (e.g. Saxton et al., 1986; Saxton and Rawls, 2006; Adhikary et al., 2008), which was the approach take in some of the cases. Alternatively, soil parameters can be found by homology, i.e. texture, soil carbon and bulk density data allowing for the identification and use of homologous soil profile data obtained from other sites where the same key parameters are known. This was also done in a few cases (case studies 2 and 8: inference from similarly textured soils; case studies 4, 6, 7, 9 and 10: estimated from particle size distribution and use of pedotransfer functions), but to ensure plausible values are used for parameterisation does require a solid background or experience in soil hydrology and significant modelling skill.

The lack of soil physical and soil hydraulic properties was recognised as a significant gap early within the project life, so more emphasis was placed on training in methods of data collection, as well as supplying some of the collaborating trainees with sampling and monitoring equipment. In some cases this allowed for the necessary soil data to be obtained during the project life (e.g. cases studies 3, 6, 11). However, it is clear from Table 1 that the lack of adequate and complete soil characterisation (DUL, CLL) and soil monitoring data (soil moisture, soil N) can be expected as a major impediment to other researchers adopting and applying APSIM (or many other models for that matter). More emphasis must be placed on designing and implementing soil sampling and monitoring regimes in current and future long term experimental trials to ensure these valuable sites can also be also used for future modelling purposes. For example, following exposure to APSIM, the IRRI CSISA team was able to identify critical datasets in some of the long term CSISA experimental sites that were missing and subsequently have established sampling regimes to close those gaps.

By comparison, crop data tended to be the most complete. In all cases, there was sufficient phenology data to adequately parameterise the rice crop module (ORYZA), and as a result, the project has generated a catalogue of crop development stage parameters for a broad range of rice varieties in South Asia, that is being made available in the web-based database (APSIM World) being developed and to be hosted on the SAC webpage.

A significant outcome of the modelling is that overall, ASPIM-ORYZA was able to be parameterised with sufficient degrees of confidence and that the model was able to reproduce cropping system dynamics with a reasonable, and in some cases, high to very high degree of reliability (Table 1). This is the first time that APSIM-ORYZA has been so extensively tested beyond the original validation datasets used by Gaydon et al. (2012a; 2012b). In fact, Table 1 tends to indicate that the quality of the parameterisation seems to have been more directly affected by the completeness of the datasets rather than the model not performing due to an inability to properly represent a particular process.

Despite this very encouraging result that significantly strengthens our view that APSIM-ORYZA can now be widely used to simulate rice-based cropping systems under a wide range of environmental and management conditions in South Asia, our work has identified some shortcomings that will require refinements or modifications to be undertaken to a few of APSIM's modules (in addition to suggestions made by Balwinder-Singh et al., 2011). Areas of the model identified during this project which would benefit from improvement:

- Simulation of crop response to limitations in micro and minor nutrients.
- Better simulation of processes associated with alternate wet-and-dry water management in rice – simulation of soil cracking and capturing the subsequent temporarily high rate of water use upon re-flooding. In real AWD systems, the required irrigation water use in re-flooding following dry-down can be significantly different between puddled soils in transplanted rice systems and non-puddled soils in direct-seed systems. The puddled situation often results in larger re-flooding water losses due to drainage below the plough-pan resulting from cracking. These processes are not yet adequately described in APSIM.
- K_s (percolation rate) steadily decreases with time in continuously ponded environment – not yet captured in APSM.
- Emergence modelling in crops – both rice and other crops.
- Changing APSIM soil water-holding parameters after tillage – better capturing the dynamics of these processes and the effects on water balance.

Table 1 Summary data characteristics of case study modelled and level of confidence in parameterisation.

Reference / case study no.	Climate data		Soils data					Crop data			Level of confidence in parameterisation
	RF years	Radiation	Texture/PSD	BD	DUL	CLL	PWP	Biomass	Yield	Phenology	
1. Akhter et al.	31	Sunshine hrs	PSD	Y	Y	Y	Y	Y	Y	4 stages	High, due to completeness of local dataset
2. Rai	8	No local data	Texture	N	N	N	N	Y	Y	3 stages	Moderate; carry over effects reduced ability to run long-term simulation; requires better soils data to improve
3. Choudhury et al.	24	Radiation	PSD	Y	Y	Y	Y	Y	Y	5 stages	High, due to good local data and model validated on an independent dataset
4. Kumar et al.	11	Sunshine hrs	PSD	Y	N	N	N	Y	Y	4 stages	Moderate to high; parameterisation largely on basis of phenology
5. Balwinder-Singh et al.	40	Sunshine hrs	PSD	Y	Y	Y	Y	Y	Y	3 stages	High, due to completeness of local data
6. Subash et al.	17	Sunshine hrs	PSD	Y	Y	N	Y	Y	Y	3 stages	High, due to good local data
7. Sena et al.	21	Sunshine hrs	PSD	Y	N	N	N	Y	Y	5 stages	Moderate; requires better soils data to improve
8. Darai et al.	12	No local data	Texture	N	N	N	N	Y	Y	2 stages	Moderate; requires better soils data to improve
9. Ahmad et al.	18	Sunshine hrs	PSD	Y	N	N	N	Y	Y	2 stages	Moderate to high; crop parameterisation was good, but lack of soil data constrained fully capturing irrigation
10. Suriyagoda & Peiris	7	Sunshine hrs	Texture	Y	Y	N	Y	Y	Y	5 stages	High, due to good local data
11. Rathnayake & Malaviarachchci	30	Sunshine hrs	PSD	Y	Y	Y	Y	Y	Y	4 stages	High, due to good local data

RF = rainfall; PSD = particle size distribution; DB = bulk density; DUL = drained upper limit (field capacity); CLL = crop lower limit; PWP = permanent wilting point

- Issues related to proper simulation of conservation agriculture practices – effect of numerous tillages vs very few tillages with retained residue; aggregate size distribution changes, with associated soil property changes; APSIM-Wheat phenology modelling under mulched systems.

Overall, the planned growing network of APSIM modellers in South Asia will continue to facilitate these types of improvement to the model through contribution of datasets, networks of interested scientists, and ongoing model testing and validation.

The ability to make such improvements will require collection of comprehensive data sets, especially in relation to soil physical properties.

Overall, based on the results presented in Table 1, we conclude that the parameterisation performed in at least half of the case studies (1, 3, 5, 6, 10 and 11) was of a good to high standard, so that the scenario analyses resulting from these case studies and discussed in the following section can be regarded with a some degree of confidence.

5.4 Results of scenario analysis

The results of the scenario analyses conducted in the 10 case studies are summarised in Table 2. The scenarios tested can be grouped into the following four topics:

1. Improving irrigation efficiency (case studies 1, 5, 6, 7, 9)
2. Optimising planting dates (case studies 3, 4, 5, 7, 11)
3. Performance of varieties over a wide range of weather conditions (case studies 2, 11)
4. Optimisation of N fertilisation regimes (case studies 3, 8, 10)

The two case studies that explored the feasibility of reducing the amount of irrigation water applied to rice crops in the western part of the IGP (5, 6 in Table 2) came up with quite contrasting results. In the case of the Modipuram site (6), reductions in irrigation water, while increasing water productivity, came at the cost of yield, with increased yield penalties which increased as the irrigation interval increased. In this case therefore it is likely that farmers would be confronted with a typical trade-off decision, making adoption trickier. However, the substantial reduction in yield in switching from continuous flooding to alternate wetting and drying with a 2-day interval (2 AWD) is in contrast with the case study 5 which was on similar soil type, where rice yield was maintained up to 4-days interval with about 50% saving irrigation water as compared to continuous flooding. Similar findings were reported from many experiments and other modelling studies in the region (Humphreys et al. 2010). Based on such findings, a 2 - 3 day interval (after the floodwater has dissipated) is the generally accepted recommendation across the IGP. It appears that further model parameterisation and/or adjustments of the simulation rules are needed in case study 6 to ensure that the model simulations more closely reflect observations in relation to AWD interval. Furthermore, the amount of irrigation water applied to 2 AWD (1,000-2,000 mm) was well in excess of that required to meet both ET and net evaporative demand (ET-rain).

In the case of the Gazipur site in Bangladesh (1), small reductions in irrigation water supply did not lead to any significant effects on yields (further modelling should explore by how much more irrigation input can be reduced before triggering yield losses). In this case it appears that the irrigation of boro was occurring within a 'luxury' regime (12-14 irrigations of 100 mm, compared with evaporative demand of about 600 – 700 mm, on a soil with low hydraulic conductivity). The results suggest that there is significant scope for irrigation water savings in boro (e.g. through AWD), necessitating further back-up by experimental work on irrigation regimes in boro, or at least, a renewed assessment of already existing results emanating from experimental work on irrigation efficiency. Achieving irrigation water savings is very attractive to farmers paying for the cost of the amount of water used (or the energy used to pump the water) provided that there is no yield loss. However the other important question is whether a reduction in irrigation water input leads to a reduction in water depletion from the region (i.e. a real water saving). To help answer this question, analysis of the other components of the water balance (ET, drainage, runoff, changes in water stored in the root zone) is also recommended for future work.

The two case studies evaluating planting dates came to quite clear conclusions in terms of optimum sowing or planting dates for the varieties tested. In north west India the optimum transplanting date for reducing irrigation water requirement was mid June (11 and 21 June), due to lower evaporative demand and higher crop season rainfall than for other transplanting dates. The findings of decline in yield in eastern India as transplanting date was delayed beyond 10 June were consistent with the experimental results of findings from north west India (Humphreys et al. 2010), apart from the dramatic decline in yield between 10 and 20 June plantings. Further delving into the model outputs to understand the reasons may provide some useful insights. A likely explanation is the fact that the rice was only irrigated 5 days after ponding ceased (5 AWD), so it is possible that later plantings suffered more from terminal drought stress following the end of the monsoon rain. Another important finding was the decline in irrigation water productivity as transplanting date was delayed. However, the availability of water for irrigation in eastern India prior to the start of the monsoon is poor (canal water is not yet available, few farmers have access to groundwater and most can't afford the cost of pumping). Therefore most farmers currently have no choice but to delay sowing their seedbeds until after the rains start, meaning that transplanting is delayed well beyond the optimum date. This case study points to the potential of model simulations to help inform policy makers about the value of investment in irrigation to increase rice production – based on this study yields could be doubled by enabling farmers to plant at the optimum time. The decline in yield of rainfed rice in Sri Lanka as varietal duration decreased, even when sown at the optimum time for each variety, was also consistent with observed lower yield of shorter duration varieties.

In both cases, the value of the scenario analysis is not so much in defining the optimum sowing date or choice of variety *per se* (which can be done fairly easily using classical experimental approaches), but that the combination of trial data and modelling could allow for a substantial shortening of the trial duration, allowing resources to be re-allocated to other experiments, because recommendations can be made sooner and on-farm testing or demonstrations commenced earlier. This in turn potentially enables the time to adoption to be significantly reduced. This is largely due to the fact that the use of a crop model provides the ability to analyse the options for the wide range of rainfall variability – in terms of yield, and also in terms of irrigation requirement and water productivity where available.

In some cases scenarios spanned two of the above topics, allowing interactions to be explored (planting date x N rate interactions, case study 3; irrigation scheduling x planting date, case studies 5 and 7; sowing date x variety interactions, case study 11). These are examples that more clearly demonstrate the power of modelling, as the permutations of treatment interactions generated often will quickly exceed experimental possibilities. In all cases, the modelling has pointed to clear thresholds, helped understand interactions and point to opportunities for synergies. For instance, in the work done by Choudhury et al. (Table 2), the results led the trainees to conclude that early planting in conjunction with moderate levels of N fertilisation (60 kg/ha) will most likely achieve the highest yields in the long term. Apart from the fact that the question asked in the above scenario analysis requires a complex multi-factorial experiment design, without a lot of additional data, it would be very difficult to unravel the causes for declining yields with later planting dates and to understand how rainfall x soil N dynamics interact to affect yield. However, in this case, a broad spectrum of model output was used to query the underlying processes leading to decreases in rice yields at late planting. This made it possible to clearly demonstrate that there is a better match between crop growth and the prevailing rainfall and radiation patterns when crops are sown at the earlier end of current farmer practice. The analysis also indicated that rainfall and radiation regimes had a greater influence on crop performance than N fertilisation, because the soils in this location have a high organic matter and nitrogen status.

Case study 5 studied rice irrigation and wheat irrigation interactions under mulch and non-mulch conditions. Wheat irrigation water input was reduced with surface retention of rice residues provided that the rice was irrigated sufficiently to maintain yield (continuously flooded, 2-d, 4-d interval irrigation), leaving a fairly full profile at the time of rice harvest. Total rice-wheat system yield was maximised with rice irrigated using 4-d scheduling and mulched wheat, and with higher irrigation water productivity than for continuous flooding and 2-d interval rice irrigation scheduling.

Table 2: Overview of the cropping system case studies modelled: characteristics, scenarios tested and key findings of the scenarios analysed.

Reference	Location	Climate	Soil type	Cropping system modelled	Scenarios tested	Objective	Outcome
1. Akhter et al.	Gazipur, Bangladesh	Monsoonal, with average yearly rainfall of 2125 mm	Alluvial, silty clay	Triple rice (T. Aus - T. Aman - Boro)	Reduced number of irrigations in Boro and T. Aus.	To assess whether reduced irrigation results in water savings without affecting yield.	Reducing irrigation from 1400 to 1200 mm in Boro did not affect yield, but significantly increased irrigation WP and gross margins.
2. Rai	Bhur, Bhutan	Monsoonal, with average yearly rainfall of 4000 mm	Acid sandy loam	Rice - fallow (non-irrigated)	Compared three improved IRRI varieties against local variety.	To assess whether improved varieties outperform local variety w.r.t drought tolerance.	IRRI RC68 has the potential to yield significantly higher. There was little difference between the local variety Kamja and the other two IRRI varieties (IR72 and IR780).
3. Choudhury et al.	Meghalaya, North-Eastern Hills Tract, India	Monsoonal, with average yearly rainfall of 2450 mm	Acid sandy loam	Rice - fallow (non-irrigated)	Compared interactions of three planting dates with three N rates.	To determine optimum plant and N fertilisation rates.	Late planting (21 July) generally resulted in yield penalties, irrespective of N rate. Optimum N rate was 60 kg/ha, as the marginal increase from 60 kg/ha to 90 kg/ha N did not result in significant additional yield gains.
4. Kumar et al.	Faizabad, Uttar Pradesh, India	Monsoonal, with average yearly rainfall of 920 mm	Alluvial, silt loam	Irrigated rice - wheat	Varied 6 planting dates of rice from early (10 June) to late (30 July).	To assess the effect of planting dates on yield and WP of irrigated rice.	Early planting predicted significantly higher yields (by about 1 to 1.5 t/ha) compared to more traditional July planting dates, as well as indicating a much higher irrigation WP.
5. Balwinder-Singh et al.	Ludhiana, Punjab, India	Monsoonal with average yearly rainfall of 734 mm	Alluvial, sandy loam	Irrigated rice-wheat	Varied sowing dates for mulched and conventional tilled wheat in conjunction with different rice transplanting date.	To find out optimum sowing and transplanting date of wheat and rice and to study the interactions between rice irrigation and wheat irrigation.	Optimum sowing date for wheat is early November for high water productivity, while optimum transplanting date is mid-June to get high irrigation water productivity in rice. Rice-wheat system water productivity can be increased by following 4-d rice irrigation schedule and followed by mulching wheat.

Table 2 contd.: Overview of the cropping system case studies modelled: characteristics, scenarios tested and key findings of the scenarios analysed.

Reference	Location	Climate	Soil type	Cropping system modelled	Scenarios tested	Objective	Outcome
6. Subash et al.	Modipuram, Uttar Pradesh, India	Monsoonal, with average yearly rainfall of 747 mm	Alluvial, sandy loam	Irrigated rice - wheat	Compared different AWD irrigation regimes in rice and reduced number of irrigations in wheat to conventional irrigation.	To assess the irrigation thresholds that optimise WP at acceptable yield penalties.	Shifting from CF to various AWD regimes in rice and reduction of irrigations in wheat is predicted to significantly decrease yields. In some cases these yield losses generated only marginal irrigation water savings.
7. Sena et al.	Karnal, Haryana, India	Monsoonal, with average yearly rainfall of 675 mm	Silty loam, sodic	Irrigated rice	Compared different planting dates and three different irrigation regimes for puddled rice	To determine optimum planting dates under AWD irrigation regime	Transplanting medium duration non aromatic rice in first week in July and applying irrigation 2 days after receding of ponded water could maintain optimum yield and sustain water resources.
8. Darai et al.	Nepalgunj, Terai, Nepal	Monsoonal, with yearly rainfall of 1000 - 1500 mm	Sandy loam	Partially irrigated rice - wheat	Compared effect of inorganic and organic fertilisers on yields of rice and wheat.	To determine optimum long term fertilisation regimes for rice and wheat.	Rice and wheat yields were predicted to respond positively with increasing N from 50 to 100 kg/ha or in the 10t FYM treatment, although effect in rice was only marginal. WUE is also likely to increase with higher N.
9. Ahmad et al.	Islamabad, Pakistan	Monsoonal, with some winter rainfall	Silt loam to loam	Irrigated wheat	Compared three sprinkler irrigation options against rainfed wheat.	To determine optimum sprinkler irrigation regime in maximising wheat yield.	Irrigation increases probability of attaining higher wheat yields by about 1 t/ha. Differences between sprinkler regimes were marginal, suggesting that the 60% of crop water requirement irrigation level is sufficient.
10. Suriyagoda & Peiris	Maha-Illuppallama, Sri Lanka	Monsoonal, low-county dry zone	Loamy, Reddish Brown Earth	Irrigated rice	Reduced N top-dressing by 25 - 100%, in the presence or absence of organic matter additions.	To determine thresholds for reduction in N rates that do not affect rice yield.	Without organic matter additions to the soil, similar rice yields could still be achieved at 25 and 50% reduction of N rates. With organic matter addition, it may be possible to achieve a 75% reduction of N top-dressing without yield penalty.
11. Rathnayake & Malaviarachchci	Batalagoda, Sri Lanka	Monsoonal, low-country intermediatezone	Sandy loam, Red Yellow Podsolic	Rainfed direct-seeded rice	Compared interactions of 18 sowing dates with three medium to short duration rice varieties.	To determine optimum sowing dates for three rice varieties (Bg366, Bg300, Bg250).	Irrespective of planting date, the shorter duration varieties indicated significant drops in yield ranging from 1 -2 t/ha. Optimum planting dates ranged from early October (long duration), 2nd week October (medium) and mid-late October (short duration).

AWD = alternate wetting and drying; WP = water productivity; WUE = water use efficiency

5.5 Lessons learnt: principles for improving future training in modelling

In Section 3.1 we summarised past experience in imparting training in modelling, and mindful of shortcomings in earlier attempts at building capacity in systems modelling, in Section 3.2 we provided an outline of how the design of this project attempted to broaden the training strategy to overcome some of the constraints mentioned in section 5.1. In the following section, we provide an assessment of what worked and what needs to be improved to make future training in systems modelling even more effective.

5.5.1 Evaluation of the effectiveness of the training

Formal feedback was sought from trainees after each workshop to assess the effectiveness of the workshop and obtain suggestions for improvements. A summary of the feedback received from collaborating trainees after the parameterisation workshop in November 2011 is provided in Table 3, and from the scenarios workshop in June 2012 in Table 4, and from the yield gap workshop in March 2013 in Table 5. Overall, rating on a scale from 1 to 5 in Table 3, where 1 is poor and 5 is excellent, indicated a high degree of satisfaction by the trainees. An exception was one trainee, who felt that the workshops needed to be much longer (15 days) to be effective. Rating from the exposure workshop and the scenarios workshop were similar.

Table 3: Summary rating of parameterisation workshop held in November 2011.

Results of a further survey by ACIAR–appointed reviewers Dr Ian Willett and Dr Pramod Aggarwal (following the Scenario Analysis workshop and Midterm Review -Kandy, Sri Lanka, June 2012) also demonstrated the trainees' perceived effectiveness of the training (Table 3 – Willett and Aggarwal, 2012)).

Table 4: Summary of responses to the questionnaire following the scenario workshop, Kandy, Sri Lanka, June 2012..

Respondent	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Existing know-ledge	Relevant to own research	Delivery of training	Data prepara-tion capacity	Can use with ext. help	Can use - no external help	Help from network except IRRI CSE	Con-straints	Improve-ments	New practices	Institution-al support	Post-project use	IRRI-CSIRO post project inter-action	Other networkers post project interaction
Bangladesh	P	Y	G	Y	Y	E	N	Y	(1)	Y	Y	Y	Y	Y
	0	Y	G	Y	Y	E	N	N	(2)	G	Y	Y	Y	P
India	P	Y	VG	Y	Y	E	Y	N	(5)	Y	Y	Y	Y	Y
	Average	Y	Ex	Y	Y	E	Y	N	(6)	Y	Y	Y***	Y	Y
	P	Y	VG	Y	Y	E	Y	N	(7)	Y	Y	Y	Y	Y
	P	Y	Ex	Y	Y	N	Y	N	(8)	N	Y	Y	Y	Y
	G	Y	G	Y	Y	E	Y	N	-	Y	Y	Y	Y	Y
	G	E	Ex	Y	Y	E	Y	Y	0	E	N	Y	Y	Y
	P	Y	Ex	Y	Y	Y	Y	Y*	(11)	Y	Y	Y	Y	Y
	G	Y	Ex	Y	Y	N	Y	N	N	Y	Y	Y	Y	Y
Nepal	G	Y	Ex	Y	E	E	N	Y**	(13)	N	Y	Y	Y	Y
Pakistan	P	Y	Ex	Y	Y	E	N	N	N	N	N	Y	Y	Y
	G	Y	Ex	Y	Y	N	N	N	0	N	N	Y	Y	Y
Sri Lanka	G	Y	Ex	Y	Y	E	Y	N	Y	N	N	Y	Y	Y
	G	Y	G	Y	Y	E	N	Y	(17)	E	Y	Y	Y	Y
	G	Y	G	Y	Y	Y	Y	Y	(18)	Y	Y	Y	Y	Y
	G	Y	Ex	Y	Y	E	Y	N	Y	N	N	Y	Y	Y

0 – none, P – poor, G – good, VG – very good, Ex – excellent, Y – yes, N – no, E – expected by time of the project's completion

Question 9 suggestions: (1) need provision of hardcopies, (2) training is needed for each module, (5), (6), (7) longer training period needed >10 days, (8) needs programming training, (11) more effort needed by participants, (13) more in-country training needed, (17) ** need more soil data, , (18) time between workshops insufficient to collect experimental data, some responded "Y" but gave no suggestion.

Other comments, * not able to use APSIM for rice CSR30, ** need more soil data, *** funding needed

Table 5: Summary of responses to the questionnaire following the yield gap workshop, Dhaka, Bangladesh, March 2013. (from Appendix 1, Willett and Pathak, 2013)

	Q 1*	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17**	Q18
Respondent	Pre-existing Knowledge	Relevant to own research	Delivery of training	Own data preparation	Can use with ext. help	Can use - no ext. help	Interact and support within network	Able to be trainers	Constraints	Improvements	Identified practices	Institutional support	Post-project use	IRRI-CSIRO post project inter-action	Other networkers post project interaction	Needs to allow continuation	Future main subject area	Comments
Bangladesh	G	V	G	Y	Y	Y	Y	Y	N	-	Y (1)	Y	Y	Y	Y	(2)	CC	-
	G	V	G	Y	Y	N	Y	Y	N	-	Y(3)	Y	Y	Y	Y	(4)	A	-
	P	V	G	Y	Y	Y	Y	Y	(5)	(6)	Y(7)	Y	Y	Y	Y	(6)	Var	-
Bhutan	G	V	E	Y	Y	N	N	Y	(5) (8)	(8)	Y	Y	Y	Y	Y	(5) (8)	Var, W	New user
India	0	V	G	Y	Y	Y	Y	N	N	(8)	Y(9)	Y	Y	Y	Y	(10)	CC	(11)
	0	V	G	Y	Y	Y	Y	Y?	(8)	(12)	(13)	Y	Y	Y	Y	-	A, CC	(14)
	0	V	G	Y	Y	Y	Y	N	N	(8)	(9)	Y	Y	Y	Y	(10)	W	-
	P	V	E	Y	Y	Y	Y	Y	Y	(8)	Y	Y	Y	Y	Y	-	A, CC	(14) (8)
	G	V	E	Y	Y	Y	Y	Y	N	(10)	(15)	Y	Y	Y	Y		A, W	(10) (14)
	G	V	E	Y	Y	Y	Y	Y	Y	(8)	Y	N	Y	Y	Y	(16)	W	-
	P	V	E	Y	Y	Y	Y	N	N	-	(17)	Y	Y	Y	Y	(18)	A, W	(18)
	G	V	E	Y	Y	N	Y	Y	N	-	Y	Y	Y	Y	Y	(19)	CC	-

Nepal	G	V	G	Y	N	N	Y	Y	(20)	(21)	Y	N	Y	Y	y	(8) (16)	A, Var	-
Pakistan	P	V	E	Y	Y	N	N	Y	N	-	N	Y	Y	Y	Y	(16)	W, CC	-
	G	V	E	Y	Y	N	N	Y	N	-	Y	Y	Y	Y	Y	(16)	W	-
Sri Lanka	G	V	E	Y	Y	Y	N	Y	(22)	(22)	(23)	Y	Y	Y	Y	(16)	W	-
	G	V	G	Y	Y	Y	Y	Y	(24)	(25)	Y	Y	Y	Y	Y	(26)	W	-
	G	V	E	Y	Y	Y	Y	Y	(27)	(27)	Y(28)	Y	Y	Y	Y	(16)	A	-
	G	V	E	Y	Y	Y	Y	N	N	-	N	N	Y	Y	Y	(29)	A	-

*0 - none, P - poor, G - good, V - very, E - excellent, Y - yes, N - no

**CC - climate change, A - general agronomy, Var - variety selection, water productivity. Numbers in brackets refer to the following notes

Notes from Table 5: The following notes summarise most of the comments. Most of the comments were edited and shortened, and some similar comments were combined (often reflecting similar responses of individuals are working in groups).

1. Modelling suggested that a reduction of two irrigations (200 mm) in boro or a reduction of one irrigation (100 mm) in T. Aus or in boro, respectively, will not significantly affect the total system productivity, and will enhance the likelihood of increased gross margin.
2. Application of the model for improved crop management for risk analysis and to train young scientists
3. Increased water productivity of boro rice
4. Apply APSIM to judicious use of water in field crops, and for sowing date adjustment experiments to address future climate change
5. Insufficient of time for practising APSIM model/requires more time for APSIM
6. Institutional support for allocation of more time and analytical facilities specially for soil and other required parameters of crops
7. Reduction of the number irrigations of rice without yield loss
8. Longer training duration (up to 2 months suggested) and more face-to-face interactions with CSIRO trainers
9. Optimum transplanting date for rice was identified helped to significantly improve crop yield and crop water productivity by capturing early monsoon rains, while escaping terminal droughts and low temperature in the reproductive phase of paddy crop. Reduction of fertiliser-N from present 90 kg/ha to 60 kg/ha did not significantly influence yield of paddy. Therefore there is scope to save the cost of 30 kg/ha fertilizer N.
10. Expanding the scope and applicability of the model to integrated farming systems, agroforestry etc. Inclusion of additional modules in APSIM to accommodate these components (animal and trees) will add a lot of value to the model and would certainly have wider acceptability and applicability.
11. We would like to continue to be associated in future scientific endeavour especially in the area of food security, enhancing resource efficiency and impact of climate change.
12. Provision of financial resources for setting up of small experiments
13. In rainfed agriculture adjustment in transplanting dates of paddy can significantly improve crop water productivity. Simulation studies revealed that introduction of one to two life-saving irrigation in the post anthesis period could lead to an increase in yield by over 25% in rainfed systems. Optimisation of fertiliser-N from present 90 kg/ha to 60 kg/ha improved the N-use efficiency without yield penalty.
14. Project has led to publications, and/or new projects or proposals
15. AWD irrigation regime for rice combined with 5 irrigations during wheat may be the best option under water limiting situations.

16. Trainee needs to join a project or network/more interactions/new project
17. Identified that the first week of July for transplanting with irrigation at 2-4 days after recession of ponded water can save about 18-20% water without significant adverse effect on crop growth and yield.
18. Application of APSIM to another research project on “water management strategies in rice-wheat systems” suggested
19. Need to continue in a SAARC-Australia project. APSIM training in dryland crops (pigeon pea) is needed.
20. Inadequate soil lab facilities and only 3 hours per day electricity availability. Imperfect weather data land lack of surveyed economic data. Need to change the traditional weather data recording system and to install a radiation remote sensor near the project location. Need to collect the economic data from farm level through the household and PRA survey
21. Needs a radiation remote sensor at the project location.
22. Need for greater knowledge about the program inside the model and knowledge and skills to write program statements when required
23. Identification of the optimum dates of sowing for paddy to utilise rain water efficiently
24. The current user-interface lacks ability for incorporation of some of the management practices or decisions that farmers make
25. Need training to write our own codes in APSIM
26. APSIM used for university teaching and research
27. Potassium (K) and phosphorus (P) are not included in APSIM models and need to be included
28. Optimum levels of irrigation, spacing and N fertilizer applications were found for rice crops from simulations
29. “It should be one of the components of the regular research program of my institute”

Currently all the trainees are capable of preparing data for use in APSIM and all except one can run APSIM with support from CSIRO. By the end of the project (Table 5), 13 out of 19 trainees can run APSIM without external support, and this represents an increase since May 2012, when there were only 2 out of 17 (Table 4). Therefore this clearly reflects that the trainees themselves consider that significant capacity building in APSIM modelling has been achieved during the course of the project. Participants get support from within the region and the results shown in tables 3-5 particularly reflect cooperation within each of India, Sri Lanka and Bangladesh.

The Bangladesh trainees particularly have increased their in-country collaboration since these surveys were performed, conducting their own in-country training session on APSIM for BRRI and BARI scientists in August 2013, completely unsupported by Australian project staff (apart from provision of materials). By all reports this workshop was very successful and another has been planned within the next 6 months. This success of the Bangladeshi trainees in moving into the role of “trainers” also reflects the contribution of another ACIAR project (Developing multi-scale adaptation strategies for farming communities in Cambodia, Laos, Bangladesh, India (ACCA), LWR-2008-019) where modelling training efforts were conducted and an effort to establish a “Bangladesh Modelling Group” was undertaken, bringing in up to 8 scientists over-and-above the Bangladesh SAARC trainees. This may illustrate the value of critical mass in a self-sustaining regional modelling group.

5.5.2 Strengths in the process adopted by the project

Collaborative spirit: Willingness by trainees to collaborative irrespective of institutional and country background gave positive insights into possibility of a functioning modeller network (see Figure 1). When together in the same room, the trainees from across the SAARC network were very open to sharing and helping one another. The primary reason such sharing and helping might cease after departing the workshops is simply related to distance and lack of infrastructure and communication vehicles to enable a functioning network. Shared visions and a willingness to make a network happen were not wanting.

Figure 1: Trainee camaraderie in action

Training materials used. A completely overhauled APSIM training workbook was developed to match the training needs for South Asian cropping systems. Actual training material covered in the workshops worked well. The training manual, its examples, the structure, and the topic progression were all rated as “very good” to “excellent” by trainees in all evaluations undertaken. This means that the training workbook constitutes a critical project output and can be used in subsequent training by SAC in South Asia.

Field training and follow-up visits. A new component added to modeller training by this project (to our knowledge absent from previously documented modeller training efforts) has been training in field techniques to collect high-quality model-ready data. This was successful from two perspectives: (i) the trainees learnt the skills and techniques necessary to obtain their own field data and were introduced to examples of the hardware and software required, and (ii) the trainees greatly enjoyed getting out into the field, getting their hands dirty, and the break from looking at the computer. It reinvigorated them for the remainder of the workshops, and it provided them with a further social opportunity to cement the friendships and linkages which are the key to a functioning network. The follow-up visits by project trainers to trainees in their home countries further provided an opportunity to link the modelling work with real on-ground measurements, experiments, and discussions.

5.5.3 Weaknesses in the project methodology

Process for selection of trainees. Whilst the overall process of selection of trainees was rigorous and free of interventions, one problem that did emerge was that in three of the participating SAARC countries, the call for applications was only issued to institutions directly affiliated with the research councils of those countries, and not more widely disseminated for instance to the university sector in those countries, resulting in a narrower field of suitable candidates. Also disappointing was the low level of applications of females (3 out of 51). In future, such calls need to be circulated more widely within SAARC Member Countries. Also, the focus of nomination was not directed to candidates which had an immediate application for modelling in their work schedules, rather people with an interest in modelling. In any future selection process, an alternative might be to target individuals who are already involved in cropping systems initiatives or project, or who have an immediate requirement to use modelling in their research. This would facilitate the trainee spending time working on the model between workshops, and greatly enhance their development as competent modellers.

Lack of institutional support. The apparent lack of institutional support in some cases indicates that perhaps the project team should have conducted a briefing to heads and research managers within those institutions once trainees had been identified, either before or immediately after workshops. This would have significantly increased project costs, but possibly would have led to a sanctioning by institutional heads of some trainees to allocate more quality time to continue their practice of modelling. To some extent we attempted this during the visits of team members to individual institutions as part of the technical support visits, but this was only partially successful.

Lack of time and motivation to work on modelling outside workshops. Whereas trainees had been granted time to attend the workshops, in some cases there was no explicit allocation of time within their home institutions to work on improving modelling work and simulations between workshops. This resulted in trainees becoming distracted from their modelling efforts and losing focus between workshops.

5.5.4 Opportunities for improvement

Changes to selection protocols for trainees. Investigate changes to selection protocols which would allow the targeting of younger scientists with an expressed desire to make cropping systems modelling a key component of their careers. Particular preference should be given to candidates who are already committed to project work with modelling deliverables, or who are already participants in other international modelling initiatives (such as AgMIP, for example).

Treat the training like a course. Design a training process built around assignments, testing, and marking. As discussed above in 5.5.3, one of the major problems encountered was that trainees would make enthusiastic progress during the actual workshops, then return to their home institutions and set aside modelling activities until the next workshop. In future, we would dispense with the idea that the training consists primarily of 3 or 4 workshops, and replace it with the idea of a continuous "modelling course" in which trainees undertake regular assignments and testing, with associated marking. These on-line or emailed components would need to be supported by several workshops, but the emphasis would be placed on regular use of the model with progressive challenges, and an overall assessment (or mark) at the end of the training (as an incentive). The project team feels that this would overcome the sporadic nature of trainee modelling effort which occurred in the current project.

Inclusion of university sector to establish the modeller "spawning grounds". Following on from the point above, such a course-work approach to modeller training could align itself with the needs of universities and could be envisaged to constitute a future university-based modelling course – available at universities throughout the SAARC countries. From the perspective of a future self-sustaining modeller network within SAARC countries, such a university option would create the "spawning grounds" for future professional modellers. After leaving university, the young researcher would already be model-exposed and ready to join/participate in the active network of practicing modeller scientists.

Include master trainers from the current cohort as assistant trainers in the following cohort. We believe that subsequent cohorts in a modeller-training initiative like the SAARC-Australia project need to be linked by a system of master trainers who become part of the training team, based on the premise that the best way to really learn something is to try to teach it to someone else. It is proposed that the assistant trainer role effectively becomes part of the education process, further cementing the learnings from being a trainee.

5.6 SAC Monograph on project achievements and learnings

5.6.1 Rationale

Learnings and achievements from the project have reached well beyond the trainees learning how to use the APSIM model. The monograph will detail learnings, achievements and criticisms in the following areas:

- What the team has learnt about their efforts to establish a network of modellers within the SAARC countries; what has been done, what is still to do.
- What the training team have learnt about the actual training process – what works, what doesn't, what would be done differently in future.
- What the trainees have learnt about modelling, and about the specific research questions they sought to investigate

- What has been learnt about the strengths and weaknesses of the APSIM model in the SAARC country environments, and what aspects should be targeted for future improvement?

The monograph will celebrate project achievements, while critically assessing the degree to which it has reached its objectives. It will document learnings about the processes, and make recommendations for future endeavours in establishing a sustainable network of APSIM modellers for South Asia. In addition to capturing learnings, the monograph will also document the results of model parameterisations and scenario analysis.

5.6.2 Progress to date

The monograph chapters have been peer-reviewed and finalised, including all of the trainee chapters. Each chapter was peer-reviewed by two other people, apart from the trainee chapters which were each reviewed by two other trainees and one member of the training team. All chapters have had at least one revision following review, in some cases several revisions.

The monograph is now ‘in-press’ with the SAARC Agriculture Centre, Dhaka. It is expected that the completed monograph will be printed and available in mid-October 2013. A pdf of the publication will also be hosted on the SAC website, and arrangements have been discussed to conjointly host it upon the ACIAR publications website. Gaydon et al. 2013 contains the final papers of the monograph.

6 Impacts

6.1 Scientific impacts – now and in 5 years

Although primarily aimed at capacity building, the project has made some scientific achievements. The application of APSIM-ORYZA to rice, and rice in rotation with other crops has gained validation testing in wide range of South Asian environments, and now has a solid grounding. Future required improvements to APSIM, revealed during the course of the project, have been documented and plans are underway to implement many of the changes in the short-term (next 6 months), and others in the medium to longer term (1-3 years). In addition to the SAC Monograph, which will serve as a practical and academic reference for any future training and network creation endeavours, the project is likely to contribute a number of peer-reviewed papers. The aim is for 2-3 monograph chapters to be enhanced for submission to high-impact international journals, and several more to national agricultural journals.

The above achievements placed APSIM-ORYZA on the South Asian map and have laid the foundation for a number of science impacts, listed below. As papers from this project are published, it is likely that these impacts will be strengthened further.

The modelling philosophy employed in this project (rigorous parameterisation of APSIM using location-specific data) and use of the model to systematically explore crop responses to a range of more complex management interventions has been recognised by CIMMYT. As a result of this, researchers in CIMMYT involved in the design of ACIAR's new flagship program in the Eastern Gangetic Plains – the Climate Resilient Farming Systems Initiative – over the past six months have worked with ACIAR and CSIRO to embed modelling as a major component in this new initiative, to underpin choices of technologies, but also to conduct additional research to improve process representation in APSIM (for some of the issues to be addressed refer to section 5.4).

In April 2012, after becoming aware of the SAARC-Australia project, Prof Ken Cassman (Uni Nebraska and Chair of the CGIAR Independent Science and Partnership Council) approached various members of the SAARC project (CSIRO, IRRI and trainees from India) to explore opportunities to link the Global Yield Gap Analysis (GYGA) project he is leading with the SAARC project. He strongly endorsed the methodological approach being taken by the project. Given the similarities in approach to model parameterisation placing a high value on using local datasets and the shared intent of making the actual parameterisations publically accessible, it was agreed that both projects would now work towards pooling their data and parameterisation sets. The primary vehicle for this to occur will be the SAC-maintained modelling database. Currently, Dr Subash and Dr Balwinder Singh are engaged with GYGA. This will help the GYGA project fill some of the gaps it is encountering in South Asia. It will also expose and involve some of the SAARC project trainees to international modelling initiatives.

In early 2012, Dr Balwinder Singh was invited by the Bill and Melinda Gates funded Cereal Systems Initiative South Asia (CSISA) project to provide training in APSIM and to help the CSISA project use APSIM-ORYZA as the primary model to use the extensive datasets being generated by the CSISA project in three main research hubs (Karnal, Dhaka, NE India). Over the coming months, the support to the CSISA project will be continued, with joint analysis of CSISA datasets.

Whilst a key task for the IRRI PostDoc Dr Balwinder Singh is to provide training support to the trainees, a significant component of his role in the project is to use existing high quality datasets sourced within IRRI (some of which originating from previous ACIAR-funded projects – e.g. CSE/2004/033 and LWR/2000/089) to more thoroughly test and improve APSIM, as well as conducting scenario analysis to develop possible strategies to increase water productivity of key cropping systems in the Indo-Gangetic Plain. As part of this work he has re-analysed data he produced as part of his JAF to develop an improved routine to predict soil evaporation. This work is about to be published (see section 3.4 for titles) and it holds promise that his routines will be incorporated into cropping systems models to improve their ability to reflect the soil evaporation process.

During a modelling workshop convened by the US consortium leading the Agricultural Model Intercomparison and Improvement Program (AgMIP- http://www.agmip.org/), a wider range of South Asian researchers and modellers were exposed to APSIM. Perry Poulton and a number of project trainees also participated in this workshop, which was conducted over 5 days at the ICRISAT campus Hyderabad, India in February 2012. The goals of the workshop were: (1) to calibrate and intercompare multiple crop models (APSIM, DSSAT, INFOCROP, and STICS) against rice and wheat data from S Asia; (2) demonstrate through participation by the workshop attendees the process of model calibration, prediction and comparison with district-level crop yields; (3) integration of crop modelling, climate modelling, economic modelling and Information Technology. This initial workshop highlighted the low exposure to APSIM by agricultural researchers in the south Asia region. At the same time it generated a demand from participants to learn more about APSIM that could not be filled during this type of workshop. This demand has been met in subsequent AgMIP workshops through training of other modellers in APSIM (training was in fact provided by some of the SAARC project trainees), broadening the use of APSIM and contributing significantly to its success in the South Asia region. This is likely to lead to a growing demand for support to use APSIM in the region. This demand potentially also constitutes an opportunity for SAC to step in as a South Asian institution capable of servicing the likely increasing demand for APSIM support.

The three most recent training workshops for AgMIP teams in South Asia: (1) Nepal, March 18-22, 2013, (2) ICRISAT, March 25-29, and (3) Nepal, July 22-23 highlighted the strong proportional representation of our SAARC-Australia project trainees in these initiatives. Figure 2 shows a trainee group photo from the third workshop, with six (6) trainees from this project circled in red.

Figure 2: South Asian regional AgMIP modelling team, with SAARC-Australia project trainees circled in red.

Two new IRRI projects funded by IFAD and implemented under the Challenge Program Water for Food have initiated several rice-based cropping system trials across the IGP (Punjab, Modipuram, Patna in India; Jessore, Khulna & Barisal in Bangladesh) which include plans to collect suitable data to enable further parameterisation and evaluation of APSIM.

6.2 Capacity impacts – now and in 5 years

The main impacts arising from this project are in the capacity building domain. In fact this project was designed in a way to maximise a strong legacy of systems analysis and modelling capability to continue beyond the life of the project.

It is anticipated that at the end of the project each of the participating SAARC partner countries (India, Bangladesh, Pakistan, Nepal, Bhutan and Sri Lanka) will be endowed with incipient networks of farming systems modellers, building sufficient critical mass across the region (rather than in a particular country) to withstand loss of individual modellers. To date this is starting to emerge in Bangladesh (joint ACCA-SAARC modelling team), India (network of Indian modellers catalysed through their involvement in AgMIP South Asia Regional Project) and Sri Lanka (the four Sri Lankan trainees have formed a modelling group; two are also part of an APN modelling project).

In the case of the AgMIP project, arguably the Indian trainees (M. Shamin, Anup Das, N. Subash, Burhan U Choudhury, Kamal P Mohapatra) would not have been successful in their proposal bid without their involvement in the SAARC project. The SAARC project was instrumental in enabling these trainees to be invited and to participate in the AgMIP planning workshop, which exposed them to a wider, international modelling network. Following their participation in the workshop, the Indian SAARC team participating in the workshop under the leadership of Dr N Subash successfully submitted a proposal to receive funding support from AgMIP to establish one of four South Asia regional AgMIP modelling teams. The Project Directorate for Farming Systems Research (PDSFR) now leads a consortium comprising several SAARC project trainees from PDSFR and ICAR Research Complex for the NEH Region, and other research groups from Bangladesh and Nepal. The project is being backstopped by IRRI (Dr Balwinder Singh), CIMMYT (Dr Andy McDonald) and CSIRO (Dr John Hargreaves, Perry Poulton).

Equally, the Sri Lankan trainees involved in the APN project were selected on the basis of the experience they gained in the SAARC project.

Broadening the current mandate of SAC to include a SAARC-wide support role in modelling continues to constitute a key pathway to achieve lasting capacity building impacts. Part of this capacity building included the refurbishment of the SAC training facility and the supply of 20 laptops to enable computer based training courses to be offered at SAC. This should significantly boost the relevance and effectiveness of SAC in SAARC Member States, in turn strengthening SAARC's ability to foster regional cooperation, one of the primary goals of the Australian Government's support to SAARC.

There has also been substantial capacity building of CSISA platform co-ordinators Virender Kumar and Sheetal Sharma of IRRI as a result of internal IRRI training by Balwinder Singh. This training has also enabled the identification of data gaps at all 4 CSISA platforms. These are now being filled as a result of these interactions.

The combined and sustained enragement of the SAARC and ACCA project teams in Bangladesh with the Chairman of BARC have also been a significant factor in influencing BARC's push for the establishment of greater institutional capacity in modelling within BARI and BRRI.

6.3 Community impacts – now and in 5 years

Given the capacity building nature of this project, significant community impacts with end users (rice farmers) are not likely to occur before 5 years after conclusion of the project. Next users of project outputs and outcomes are research scientists and NARS managers in the partner countries, and in their case impacts can be expected in 0 - 5 years after project completion. Initially these impacts will also be more in the science and capacity building domains (see above). Hence, at this point in the life of the project, there are not yet any community impacts that we can report on.

The main envisaged pathway to impact is the assumption that use of modelling to underpin experimentally based choices of improved crop water and nutrient management options will shorten the time required evaluate promising techniques, as modelling will allow a more rapid temporal and spatial extrapolation of feasible technology. In fact, some of the results of the scenario analysis have spawned a range of new trials or modifications to trials with a view to accelerating the time to impact, mainly through better definition and targeting of research questions being tackled. Examples include the work by Akhter et al., Choudhury et al., Balwinder-Singh et al., Subash et al. and Suriyagoda et al listed in Table 2.

The other main envisaged pathway to community impacts is based on the assumption that modelling will increasingly be used to inform policy making in the NARS (in particular some of the Agricultural Research Councils), for instance in evaluation of options to adapt to climate change or trade-offs between reduced water use for irrigation and crop productivity. Ultimately, this should lead to better informed policy decisions, as well as a more effective and efficient deployment of scarce agricultural research funds.

6.3.1 Environmental impacts

No environmental impacts are expected as yet, but they may accrue in the longer term, 5 to 10 years as farmers implement water-saving and more nutrient efficient technologies shown by modelling to be environmentally acceptable. Some possible avenues for more nutrient and water efficient crop management were generated through the scenario analysis conducted by the trainees, the results of which are summarised in Table 2. It is expected that skills in cropping systems modelling will also provide SAARC country scientists with the skills to contribute effectively to national decisions on adaptation to future climatic changes.

6.4 Communication and dissemination activities

Monograph

Gaydon, D.S., Roth, C.H., Humphreys, E., Balwinder-Singh, Saiyed, I (eds.), 2013. The SAARC-Australia Project – Developing Capacity for cropping systems modelling in South Asia, SAARC Agriculture Centre Monograph, Dhaka, Bangladesh, 2013.

Journal papers and conference presentations

Balwinder-Singh, Humphreys, E., Gaydon, D.S., Yadav, S., 2013. Conservation agriculture for rice-wheat systems in NW India – tradeoffs between yield, water productivity and water depletion, for submission to *Field Crops Research*

Balwinder-Singh, Eberbach, P.L., Humphreys, E., (2012): The simulation of evaporation from the soil surface in cropping systems. Agricultural Water Management (submitted)

Balwinder-Singh, Humphreys, E., Gaydon, D.S., Eberbach, P.L. (2012): Evaluation of rice residue management, irrigation schedules for zero till wheat growth, yield and water productivity in north-west India using a cropping system model. (advanced draft)

Balwinder-Singh, Humphreys, E., Eberbach, P.L. and Gaydon, D.S., (2011): Evaluation of mulch for irrigated zero till wheat in north-west India. Oral presentation at 5th World Congress of Conservation Agriculture, Brisbane, 26-29 September, 2011.

Training manuals

APSIM training manual for South Asia. Don Gaydon, Perry Poulton, Shaun Verrall (2011)

http://www.apsim.info/Documentation/TrainingManualsandResources/TrainingManual(SouthAsia).aspx

Databases

APSIM-World Database. Justin Fainges, CSIRO, 2012.

http://www.apsim.info/THESTACK/ (see appendix one for directions to access the South Asian component developed in this SAARC-Australia Project)

Stakeholder engagement

The project advisory committee consisting of NARS representatives has been kept informed about the project through regular reports and briefings. It participated in the midterm review of the project. The current membership consists of:

- Dr Ahmed Ali Hassan, Member Director (NRM), BARC, Bangladesh
- Mr Chhimi Rinzin, Chief Agriculture Officer, DOA, Bhutan (in place of Mr Chencho Norbu)
- Dr Alok Sikka –Deputy Director General NRM, ICAR, India
- Dr Niranjan Prasad Adhikari, Director Crops & Horticulture, NARC, Nepal
- Dr Shahid Ahmed – Member Director NRM, PARC, Pakistan
- Dr WMADB Wickramasinghe, Additional Director NRMC, Dept. of Agriculture, Sri Lanka

Additional stakeholders from India, Nepal, Bangladesh, Sri Lanka and Bhutan (members of the SAC Governing Board) were briefed on results of the scenario analysis during the midterm review workshop in May 2012.

A modelling awareness seminar will be held in Dhaka involving the Bangladesh Secretary of Agriculture, NARS chiefs and BARC Chairman, during the final project workshop in March 2013, for the purposes of strengthening institutional support for modelling in Bangladesh. Trainees will attend and be provided with a copy of the presentations so they can undertake similar awareness seminars upon return to their home countries.

The Chairman of BARC continues to take a strong personal interest in the project, and has been regularly briefed by the Project Leader(s) in the course of each visit to Bangladesh.

The former DDG of ICAR, Dr AK Singh has also been kept briefed about the project through ACIAR's Country Manager for South Asia, Dr Kuhu Chatterjee. This has led to plans for ICAR to fund and send selected trainees from the Project Directorate Farming Systems Research to Australia for longer term training (1-3 months).

The incoming Secretary General of SAARC has been made aware of the project by the Australian Ambassador to Nepal, Susan Grace and Christian Roth, during a meeting in Dec 2012. Discussions with the new SAARC Director of Agriculture and Rural Development, Mr Tareque Muhammad, have taken place regularly, including during the joint midterm review / stakeholder meeting and subsequent visits to SAARC by Christian Roth.

7 Conclusions and recommendations

7.1 Conclusions and recommendations from the scenario analysis

The project has achieved a broad and comprehensive testing of the APSIM model through the testing and validation work performed by trainees during their training, using a mixture of both existing and newly-generated datasets from each of the home countries. This has achieved two things:

- It has provided confidence in the model's performance and future use in the region, and
- It has also identified several key areas where the model needs improvement.

The evaluation of the performance of the APSIM-ORYZA model and the synoptic reflections on the results of the scenario analyses allows for the following main conclusions and recommendations.

1. Data gaps that preclude a location-specific parameterisation of cropping systems models were, and are likely to continue to be a constraint to modelling. This is particularly true of certain climate parameters (radiation), soil characteristics (DUL, CLL) and soil dynamics (soil moisture regime, N dynamics).

Recommendation: Soil, climate and crop data acquisition regimes that fulfil minimum data requirements for models need to be designed into future major long term experimental trials, and where feasible, implemented with existing trials (e.g. CSISA platform trials).

2. Overall, APSIM-ORYZA performed satisfactorily and can be confidently recommended as a model to simulate rice-based cropping systems in South Asia. The level of confidence in modelled outputs is more related to the quality of input data and the parameterisation skills of the modeller than to shortcomings in process representation within the model. However, a number of gaps were identified and there is scope for improvement.

Recommendation: The APSIM-ORYZA developers should consider implementing the identified model improvements specified in earlier in this report:

- Simulation of soil hydrologic dynamics in AWD water management systems
- Conversion from conventional tillage systems to reduced and zero systems
- Changing APSIM soil water-holding parameters transiently after tillage
- Improving APSIM-Wheat phenology modelling under mulched systems and under abiotic stress situations
- Effect of soil moisture, temperature etc on rice emergence in direct seeded crop
- Including dynamics of root growth and water extraction factors for aerobic rice
- Simulating phosphorous dynamics for rice crop

3. The results of the scenario analyses point to a range of benefits than can be achieved when modelling is used as a complementary tool to experimental approaches. On the one hand, modelling can shorten the duration of trials designed to determine optimum planting dates or to select varieties, as well-parameterised models will to able to more effectively extrapolate crop performance over a range of seasonal and climate conditions. On the other hand, when used as a learning tool to query and explore causes for crop responses, modelling can help

generate deeper process understanding, particularly in more complex water-nutrient-crop system interactions. This to some degree obviates the need for complex trials to test interactions, while still placing conclusions and recommendations for improved practices on a sounder theoretical base.

Recommendation: NARs should increasingly couple modelling approaches with experimental approaches to shorten trial duration and complexity, to reducing costs and freeing up research funds that could be deployed elsewhere. Shortening of trial duration also accelerates the time to market or adoption of new technologies.

Recommendation: Further in-depth training should be provided to modellers so that they acquire the necessary skills to fully capitalise on model capability in querying and exploring more complex systems interactions. The net effect should result in efficiency gains in the research process.

4. The scenario analyses to date have largely focussed on a limited range of management factors for individual crops within a cropping system. How each crop in the system is managed may affect the performance of other crops in the system. This is especially likely to be the case when changing rice establishment method from puddling and transplanting to dry seeding, and with the introduction of conservation agriculture (reduced tillage, residue retention, suitable crop rotation).

Recommendation: Once adequate data sets and sufficient expertise is developed, whole system analysis is needed to identify optimal crop combinations and management depending on resource availability (especially water) and local priorities of farmers, resource managers and policy makers.

7.2 Conclusions and recommendations from the training process

This project has endeavoured to lay the foundations for a sustainable network of cropping systems modellers in the SAARC countries. It has been recognised that individual modelling skills, critical mass and linkages for support and collaboration are important elements. The strategy has centred around the following:

1. Training of individual scientists
    - In general modelling philosophies (parameterisation, calibration, validation, and scenario analysis)
    - The role of modelling in agricultural research (to augment experiments, to add value and a deeper understanding of long-term system variability/risks; to probe the biophysical drivers of observed experimental behaviour
    - Use of the APSIM model for rice-based systems
    - in field data-collection methods and the need to collect high-quality model-specific data in their home countries
    - Framing of research questions, and the use of models for scenario analyses
    - Climate change applications
    - Appropriate presentation methods for simulated data (graphical methods such as cumulative distribution functions (CDF's), box-plots etc)
    - Writing of scientific papers and reports which detail modelling results
2. Establishment of framework to support a network of APSIM modellers in the SAARC countries
    - Institutionalisation of a modeller network support position within SAC
    - Increasing SAC's profile within SAARC through it's leadership of this initiative (starting points include the SAC monograph which has been produced during this project)

    - Establishment of an easily accessible (on-line) APSIM model database for SAARC countries – providing data on soil and crop parameters, climate files, and complete validated APSIM simulations for future scientists to utilise in their own modelling efforts.
3. Creating new opportunities
    - Several SAARC-Australia project trainees are now involved in additional international modelling initiatives in South Asia (such as AgMIP) – opportunities which have come their way as a result of their involvement in this project.
4. Planning for the next generation
    - Developing plans for a follow-on project which will equip the university and training sector (the "spawning ground" for new agricultural modellers) with the coursework and skills to train young modellers.
    - Using ex-trainees as assistant trainers (rather than "master trainers" initially) in subsequent training cohorts, as in intermediate step to them becoming "master trainers".
5. Building support for cropping systems modelling within in-country agricultural institutions and NARS of the SAARC countries
    - Conduct of "modelling awareness seminars" to high level managers in these institutions. These seminars contain information on the vital future role which modelling can play in future agricultural research for food security and sustainability in a changing climate. An initial seminar will be conducted with the final project workshop and review meeting, and will equip trainees with the presentations and knowledge required to give similar seminars to senior managers in their home countries

The project has also resulted in significant learning by the team of trainers in how best to conduct future training for modellers in SAARC countries:

- Improved guidelines on how to select future trainees - future selection of candidate should favour younger scientists who either have strong, demonstrable institutional support for their time commitment to this initiative, or even more ideally have specific modelling tasks in their work-plans (for example, are officers in projects which have modelling deliverables).
- Improved plans for the educational process, with the future emphasis to go off individual workshops and to go more onto continual coursework and assessment, much like a unit of study at a university. Workshops would then play a supplementary role, rather than a central role, because the key to increasing skills and capability as a modeller is regular application, and regular solving of model-related problems which the trainee encounters.

Recommendation: retain the momentum and significant achievements of this project through a follow-on SAARC-Australia project. That project should aim to continue assembling the building blocks for a self-sustaining network of cropping systems modellers for the SAARC countries by building upon the successes and learning from the shortcomings of this first project. It is recommended that such a follow-on project should:-

- Include the most promising trainees from the first project as "Assistant Trainers" in the next phase project – recognising this as an intermediate step on their path to becoming "Master Trainers" for their home countries.
- Continue to build, structure, and publicise the SAC APSIM-World database.
- Continue to strengthen SAC's role as coordinator of the growing modeller network, by establishing communication processes (blogs, online user groups, email groups, conferences etc)

- Improve the selection process for the next cohort of SAARC country trainees – specifically to seek young early-career scientists with appropriate career plans, institutional support, and ideally committed involvement in other modelling initiatives or projects.
- Implement a course-work focus to the training, involving the university sector which must ultimately become the "spawning ground" for young modellers in the SAARC countries.
- Continue work to build awareness and demonstrate the value of modelling in agricultural research to institutional stakeholders through the use of relevant examples on important issues (eg climate change, increasing water-use efficiency, etc.).
- Link strongly with other international modelling initiatives and projects in South Asia, ideally by sharing trainees.

7.3 Responses to recommendations from the final project review

The final project review was conducted subsequent to the final project workshop (Yield Gap Analysis) at SAARC Agriculture Centre, Dhaka, 14 March 2013 by the ACIAR-appointed reviewers Dr Ian Willet (Australia) and Dr Himanshu Pathak (India). The executive summary of the final review report is included below, together with project team responses to the review recommendations:

This project aimed to build capacity in farming systems research by introducing APSIM to 19 scientists from South Asian Association for Regional Cooperation (SAARC) countries. It established an incipient network of agricultural research scientists in SAARC member states collaborating on rice-based cropping systems modelling. The project successfully applied APSIM-ORYZA simulations to identify practices that have potential to improve crop and water management in a range of rainfed and irrigated rice-based cropping systems, and strengthened institutional support of the SAARC Agricultural Centre (SAC) and in some SAARC member states for APSIM modelling, particularly in India and Bangladesh.

The training was relevant and rated very highly by the trainees and has attracted on-going support for SAC from SAARC. A questionnaire also revealed that the training was effective and 13 South Asian scientists are now capable of operating the model without direct external support. The training materials from the project are valuable and should be retained for future use, leading to our first recommendation:

Recommendation 1 (R1): In future the training materials for model operation and data collection should be consolidated into a compact manual suitable for South Asia. The materials should be made available on-line for on-going training activities for existing and new trainees.

Project team response to R1:

Agreed and already implemented. The training materials from the SAARC-Australia Project are now available on the website http://www.apsim.info, and are accessible to anyone. A range of independent researchers from the South Asian region who have approached the project team for APSIM training information since the project conclusion have been directed to this site and have reported successfully accessing the material, installing the software on their own machines, and exploring the tutorial exercises. The range of materials available will be enhanced as the project team embarks upon the extension phase of the SAARC-Australia project (to be funded by AusAID) in 2013-16.

The project has influenced research managers on the value of APSIM leading to increased support of scientists in some member states, but has not yet had any influence on policy makers, who were identified as potential users of the simulation results:

Recommendation 2 (R2): Stakeholders in influential positions for policy development in regional governments should be introduced to the value of crop model outputs, and be informed of the consequences of well-founded simulation results.

Project team response to R2:

Agreed. Continuing model awareness exercises are planned for the extension phase of the SAARC-Australia project, to be conducted in each of the SAARC countries by project trainees with support from the project team. "Model Awareness Seminars", similar to that conducted in Bangladesh (13 March 2013, Appendix 6) will introduce key decision-makers, science managers, and policy people to both the basic concepts of cropping systems modelling and relevant (more detailed) case-studies to illustrate the importance of cropping systems models as research tools in the toolkits of their national agricultural research scientists. As was the case throughout the SAARC-Australia project, special emphasis will be place on the importance of thorough calibration, parameterisation, and validation of models in the region and environments of interest, before they are employed in scenario analyses to help answer research questions.

APSIM has been applied as a research tool and has resulted in substantial capacity in South Asia for its application to rice rotations, including wheat. Its continuing use in the region is still dependent on external support, and this is likely to be supplied by CSIRO with funding from AusAID as part of a larger activity. SAC will contribute to continued use of APSIM by its support of an on-going staff member and the training facilities established by the project. The reviewers think that the future lies in linking the trained scientists into projects that will apply simulation models to projects aimed at finding solutions to agricultural and natural resource management problems:

Recommendation 3 (R3): Future work should be directed to applying existing modelling expertise in South Asia by linking it to research and development activities that have defined impact pathways, building on three decades of training involving crop modelling, rather than simply increasing the number of trainees.

Project team response to R3:

Agreed. One of the identified deficiencies of this project was that many of the trainees nominated by their home countries had interest in modelling but no immediate application in their existing work programs. We believe their training will still yield important flow-on benefits, as these trainees will seek to build modelling components into their future work plans and thereby establish impact pathways. Many of them have already done this or have started to do this (see section 5.2.3). However, in the plans for the SAARC-Australia extension project (AusAID), we will explicitly make membership of existing projects with modelling outputs as an essential criterion for participation of new trainees in this project extension – thereby ensuring immediate and effective impact pathways for our future training. Selected trainees from the initial project (particularly those who have taken the initiative to establish themselves into international modelling initiatives and/or projects) will also remain active participants in the second project, both as fledgling trainers helping the new cohort, but also in the continuation of support for their own research efforts from the project training team. In this way, we will ensure that the gains from the first project are built upon in the ways most likely to yield on-ground impact, whilst also realising the imperative of continuing to build towards critical mass for the APSIM modelling network in South Asia through new trainees.

The project already has some links to appropriate R&D projects and the reviewers have suggested some applications for each participating country.

Given the funding context of this project – the direct funding of CSIRO by AusAID of a new phase as part of a larger activity and the existing linkage to the ACIAR Climate Change project in Bangladesh in particular – we suggest that the recommendations in this review be considered by both AusAID and ACIAR when they plan new phases or projects.

Project team response

Agreed. The above recommendations and the lessons learnt in this project are being taken into account in the design of the planned follow-on project.

8 References

8.1 References cited in report

Adhikary P.P., Chakraborty, D., Kalra, N., Sachdev C., Patra, A.K., Kumar, S.S., Tomar, R.K., Chandna, P., Raghav D., Agrawal, K. and Sehgal, M.. 2008. Pedotransfer functions for predicting the hydraulic properties of Indian soils. *Austr. J. Soil Research*, 46: 476-484.

Carberry, P. 2005, in 'Adoption of ACIAR Project Outputs: Studies of Projects Completed in 2000-2001', p. 13. http://aciar.gov.au/files/node/686/ACRC138_layout_A4.pdf

Gaydon, D.S., Roth, C.H., Humphreys, E., Saiyed, I. (Editors), 2013 (in press), The SAARC-Australia Project: Developing capacity in cropping systems modelling for South Asia, SAARC Agriculture Centre Monograph, Dhaka, Bangladesh, November 2013

Gaydon, D.S., Probert, M.E., Buresh, R.J., Meinke, H., Suriadi, A., Dobermann, A., Bouman, B.A.M., Timsina, J., 2012a. Rice in cropping systems - Modelling transitions between flooded and non-flooded soil environments, *European Journal of Agronomy* 39, 9-24.

Gaydon, D.S., Probert, M.E., Buresh, R.J., Meinke, H., Timsina, J., 2012b. Capturing the role of algae in rice crop production and soil organic carbon maintenance, *European Journal of Agronomy* 39, 35-43.

Humphreys, E., Kukal, S.S., Christen, E.W., Hira, G.S., Balwinder-Singh, Sudhir-Yadav and Sharma, R.K. 2010. Halting the groundwater decline in northwest India – which crop technologies will be winners? *Advances in Agronomy,* 109: 155-217.

Keating, B.A., Carberry, P.S., Hammer, G.L., Probert, M.E., Robertson, M.J., Holzworth, D., Huth, N.I., Hargreaves, J.N.G., Meinke, H., Hochman, Z., McLean, G., Verburg, K., Snow, V., Dimes, J.P., Silburn, M., Wang, E., Brown, S., Bristow, K.L., Asseng, S., Chapman, S., McCown, R.L., Freebairn, D.M., Smith, C.J., 2003. An overview of APSIM, a model designed for farming systems simulation. Eur. J. Agron. 18, 267–288.

Saxton K.E., Rawls, W.J., Romberger, J.S. and Papendick, R.I. 1986. Estimating generalized soil-water characteristics from texture. *Soil Sci. Soc. Am. J.* 50: 1031-1036.

Saxton K.E. and Rawls, W.J. 2006. Soil water characteristic estimates by texture and organic matter for hydrologic solution. *Soil Sci. Soc. Am. J.* 70: 1569–1578.

Ten Berge, H.F.M. 1993: Building capacity for systems research at national agricultural research centres: SARP's experience. In: Penning de Vries, FWT, Teng, PS and Metselaar, K (eds.). Systems approaches for agricultural development. Kluwer, Dordrecht, pp. 515-538.

Willett, I., and Aggarwal, P.K., 2012. Mid-term Project Review Report - LWR/2010/033 - Developing capacity in cropping systems modelling to promote food security and the sustainable use of water resources in South Asia, ACIAR, June 2012.

Willett, I., and Pathak, H., 2013. Final Project Review Report - LWR/2010/033 - Developing capacity in cropping systems modelling to promote food security and the sustainable use of water resources in South Asia, ACIAR, March 2013.

9 Appendixes

9.1 Appendix 1: Instructions for accessing the SAC APSIM-World Database

There are two ways to access the database information:-

- Online http://www.apsim.info/THESTACK
- Via Google Earth

Specific instructions for both are below:

1. **Online access**
   - Click on the link which takes you to the APSIM-World homepage.
   - You can apply for your own username and password as directed
   - Once these are obtained, enter them into the required fields on the homepage and enter APSIM-World
   - Click "Manage files you have uploaded to Apsim World."
   - Enter the folder "SAC Simulation" and you will be able to see folder for all of the SAARC-Australia Project trainee sites. By clicking again on any of these folders, you will be able to view the contents of the repository, however you will NOT be able to download the files from here. This is for viewing available files only. For downloading the desired APSIM files, including soils, climate and crop data, please access via the Google Earth interface (see below)

2. **Google Earth Interface**
   - On the initial occasion, you will need to download and install Google Earth. It is free and the installation is straightforward **http://www.google.com.au/earth/download/ge/**
   - On the initial occasion, you will then need to download the Google Earth interface for the APSIM-World database. It is called "APSIM.kmz" and is obtained by entering the APSIM-World online homepage (as described above) and clicking on "Download a Google Earth interface to Apsim World. This may take a few moments."
   - You will then get the option to save a file called "APSIM.kmz". Choose 'save' and save this file to a suitable location on your computer hard-drive to which you can easily navigate later.
   - You can now exit the APSIM-World online page.
   - Open Google Earth (via icon on your desktop).
   - Go to the top left hand corner of the page, choose "file", and select "open"
   - Navigate to the "APSIM.kmz" file which you previously saved to your hard-drive. Select "open".
   - Google Earth will now open using the APSIM.kmz file, which allows you to navigate to APSIM data stored in the database from all over the world.
   - For example, begin to zoom in on South-East Australia. (Double-clicking allows you to zoom in closer to a location; dragging the cursor over the map allows you to move around). You will see a range of small shovel icons which indicate an APSIM soil file for that location.
   - By right-clicking on one of these, you have the option to download that soil information to your computer.

- If you now browse to the SAARC countries, you will see a range of icons representing the type of APSIM data available for download.
- For example, browse to Gazipur, Bangladesh – just to the north of Dhaka.
- You will see a different icon, like an “A” with a wheat stalk – this indicates complete data available for running an APSIM simulation (eg, soil, climate, crop and APSIM simulation file)
- If you left-click on this icon, it spiders out to show 4 simulations and a climate file. Any of these can be downloaded by left-clicking on them and choosing to “download all files in this folder“
- As the SAARC-Australia project team continue to refine this database, validated simulations from across the SAARC countries will be easily accessible to anyone in this way.
- When you exit Google Earth, it will remember the APSIM.kmz file as one of your “Places” so you will not need to re-open it.
- The next time you open Google Earth, you can go directly to the APSIM-World database interface by double left-clicking on the APSIM.kmz file in your “places” listing on the left-hand side screen menu.