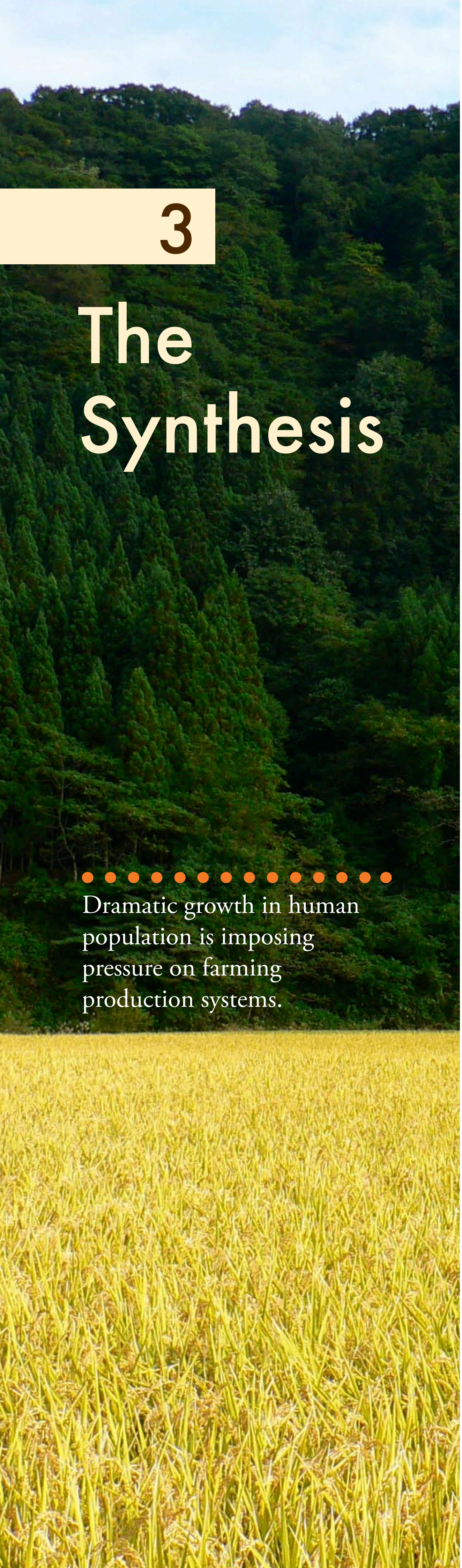

3 The Synthesis

Dramatic growth in human population is imposing pressure on farming production systems.

3.1. Food, Agriculture and Climate

3.1.1. Seasonal to inter-annual climate variability

3.1.1.1 Issues and significance

Farmers and farming communities throughout the world have survived and developed in most cases by mastering the ability to adapt to widely varying weather and climatic conditions. However, the dramatic growth in human population is imposing enormous pressure on existing farming production systems. In addition, farmers are expected to manage the ever more difficult effects of long-term climate change that may now be occurring at an unprecedented rate. Increased productivity can be associated with increased economic and environmental risk as farming systems become more vulnerable to weather and climate. More targeted climate information can increase preparedness and lead to better economic, social and environmental outcomes for farmers.

3.1.1.2 Scope of the activities

Important issues for APN support were activities that used climate information to improve food production. In this regard, the first stage of the present synthesis of activities under Food, Agriculture and Climate was to perform a "stock take" of the tools involved, including implementing crop/climate models to enhance the operational use of seasonal climate prediction in target APN countries. Issues also included the effective communication of these climate prediction tools for farmers and farming communities by climate and agricultural experts.

APN supported activities that established a network of teams with the capacity to apply agricultural systems analysis to evaluate options for managing climatic risk. Projects building from this documented the benefits delivered from mainstreaming climate information to agricultural decision-making, with the building of a large-scale system of support for the operational use of seasonal climate information for target countries India, Pakistan and Indonesia. Project CSP17 produced twelve (12) peer reviewed publications (***Appendix 3***), the most notable one entitled, "**Actionable climate knowledge – from analysis to synthesis**." This also included the development of environmentally friendly strategies for agricultural pest management, with papers published in the book "**Weather and climate risks in agriculture**" from CSP24. Further workshops used this research to promote the use of climate prediction tools for farmers and farming communities.

An international workshop on "Content, Communication and Use of Weather and Climate Products and Services for Sustainable Agriculture (CSP55)" was held, which evaluated climate products that can be used by farmers and farming communities. This workshop placed special emphasis on the communication of products to farmers and the development of new products to enhance interaction between climate services, farmers and farming communities. The workshop developed new methods, including interfacing climate tools via web-based technologies to farming communities, which were trialled in the Cook Islands at www.climatecookislands.com.

An APN workshop developed new methods to communicate climate information from climate and agricultural experts to farmers in the Pacific Islands.

3.1.1.3 Outcomes

Results

For agricultural management decisions, seasonal climate information and prediction offer a means for farmers to manage increasing climate variability. Currently, the skill of dynamical seasonal climate forecasting is improving. Reasonable seasonal predictions are now available from statistical and dynamic downscaling of GCMs over South Asia. Prediction skill is greatest when El Niño and La Niña events are occurring. Near-global analysis has demonstrated that the Madden-Julian Oscillation (MJO), a large-scale, tropical atmospheric anomaly that originates in the Indian Ocean and moves eastwards at intervals of 30–60 days, is a significant phenomenon that influences daily rainfall patterns even at higher latitudes. This also influences the onset and breakdown of the Asian-Australian monsoon system and is very useful in these longitudes. The ability to combine MJO forecasts improves tactical climate risk management. Work remains on improving dynamical forecasting of the Indian summer monsoon although good progress is being made.

APN built an international multi-disciplinary network of scientists providing "actionable climate knowledge" to farming groups in parts of South and Southeast Asia.

GCM outputs are too coarse in resolution for application to crop decision-making and therefore must be downscaled for use at the field decision-making level. Downscaling can be achieved by statistical or dynamical modelling. These techniques are being used in India, Pakistan and Indonesia to provide improved climate predictions and hence a better understanding of climate impacts.

Field experiments and data analyses have established important functional relationships for disease risk and climate for late "leaf spot" in peanut, "Sclerotinia rot" and "Alternaria blight" in canola and mustard. This has enabled the validation of the *Cropgro* and *Infocrop* climate and disease models for these crops in Bangladesh and Cambodia.

By using systems analysis and modelling, the best response to climate forecasts can be uncovered. This has been achieved for Tamil Nadu in India for groundnut, horsegram, sorghum and cotton; for pigeonpea and groundnut in the Pavagada region of India; drought costing in Bandung, Indonesia; on farm trials and wheat simulation in Pakistan; and whole farm optimization for Tamil Nadu. Examination of the value of climate forecasts in Tamil Nadu showed that the value of forecasts in smallholder systems depends on the prediction skill, Southern Oscillation Index phase, and types of decisions and their responsiveness to climate forecasts. Though the forecast skill for the summer monsoon is moderate, the value is greater for groundnut and cotton management. The winter monsoon rainfall forecasts are more skilful but have low value for sorghum management. The economic value of a forecast was found to be very sensitive to the response action; for example, modifying the groundnut planted could be ten times more valuable than modifying the amount of fertilizer applied to groundnuts.

From these approaches, it is necessary to establish a network of research teams for capacity building in the application of agricultural systems analysis to evaluate options for managing climate risk. This has been established for Pakistan, India and Indonesia. Crop simulation modelling has been found to be essential as the bond that connects several disciplines providing a focus on outcomes and products useful to farmers and farming communities.

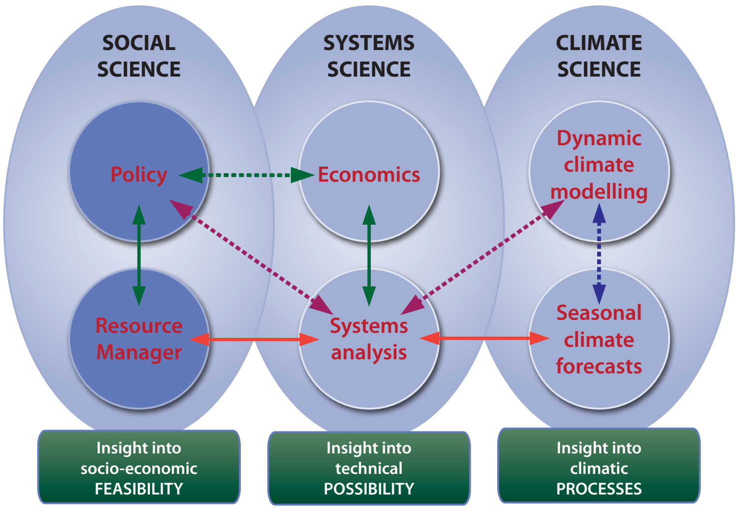

Figure 12: Disciplines, relationships and linkages for effective delivery of climate information for decision-making. Operational links are indicated by the solid arrows; dashed arrows indicate where an operational connection is still weak or does not exist [Source: Meinke]

By these and other means, a multi-national network of scientists working in different disciplines, has been established for the creation of useful climate knowledge by building partnerships with farmers and farming communities. This process is depicted in ***Figure 12***.

Considerable advances have been made in the past decade in the development of the collective understanding of climate variability and its prediction in relation to the agricultural sector and scientific capacity in this field. More sophisticated and effective climate prediction procedures are now emerging rapidly and finding increasingly greater use. By using crop simulation models in a decision systems framework, alternative decisions are being generated, but there is a clear need to further refine and promote the adoption of current climate prediction tools. Equally, it is important to identify impediments to the further use and adoption of current prediction products.

A comprehensive profiling of the user community in collaboration with social scientists and regular dialogue with users will assist in identifying opportunities for agricultural applications. Active collaboration between climate forecasters, agrometeorologists, agricultural research, and extension agencies in developing appropriate products for farming communities is essential.

Communication of climate information is an essential part of the process. Despite advances made in improving climate forecasts, the application of these products at the farm level has not been "up to the mark" because of the lack of effective contact between climate information and farming communities.

Capacity Building

The activities funded by the APN have created an international, multi-disciplinary network of scientists who support the mainstreaming of climate information to farmers in India, Pakistan and Indonesia. The work has improved the understanding of climate variability impacts and related vulnerabilities on farming communities. It has also provided a consortium of partners for extension and further pilot studies. Crop/climate and crop/disease models have been developed and enhanced.

Assessments have been made and published on the applications of seasonal to inter-annual climate variability to agricultural production. Capacity building has also occurred among scientists from developing and developed countries. Improvement in communication between climate and agricultural experts and a farming community occurred on a small island state.

3.1.1.4 Conclusions

The first decade of 2000 has shown great improvement in the skill and resolution of seasonal to inter-annual climate forecasts. In addition, there has been improvement in communicating climate information to farmers and farming communities. Farmers collectively have some knowledge of climate, water and crop management. Assistance for farming communities, business and policy-makers to better cope with climate-related risks is improved by synthesizing information across disciplines to include end-users in the process. This includes control of climate-sensitive crop diseases. Climate information is valuable to farmers because agriculture is very climate sensitive. However, there needs to be greater interaction between the farming community and the national meteorological services in the communication of this information.

Changes in the frequency of climate extremes because of climate change will significantly impact agricultural production in those communities with the least resources and infrastructure to cope.

3.1.1.5 Recommendations

- Seasonal to inter-annual forecasts are critical to agricultural risk management. Further work is needed to improve the skill of forecasts and associated downscaling, so that better risk management decision-making can occur at the whole farm level.
- Identification of critical areas where agricultural production is sensitive and vulnerable to climate requires close monitoring of climate.
- Targeted climate synthesis and integration into applied risk management are required at the farm level. This requires new institutional arrangements and multidisciplinary partnerships especially between National Meteorological and Hydrological Services (NMHSs), ministries of agriculture and the whole farm level.
- The increasing frequency and severity of floods, droughts and extreme temperatures requires use of appropriate indices to improve monitoring and prediction of these extreme events.
- Formation of farmer groups and associations are needed to improve the dissemination of collective knowledge of farming communities on climate and crop management.
- Mainstreaming climate information to farmers is required from experts in meteorological services and agricultural ministries through improved communication via various media. This requires close collaboration with media organizations.

3.1.2. Long-term change

3.1.2.1 Issues and significance

Climate scenarios during the 21st century for the Asia-Pacific region indicate a drying of the subtropics, a more vigorous monsoon season, but with increases in extreme events such as high intensity rainfall, drought and heatwaves. During the past four decades, climate extremes such as droughts, floods, storms, tropical cyclones, heatwaves and wildland fires and windstorms have caused major losses in the agricultural sector. Communities that are most exposed to these risks are those with limited access to technological resources and with limited development of infrastructure. One of the most important strategies is the improved use of climate knowledge and climate risk technologies. Both structural and non-structural measures can be used to reduce the impacts of the variability (including extremes) of climate resources on crop production. Planning, early warning and well-prepared response strategies are the major tools for mitigating losses due to climate change. Hence, climate variability and climate change are considered in evaluating all environmental risk factors and coping decisions.

Currently, many opportunities exist that can assist in coping effectively with agrometeorological risks and uncertainties to long-term change. One of the most important strategies is the improved use of climate knowledge and technology, which includes the development of monitoring and response mechanisms to current climate. By providing new, quantitative information about the environment within which farmers operate or about the likely outcome of alternative or relief management options, uncertainties in crop productivity can be reduced. Quantification is essential and computer simulations can assist such information and may be particularly useful to quantitatively compare alternative management and relief options in areas where seasonal climatic variability is high and/or prone to extremes. One of the most important strategies to cope with risks for long-term change for agriculture and fisheries includes the development of climate knowledge and technology for future climate change.

3.1.2.2 Scope of the activities

For fisheries, APN held two workshops: one to examine the consequences of climate-induced changes on pelagic fisheries in East Asia and the other to model the annual to inter-decadal variability of sardine and anchovy populations.

APN produced the first major assessment of climate change and its impacts on water resources and agricultural production for South Asia.

For rice and wheat production in South Asia, field visits by researchers to villages in the Indo-Gangetic Plain (IGP) have improved their understanding of climate change and water issues. APN also held a workshop of experts on rice pests, which established a regional network of scientists throughout South Asia for projecting pest damage impacts of climate change.

APN supported two major activities on climate change and its effects on water resources and food production in South Asia. CSP36 organized four regional capacity-building workshops for the training and application of RCMs with crop simulation models then two workshops to consider the model output for climate change. This was followed by research on the assessment of various climate trends in Bangladesh, Nepal and Pakistan over the past five decades; projections of climate in these areas to 2100 at high resolution; assessment of 21st century climate trends on yields of wheat, rice and maize in the three countries; as well as evaluating the impacts of climate change on annual and seasonal flows of three main rivers. The monograph "**Climate change: global and OIC perspective**" and many other publications were produced from this project (***Appendix 3***).

The work was preceded with the assessment of adaptation and coping mechanisms to cope with negative impacts of climate change on agriculture and water resources (CSP56). The regional activities, which included India, prepared regional maps of climate change risk to water and agricultural resources. These results were presented to end-users so that vulnerabilities and coping mechanisms could be assessed. A major publication "**Climate and water resources in South Asia**" was prepared from these activities.

APN supported international workshops to reduce vulnerability and devise coping strategies for agricultural impacts due to climate variability and change.

Two international workshops were held on reducing the vulnerability of agriculture and forestry to climate variability and change, and devising coping strategies. These reviewed the latest assessments of climate variability and change and likely impacts, and considered a range of adaptation options. The second workshop built on the first by considering coping strategies of which crop risk insurance was one main option. These workshops provided capacity building for scientists from developing countries with scientists from developed countries. From CSP13 the book "**Increasing climate variability and change: Reducing the vulnerability of agriculture and forestry**" was published.

One method of promoting climate change adaptation is to mainstream it in national sustainable development policies and programmes. This is founded on the notion that climate adaptation and sustainable development share common goals and determinants. APN supported a study in the Philippines, Indonesia and Viet Nam to assess how climate adaptation can be integrated into national plans and programmes especially in agriculture and water resource management.

3.1.2.3 Outcomes

Fisheries

Small pelagic fisheries such as sardine, anchovy, herring and mackerel constitute a large portion of the fisheries catch off the coasts of East Asia. Zooplankton biomass for the period 1965–1998 increased after the late 1980s corresponding to a warm regime of ocean climate. During the 1990s fish catches in the Chinese pelagic fisheries increased reaching the highest production in 1998, while many stocks showed low recruitment off Southwest Japan. The proportion of small pelagic fish increased off southern Korea during the 1980s. The multidecadal changes in stocks such as anchovy and mackerel in the Pacific showed a 55–65 year variability relating to climate indices such as the Pacific Decadal Oscillation (PDO). Further work on anchovy and sardine catch off California, Japan, Chile-Peru and in the Benguela region shows multidecadal variations with large changes in the mid-1940s and the mid-1970s when PDO phase changes occurred.

Agriculture and water resources

Rice and wheat production in the IGP is very important for food security in South Asia. Crop models, which are geo-referenced, are required to investigate management strategies to cope with climate change. An assessment of water resources and climate change in South Asia showed that air temperatures increased in all countries in the latter half of the 20th century. Pre-monsoon rainfall increased in northern Bangladesh, with increases also apparent in the southwest, and decreases in the southeast. No trends were observed in Nepal, but in Pakistan, rainfall was more extreme for both wet and dry anomalies. There were no changes in the All-India rainfall statistics. The Indus River simulations showed declining flows (***Figure 13***) but for the Ganges and Brahmaputra no trends were detected in runoff. The eastern parts of South Asia, especially Bangladesh, Nepal and parts of India are flood-prone.

Recent analysis suggests that the frequency of devastating floods in Bangladesh is on the increase, with four of the most severe occurring in the past 30 years. In northeast India, where the Brahmaputra drains, there has been significant erosion with problems owing to overbank spillage, drainage congestion, bank erosion and landslides. In the western region of India and adjacent Pakistan, rainfall is very erratic leading to extremely arid conditions interspersed with >90% of the annual mean rainfall in a single month causing devastating short-duration floods. For the Indus river system because of extensive deforestation in the Himalayas, this has led to major floods in Pakistan with seven of the ten worst floods in the last 100 years occurring in the last 25 years. These floods were caused by unprecedented melting of snow on glaciers due to an increase in temperatures. Five glacial lake outburst floods (GLOFs) occurred in Nepal over the period 1977–1998. Devastating droughts are common in Pakistan and northwestern India. The most severe drought occurred in Pakistan from 1998–2002, where surface water availability was reduced by 30%. In India, about one third of the country is drought prone. There are approximately 20 droughts per century.

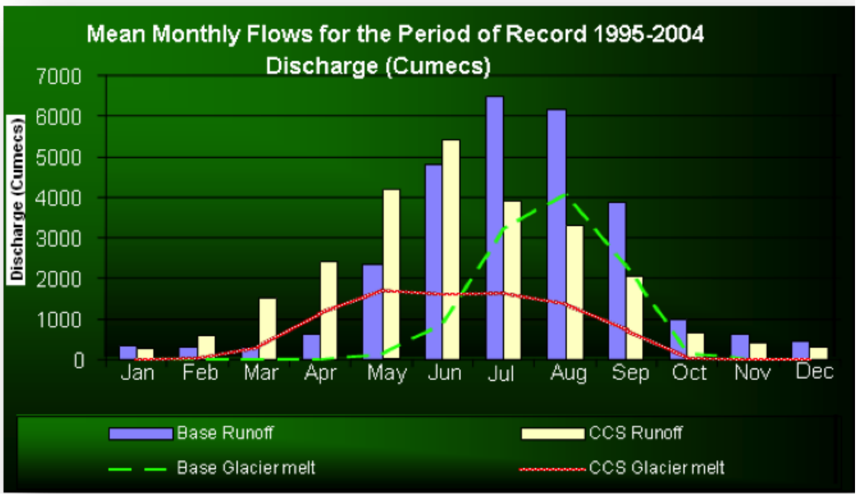

Figure 13: Simulated mean monthly flows of the Indus River under the baseline (1995-2004) conditions and under the influence of a hypothetical climate change scenario (CCS) [Source: Khan]

The impacts of floods and droughts are dramatic on agriculture in South Asia. Floods in South Asia have resulted in crop losses with the 1974 Bangladesh flood severely damaging the Aman crop, and the 1993 Nepal flood reducing agricultural production by 12%. The 2000–2001 drought in the Sindh and Balochistam provinces of Pakistan reduced overall agricultural production by 3%. Nine droughts in the pre-monsoon season in Bangladesh have occurred since 1951 affecting about half the country.

For water resources, the melting of mountain glaciers in the Himalayas is having several effects. More water will be supplied to glacier dependent perennial rivers. But this is likely to increase the chances of GLOFs; Nepal has 2315 glacial lakes and 26 are considered dangerous. On longer timescales, dry season flow in the upstream reaches will be greatly reduced. North Pakistan agriculture is becoming increasingly dependent on ground water irrigation. Prolonged drought and high temperatures between 1990 and 2000 significantly reduced recharge to the aquifer.

GCM-based coarse resolution climate scenarios show that increases in temperature on an annual as well as seasonal basis are comparable for Nepal and Pakistan, but lower for Bangladesh, and higher in winter than in summer (***Table 2***). There are clear indications of precipitation increases in summer, but decreases in winter. The impacts of these on agriculture and water resources have been investigated using crop/climate and watershed models. CERES-Wheat model simulations for Pakistan show that the growing season length decreases throughout the country with increases in mean temperature.

Precipitation Change (%), A2 Scenario			
	Pakistan	Nepal	Bangladesh
2020s			
Annual	2.79 ± 2.94	-3.60 ± 3.08	-1.02 ± 1.09
Summer	5.31 ± 4.13	-0.76 ± 4.07	-0.31 ± 1.15
Winter	-16.2 ± 2.84	-11.74 ± 2.69	-11.32 ± 4.17
2050s			
Annual	5.53 ± 4.63	1.81 ± 4.76	2.72 ± 1.79
Summer	12.55 ± 7.13	5.88 ± 6.67	3.09 ± 1.63
Winter	-1.62 ± 3.56	-10.93 ± 3.63	-9.58 ± 8.05
2080s			
Annual	3.48 ± 5.78	6.22 ± 6.56	8.39 ± 2.15
Summer	12.16 ± 8.91	14.98 ± 9.74	10.02 ± 1.48
Winter	-5.12 ± 4.78	-17.58 ± 2.53	-11.55 ± 6.46

Table 2: Projected changes in annual and seasonal prediction (%) in 2020s, 2050s and 2080s over Pakistan, Nepal and Bangladesh for A2 Scenario, based on 13-GCM Ensemble [Source: Khan]

Yield increases in Pakistan until about 4°C above the baseline then decreases. This reveals that yields will decrease in the order of 5% for IPCC-SRES A2 and B2 scenarios by the 2080s. Similar results for Pakistan occur using the CERES-Rice model, which reveals rice crop yields will decrease by 15 to 18% by the 2080s.

For Nepal, model-based studies show that a 4°C increase in mean temperature has positive impacts on all crops, except maize, where a 2°C increase results in decreases in yield in the mountain zone. Unfortunately, the impacts on water resources of climate model output could not be assessed because the watershed models could not be satisfactorily validated or had very demanding data input requirements, which were not available.

Perceptions of risk were carried out in Pakistan, India and Nepal. In Pakistan respondents observed that the intensity of drought had increased compared with the past, and in India the drier areas anticipate drought where recovery usually takes 2 to 3 years. Drought causes hardship leading to migration. For Nepal, rainfall extremes were perceived as the main cause of floods. The 1993 event was the largest since 1954. The rise in river flows in Bangladesh was perceived as the major cause of floods, with the intensity and duration on the rise. Current coping strategies for drought in India and Pakistan include borrowing money, migration for alternative livelihoods and destocking. Flood coping strategies include migration, stock protection and crop insurance.

Reducing vulnerability

Changes in temperature have reduced the number of frost days and increased the length of the growing season. Land cover changes and other changes have led to changes in rainfall patterns and extremes. However, it should also be mentioned that the role of land-use change in modifying rainfall is often over-stated. These all increase the risk to long-term change. As well as seasonal to inter-annual forecasting, the development of multi-year climate forecasting will be an important tool. Old (radio) and new (internet and SMS) communication strategies when adapted to local applications assist the dissemination of useful information to farming communities. However, developed countries have the technology to adapt more readily. In many developing countries, agriculture is marginal and the ability to adapt in the tropics and subtropics and countries in transition will be difficult. Traditional knowledge, indigenous technologies and local innovations can also be used to improve farming systems.

Coping strategies include the use of seasonal climate forecasts to assist in alleviation of food shortages and to cope with drought and desertification; and the use of integrated agricultural management systems incorporating climate-forecasting systems together with crop simulation models. Improvements can be made in water-use efficiencies through surface irrigation, reduction in excessive groundwater utilization and increased efficiency in the rainfed areas, and crop diversification. Local indigenous knowledge provides coping mechanisms for change, as well as improved cultural and farming practices and crop diversification. Crop insurance spreads the risk for adverse periods of climate.

3.1.2.4 Linking climate change adaptation to sustainable development

APN-supported research has shown that current national plans and programmes do not adequately reflect a concern for climate adaptation. There is, however, strong perception that climate adaptation should be mainstreamed into national plans and programmes including agriculture and water resources. Options for doing this have been demonstrated in the Philippines, Indonesia and Viet Nam. For example, the critical role of Local Government Units (LGUs) in promoting climate change adaptation at the ground level in the Philippines has been shown. Neglecting climate risks could also imperil attainment of the Millennium Development targets on eradicating poverty as has been shown on the potential impacts of climate change on rice production in Indonesia and in agriculture in the Mekong delta in Viet Nam. Clearly, more intense efforts to link climate adaptation to development planning are needed.

APN supported a regional study on how climate change adaptation can be linked to sustainable development in Southeast Asia.

3.1.2.5 Conclusions

Small pelagic fishery stocks of anchovy and sardines in East Asia are related to multidecadal changes in ocean climate. These data sets have been used to model climate change effects on marine ecosystems to quantify the effects on fish growth and production of anchovy and sardines.

For wheat and rice crops in South Asia field research and crop simulation modelling improvements are needed for climate change research. Much better data are required to model rice pests. Simulation models of climate change have been used to assess impacts on agricultural production and water resources in Pakistan, Nepal and Bangladesh. Ultimately, with increased warming crop production decreases. However, because watershed modelling is complex, it has not been possible to simulate river flows in different watersheds.

Analyses reveal that the climate of three Indian subcontinents has been changing with increases in temperature and increasing rainfall variability in the eastern Himalayan region, and decreasing rainfall in the western Himalayas (Pakistan and Northwest India). As much of the food production is subsistence, these regions are more susceptible to climate extremes with change. Floods and droughts are common. Drought management through irrigation is only possible if enough water is available, particularly during the dry season. Dealing with floods is more complex as the existing levee banks on roads do not have adequate drainage infrastructure, with the channels of the major rivers, and their tributaries, heavily silted up. The intensity and duration of floods and droughts is on the increase recently and efforts need to be made for adaptation strategies and coping mechanisms.

APN work has developed approaches to characterize and manage risk, which includes risk scoping, risk characterization and evaluation, risk management and monitoring and review. This leads to preparedness planning with risk assessments, utilizing early warning systems so that vulnerability to society can greatly lessen climate risks to society and communities. With effective risk management, management and policy changes between climate hazard events are used so that the risk associated with the next event is reduced. This is through the implementation of well-formulated policies, plans and mitigation actions that are being utilized by farmers and others.

Farmers have a combination of strategies and tools for managing the risks they face. Approaches include taking action to reduce the likelihood of the risk event occurring, avoiding the risk, redistributing the risk and reducing the consequences. Actions can consist of enterprise diversification, contract hedging, having financial liquidity, use of crop yield insurance, crop revenue insurance and household off-farm employment or investment. Latterly weather derivatives and weather index insurance play a role in developing agricultural risk management strategies. However, there are requirements for the management of these risks by farmers and communities.

There has to be awareness that weather and climate extremes, their variability and climate change will impact farm operations. This requires an understanding of climate processes, including the causes of climate variability and change, which can operate over large spatial scales. Part of this requires a good knowledge of climate variability and extremes in the location of farm operations, and analytical tools to describe these. Forecasting tools and early access to early warning and forecast conditions on the multiseasonal timescale gives advance advice on the likelihood of extreme events and climate anomalies. However, the farmer must have the ability to apply these forecasts and warnings in the decision-making process. There is a range of risk coping strategies that can be utilized.

3.1.2.6 Recommendations

» Much work is required to link field data with climate conditions in South Asia so that crop simulation and disease simulation models can be refined and validated.
» Recent improvements in crop model simulations should be extended to all important crops in South Asia so as to better define the impacts of climate change.
» Watershed and water management models need to be used in conjunction with crop simulation models so use of available water under changing climate can be optimized for food production.
» The use of advanced remote sensing and GIS techniques should be further encouraged so as to provide ongoing monitoring of snow and water cover and temporal changes in the major glaciers of the Hindukush-Karakoram-Himalaya region, which feeds South Asia's major rivers, together with an emphasis on the forecasting of extreme events, especially floods and droughts, and the dynamics of the Himalayan glaciers, which play a crucial role in determining agricultural water resources for South Asia.
» Coping strategies to combat climate change involve the development of a proactive risk-based management approach to deal with adverse consequences of extremes and climate anomalies including risk scoping, risk characterization, risk management, and monitoring and review.
» Use of decision-support systems as risk management tools should be promoted as an effective means of providing outputs of integrated climate-agronomic information.

- Climatic risk zoning should be utilized to quantify climate-plant relationships and the risk of meteorological extremes for planning of changes in agricultural enterprises.
- Increased attention in many developing countries is needed to facilitate access by the rural poor to technical expertise and technological innovations.
- Because of climate change, an urgent review of drought contingency planning, drought preparedness and drought impact assistance policies is needed, and measures to reduce desertification must be vigorously pursued.
- Ways to accelerate mainstreaming or integration of climate adaptation into national development planning processes should be explored.

3.2. Seasonal Climate Prediction and Applications

3.2.1. Issues and significance

Developing predictive capacity to manage climate variability and climate change-related vulnerability, strengthen overall climate responses and build resilience to socio-economic and environmental shocks is one of our urgent development needs.

It is becoming increasingly clear that climate variability and climate extremes associated with El Niño and La Niña (El Niño–Southern Oscillation [ENSO]) cycles and Sea Surface Temperature Anomalies (SSTA) in the Pacific Ocean are adversely affecting the environmental and socio-economic aspects of Asia and Pacific Island Countries. For example, recent statistics show that due to the effect of the 1997/98 El Niño event, global and regional climate changed (relative to the observed long-term trends) and the associated large-scale natural disasters led to approximately 5 million people being made homeless resulting in a direct economic loss of approximately US$33.9 billion. However, while changes in ENSO activity are probably likely in the future, it is still unclear how the frequency and intensity of El Niño events will change as a result of global warming (IPCC 2007).

The monsoon system that dominates the climate of the Asia-Pacific region has been found to impact about 60% of the global human population by influencing lives and livelihoods, ecosystem goods and services, water resources, agricultural productivity and socio-economic activity. According to the IPCCAR4, as global warming accelerates, the magnitude and intensity of these impacts are most likely to increase. GCMs are used not only to simulate the overall behaviour of the climate system but also to produce projections of future climate variability and change. While these models are able to quite successfully reproduce large-scale climate processes, they have to be "downscaled" to produce results that are relevant at the regional level.

Skill development to downscale GCM outputs to produce locally relevant information and their application to climate proofing humans and ecosystems is a major priority for APN.

Although the Asia-Pacific region's vulnerability to climate variability and climate change is very high, the region's capacity to address sectoral impacts is relatively underdeveloped. *This situation calls for urgent intervention to enhance the skills of regional scientists, forecasters, disaster management officials, and resource managers* in the development and use of climate information relevant for improving human and ecosystem resilience.

3.2.2. Scope of the activities

Given the huge capacity constraints in the Asia-Pacific region to understand, anticipate and respond to climate and extreme events, APN has funded eight (8) research and capacity building projects in the region, four of which addressed computer model-based climate prediction, while the rest were intensive training for long-term capacity building at an advanced level. "Train the trainers" approaches were also designed to multiply training opportunities at the national and local levels of participants.

One of the projects resulted in a network involving nine countries sharing climate data from the Tropical Ocean Global Atmosphere-Tropical Atmosphere Ocean (TOGA-TAO) and South China Sea Monsoon Experiment (SCSMEX) buoys, and oceanic and satellite observations. Another focused on training participants from NMHSs to develop capacity using lectures and computer laboratory sessions at the Asia-Pacific Economic Cooperation (APEC) Climate Centre (APCC), using their Multi-Model Ensemble (MME). Seasonal climate forecasts were determined using meteorological data from fifteen prominent climate-forecasting centres (***Figure 14***).

These projects focused on vulnerable countries in the Pacific Islands, Southeast Asia and low-lying delta communities. A special feature of all training sessions was the emphasis placed on the science of climate

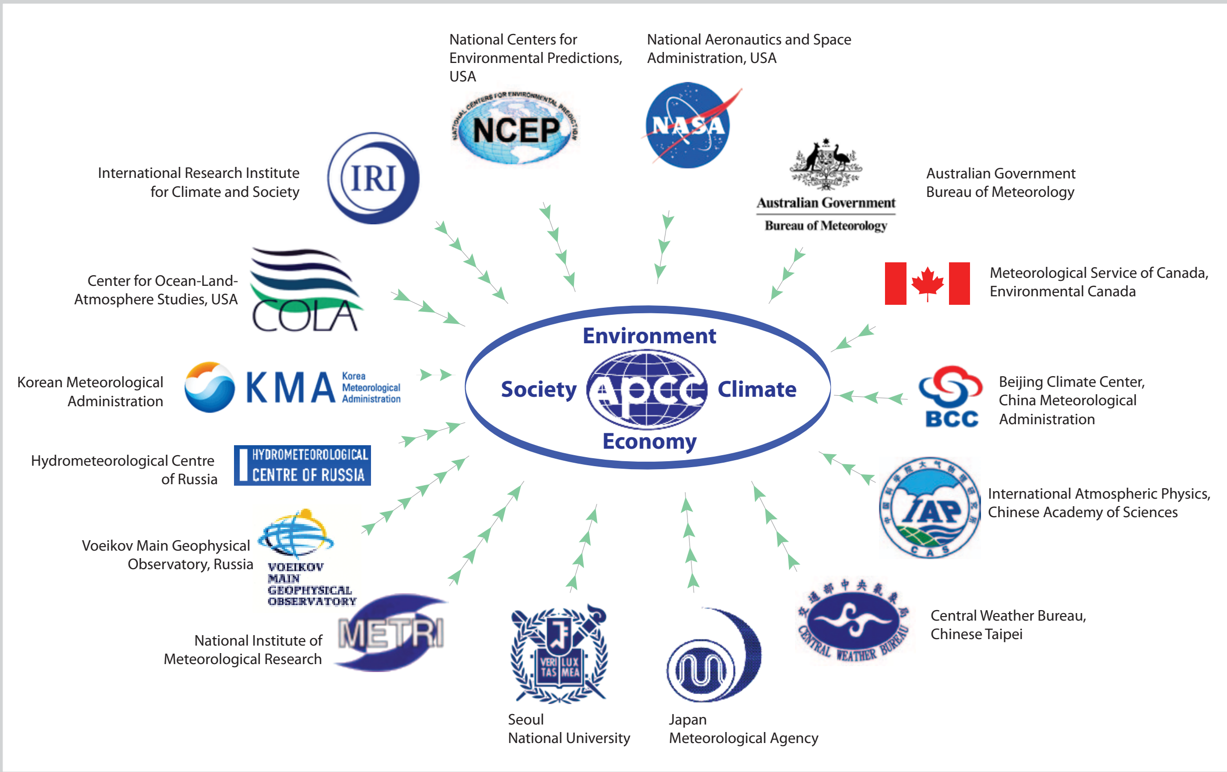

Figure 14: Multi-Institutional cooperation [Source: Ashok]

change and climate system functioning and the role of policy and governments in the implementation of mitigation and adaptation measures.

3.2.3. Outputs and outcomes

The projects considered under this section have all helped to bridge two major gap areas, namely: (i) the lack of reliable local climate predictions at seasonal to annual scales; and (ii) the lack of capacity to apply prediction tools to generate region and sector-specific climate information and products relevant for implementing adaptation and mitigation measures. Such model-based outputs are critical for national climate negotiators to be effective at international fora as they develop multilateral climate agreements. At the national level, such capacity building has resulted in the development of climate frameworks and large-scale climate adaptation projects through bilateral (AusAID project in Fiji) and multilateral (GEF and EU projects in the Asia-Pacific region) assistance.

The climate prediction project teams established networks with access to climate data archived in research centres of Hawaii, Japan and the Republic of Korea and mentoring support from senior scientists from these laboratories and user-friendly climate modelling software such as SimCLIM from the International Global Change Institute (IGCI) for Pacific Island users and CLIK software from APCC for Asian users. The Pacific Island Training Institute in particular (*Figure 15*) helped train media groups to produce accurate climate information and awareness materials, especially during cyclones, floods and drought-related disasters.

APN projects have contributed substantially to building regional capacity for mainstreaming climate change into national sustainable development strategies and action plans.

Figure 15: APN-CAPaBLE Training Institute on Climate and Extremes. Institute participants discussing climate change adaptation. Kiribati, July 2006. [Source: Koshy]

All of the projects produced peer reviewed publications, technical documents, awareness materials in both English and local languages, seminar presentations, new follow-up projects and web-based resource materials. Also, in a number of the capacity building activities, some of the networks created have been sustained. One example is the Alumni of Young scientists who attended the Advanced Institute on the Asian Monsoon (CSP41) through START's Alumni Network.

3.2.4. Conclusions and recommendations

Conclusions

» Regional networks are an effective means to address the shortage of climate monitoring and prediction needs.
» Without long-term commitment on the part of network partners and donor agencies, effectiveness will be short lived.
» Without structured follow-up, it will be hard to determine how developed capacity is being used at individual and institutional levels.
» As an effective sustainability approach for the Pacific Island Climate and Extreme Events Training (CSP26), a formal course was introduced at the University of the South Pacific in 2007, which attracts about 25 participants each year. This course is available through distance and flexible mode with "mature entry" provisions.
» "Train the trainers" exercises should include training for the development of new proposals. This skill is critical to sustain skills developed.

Recommendations

» Climate variability predictions are needed for different temporal scales – months to seasons and inter-annual.
» There is a need for a series of advanced training courses on climate prediction, monitoring and capacity building.
» Training workshops on downscaling need to be replicated in the region.
» Community-based climate adaptation, as well as reducing vulnerability and building resilience, requires *much more attention* as this is where most adaptation activities in *developing countries* will take place in the future.
» Climate change and disaster risk management must be mainstreamed into national development strategies and brought under appropriate ministries for budgetary support and to secure substantial international support.

3.3. Climate Variability, Trends and Extremes

3.3.1. Issues and significance

It is clear that the frequency and intensity of extremes in weather and climate have profound impacts on societies and the natural environment. For example, about 20% of the land area in Pakistan was flooded in 2010, resulting in the death of approximately 2000 people and the displacement of 20 million people. Despite universal recognition of the importance of understanding the nature of climate variability and extremes, in 1996 the IPCC recorded in its Second Assessment Report (SAR) that the data on climate extremes and variability at that time were inadequate to support any statement on global changes in climate extremes. Consequently work commenced in the mid-1990s to coordinate the analysis of climate data to detect trends in extreme events in temperature and rainfall in many developed countries. To complement this work, there was a need for capacity building in developing countries to enhance their capability and interest in managing and analyzing their climate records for trends and variability in extremes. This need was recognized by the APN in 1997 and a substantial investment was made in supporting relevant activities in the following years.

Extreme climate events have profound impacts on societies and the natural environment.

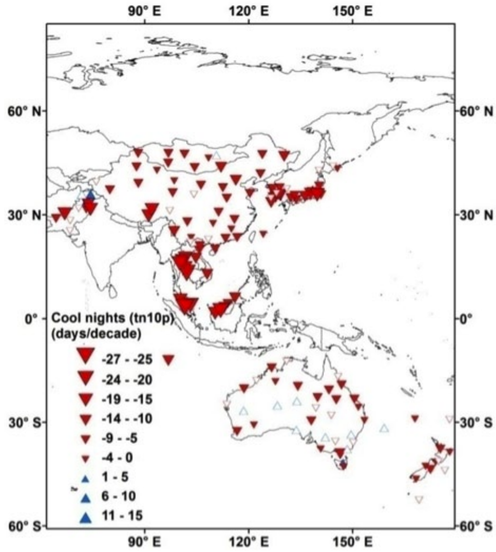

Figure 16: Trends (days/decade) in the frequency of cool nights over the period 1955-2007 across ten APN countries; colour-filled symbols indicate trend is significant at 95% level; the frequency of cool nights is decreasing across the region [Source: Kwon]

The regional need for capacity building has posed particular challenges in the Pacific where climate variability is largely owing to the influence of ENSO and where such influences have specific impacts on the many Small Island States. South Asia also has specific challenges associated with data access and capabilities in detailed climate analysis in some countries. Moreover, strategies for capacity building in the Asia-Pacific region need to be sensitive to differences in culture and institutional responsibilities. The APN-supported projects aimed at accounting for these regional issues.

The reconstruction and analysis of paleoclimate data are important contributions to the overall climate record because those data provide the context for the more recent instrumental climate record. Paleoclimate data also allow us to understand past climate regimes and to test models, used for projections of future climate, in quite different past regimes. The APN supported activities to raise the awareness of paleoclimate data across the Asia-Pacific region.

The Global Earth Observation System of Systems (GEOSS) was established in 2005 to provide a framework for earth observations to support societal needs for the whole world. The APN recognized the need to promote regional activities that followed on from the global planning.

3.3.2. Scope of the activities

In order to enhance the capabilities to quality control and analyze the climate record for trends in extreme events in Southeast Asia and the Pacific, the APN supported a series of workshops involving experts from more than a dozen countries. The first five workshops were held in Australia and the sixth was held in the Republic of Korea. The first workshop in 1998 identified issues of data quality and accessibility, and agreement was reached on appropriate indicators of potential trends in climate based on daily temperature and precipitation data. Further workshops brought together experts from each country to analyze their national data in order to identify trends both nationally and regionally, to investigate links between the trends and the large-scale factors that influence climate across the region, and to address issues of data quality and accessibility. The work was linked to the international activities of the WCRP on global change detection.

Initially the analyses used climate data since 1970, but by the sixth workshop, it was found that the time period could be extended back to the mid-1950s in most countries. The early workshops also analyzed data from only about six high-quality sites from each country, but the number of sites was extended for the sixth workshop as countries made progress in data digitization and rehabilitation. A key result of the analyses is that the trends found at the early workshops have persisted as the period under consideration has been extended. There are trends in temperature extremes, such as increases in the number of hot days and decreases in the number of cold nights each year, across the whole region (***Figure 17***). On the other hand, trends in precipitation extremes are more localized.

APN workshops produced the first regionally consistent analyses of trends in temperature and precipitation extremes across Southeast Asia and the Pacific.

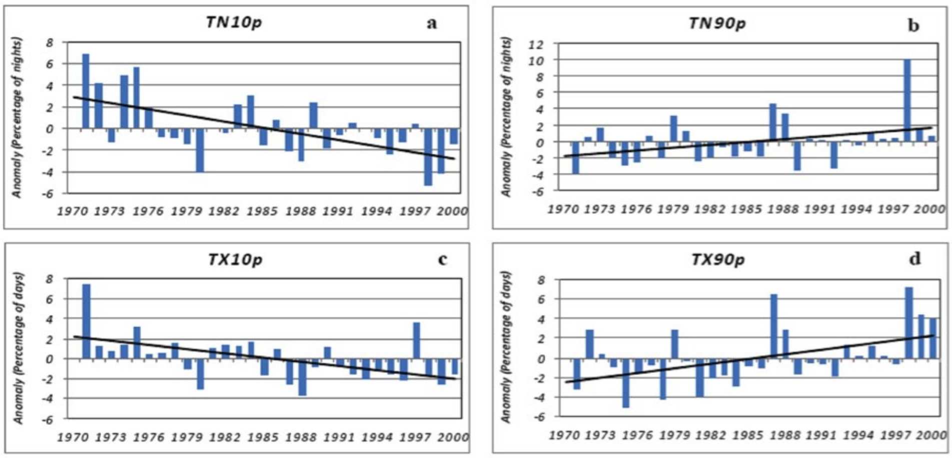

Figure 17: Trends in (cool nights) TN10P, warm nights (TN90P), cool days (TX10P) and warm days (TX90P) averaged over South Asia [Source: Sheikh]

The APN also supported three workshops on climate trends and variability for the Pacific Islands and fourteen (14) countries were involved. The activities included collaboration on data stewardship, regional analyses of climate trends across the Pacific and consideration of large-scale drivers of climate in the region and their impacts on the trends.

Other workshops were supported in South Asia to promote regional cooperation in analyzing climate data for trends in extreme events in a consistent manner. These workshops, which involved experts from Bangladesh, India, Nepal, Pakistan, Sri Lanka, USA and Australia (***Figure 18***), built on experience from the earlier APN workshops and from similar activities supported by international agencies such as the WMO.

Recognizing the relevance of paleoclimate reconstructions for the Asia-Pacific region, the APN supported the Open Science Conference of the international PAGES (Past Global Changes) programme in Beijing, China in 2006. Scientists from fourteen (14) APN countries participated in the conference.

Following the establishment of GEOSS in 2005, the APN supported two workshops in Japan in 2006 and Thailand in 2007, aimed at determining the regional actions required to implement GEOSS. Sixteen (16) countries from the Asia-Pacific region participated in the workshops, which included presentations and break-out sessions to identify regional observational needs, and capacity building requirements to support vulnerability assessments.

3.3.3. Outcomes

By supporting a sustained programme of workshops across the Asia-Pacific region, the APN established a network of experts in more than a dozen countries who continue to collaborate to collate and analyze national climate records at the regional level. The activities facilitated enhancements in the national infrastructure required for quality control and analysis of climate

APN workshops on trends in climate extremes provided a framework for international trend analysis in developing countries around the world.

data. Thus, the APN activity has been very effective in building scientific capacity across the entire Asia-Pacific region.

Figure 18: Participants and resource persons of the APN Technical Meeting for the finalization of research publications on climate extremes, Kathmandu, Nepal [Source: Sheikh]

The scientific capacity building activities of APN have led to improved data stewardship and to substantial scientific progress on the analysis of climate trends. The observed trends in temperature and precipitation extremes from the early workshops fed directly into the Third Assessment Report (TAR) of the IPCC, and subsequent results were included in the IPCCAR4. The advancement in climate science since 1996 has allowed the IPCC in its third and fourth reports (IPCCTAR & IPCCAR4) to make authoritative statements on trends in extremes in temperature and precipitation on a global scale.

The format of the early APN workshops was taken up by other international groups, such as the WMO and applied in other regions, including the Caribbean, Africa and Central Asia. Moreover, the APN-supported workshops in the Pacific provided the basis for further activities across the region under the auspices of the Global Climate Observing System (GCOS) and other regional bodies. These activities included vulnerability assessments in agriculture and forestry.

The APN focus in South Asia led to the development of consistent analyses of climate extremes across that region through direct collaboration between all the involved countries. Indeed, the activities have created a collaborative network across the countries of South Asia, which is working to link the observed trends in extremes to large-scale climate drivers.

Support for the PAGES conference ensured that 14 countries in the Asia-Pacific region were able to participate in this event of the GC community, and the GEOSS workshops in Japan and Thailand brought together 16 countries to identify regional observational needs as well as associated requirements for capacity building.

3.3.4. Conclusions and recommendations

It is clear that the APN has played a fundamental role in establishing the process for scientific capacity building for the analysis of climate extremes on a regional basis and within a globally-consistent framework. Moreover, the pioneering APN activities provided the first regionally-consistent analysis of trends in climate extremes across Southeast Asia and the Pacific.

> Open access to climate data, including relevant socio-economic data, will be essential for countries in the Asia-Pacific region to carry out risk assessments of their vulnerability to trends in climate.

Progress on the application of the results of trend analyses in climate extremes to societal issues will depend upon the extension of systematic data collection, analysis and access to socio-economic data. Thus, there is a need for regional policy action to support international efforts to *promote open access to all climate data*, as agreed under the UNFCCC. Increased access to relevant environmental and socio-economic data will enhance regional and national capabilities to use climate data for vulnerability studies, especially related to disaster management, and for integrated assessments of the impacts of climate change and the development of management strategies.

3.4. Regional Climate Modelling

3.4.1. Issues and significance

Developing RCMs in Asia has helped provide more detailed information on monsoon circulation. High-resolution regional/local information from RCMs can be used in impact, vulnerability and adaptation studies.

GCMs have advanced significantly in recent decades, and the Earth Simulator Centre (ESC) in Japan is now running GCMs at resolutions of 3.5 km. However, at the same time, RCMs are being widely used by researchers as a complementary research method, allowing more detailed process studies and simulation of regional/local climate. High resolution information about climate change, variability and extremes is required to develop regional/local climate change projections, which are used in impact, vulnerability and adaptation studies.

The Asia-Pacific region is a hotspot for climate change because of its significant regional monsoon climate, interaction with the global climate system and greater economic activity in recent decades. The simulation and prediction of the Asian monsoon at higher resolution and lower uncertainty under the background of climate change and rapid regional development is not only a crucial scientific research issue, but also a key sustainability issue for both national and local decision- and policy-makers.

Significant requests have come from countries within the Asia-Pacific region for capacity building activities that develop the skills required to master and run RCMs, develop tailored RCMs, and improve downscaling methodologies and application of RCMs for future climate projection and for vulnerability and impact assessment studies.

3.4.2. Scope of the activities

Through support from the APN, an "Asian RCM network" was developed that supported scientists from the region and fostered collaboration with other RCM/GCM modellers under the flagships of WCRP, IGBP and START. APN promoted the development of RCMs tailored for Asian projections in order to improve the understanding of the Asian monsoon system and develop skills for predicting future climate change in the Asia-Pacific region. The capacity to develop and use RCMs has been improved through workshops, training schools and fellowships.

A network of RCM scientists was built through APN projects, workshops and fellowships; and a regional model inter-comparison project (RMIP) was undertaken in the Asia-Pacific region.

From 1999 to 2002, the APN's research programme, the ARCP, provided continuous funding for an Asian Regional Climate Modelling project by supporting the development of RCMs in Asia and promoting the "Regional Climate Model Inter-comparison for Asia (RMIP-Asia)" project and its activities. This aided the development of RCMs at the START Temperate East Asia regional centre and at Nanjing University. Nine (9) regional models from Australia, China, Japan, Republic of Korea, and the USA collaborated in the RMIP-Asia activities in Phase One of the project (***Figure 19***) and the ten (10) subsequent peer reviewed papers from these activities are listed under CSP1 in ***Appendix 3***. A number of these were picked up by the IPCC for their TAR and AR4 reports.

The APN's goal of transferring technology and expertise was supported by an APN-funded 5-week training course hosted by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Atmospheric Research on "Analysis of Climate Change Simulation of Southeast Asia," using the DARLAM (Division of Atmospheric Research Limited Area Model) high resolution model for Southeast Asia. Participants from Southeast Asia and the Pacific Islands were represented and a high-resolution simulation was conducted over Samoa.

Properties of participating RMIP models for phase one									
Model	RIEMS	DARLAM	CCAM	JSM_BAIM	RegCM	RegCM2a	RegCM2b	ALT.MM5/lsm	SNU RCM
Group leader	C. Fu	J. McGregor	J. McGregor	Y. Sato	J. Kim	M. Suh	H. Kato	W. Gutowski	D. Lee
Country	China	Australia	Australia	Japan	Republic of Korea	Republic of Korea	Japan	USA	Republic of Korea
Vertical levels	σ-17 levels	σ-18 levels	σ-18 levels	σ-23 levels	σ-15 levels	σ-15 levels	σ-14 levels	σ-23 levels	σ-23 levels
Dynamic process	Hydrostatic	Hydrostatic	Hydrostatic	Hydrostatic	Hydrostatic	Hydrostatic	Hydrostatic	Nonhydro-static	Nonhydro-static
Lateral boundary condition	Linear relaxa-tion	Exponential relation	Exponential relation	ER+spectral coupling	Exponential relaxation	Exponential relaxation	Exponential relaxation	Linear relaxa-tion	Exponential relaxation
Convective scheme	Kuo-Anthes	Arakawa-Gordon	Arakwa-Gordon	Moist convec-tive adjust-ment	Grell	Kuo-Anthes	Kuo-Anthes	Betts-Miller	Grell
Land surface	BATS	Kowalczyk	Kowalczyk	BAIM	BATS	BATS	NCAR/LSM	NCAR/LSM	NCAR/LSM
Planetary boundary layer scheme	Holtslag	Louis	Louis	Yamada level 2 louis scheme	Holtslag	Holtslag	Holtslag	MRF	MRF
Longwave radiation scheme	CCM3	GFDL	GFDL	Sugi	CCM3	CCM2	CCM3	CCM2	CCM2
Shortwave radiation scheme	CCM3+ Aerosol	Lacis and Hansen	Lacis and Hanse	Lacis and Hansen	CCM3+ Aerosol	CCM2	CCM3	CCM2	CCM2

Figure 19: Properties of participating RMIP models for Phase One [Source: Fu]

APN also co-funded the WCRP regional-scale climate modelling workshop in June 2004 in Baltimore, USA in collaboration with CLIVAR/WCRP groups, thus ensuring the active participation of developing countries from the Asia-Pacific region.

3.4.3. Outcomes

The Regional Integrated Environmental Modelling System (RIEMS), which is an integrated RCM for the Asian monsoon region, was developed at the Institute of Atmospheric Physics, Chinese Academy of Sciences, with climate-vegetation and climate-aerosol coupling, and has become one of the leading regional models in China.

An Asian RCM group was formed to share the knowledge and experiences of regional model simulations. To support the modelling inter-comparison (RMIP Asia) activity, a data network on *in situ* and modelling outputs was established and a ten-year databank (1989–1998) of meteorological observations and six RCM simulation outputs in the Asian region was built through the APN projects.

APN supported the development of RCMs in the Asia-Pacific region by improving the simulation of the Asian monsoon system and applying RCMs at national and local levels.

Training workshops on the application of regional climate simulations at national and local scales for climate change impact and assessment studies helped scientists in Asia to develop their own RCMs. From the APN-funded regional modelling research project, ten (10) peer review papers were published and contributed to WCRP and IGBP modelling activities and IPCC reports.

3.4.4. Conclusions and recommendations

RCM activities in the Asia-Pacific region should have more interaction with APN climate change impact/ assessment studies in future.

- With APN support, a strong Asian RCM network has been established and the RMIP project is moving into its next phase. To respond to the requests for climate change impact studies in Asia, this group still needs leadership, coordination and support from APN.
- Based on current regional climate/environmental models in Asia now, promotion of studies on monsoon processes in the region is needed, including studies of the monsoon intraseasonal and seasonal cycles at local scales. These activities will also help to improve GCM simulation of the Asian monsoon system.
- Further work is needed to demonstrate the application of RCMs in climate change impact/ assessment studies such as agriculture, water resources and land/water management at local scales. This will require greater interactions across the APN communities, including the Asian Water Cycle Initiative (AWCI) who is supported by the APN.
- Training and strengthening the capability of scientists in the Asia-Pacific region in techniques and applications of downscaling climate change projections needs to be continued. This can lead to better understanding of the strengths and limitations of GCMs and downscaling, which will be of value to those who are involved in policy-making processes. Specifically, strengthening the simulation capacity in Southeast Asia, Small Island States and high altitude areas of the Asia-Pacific region is especially needed.
- There is a need to effectively communicate the uncertainties of climate modelling and the methodologies used to reduce these uncertainties.
- More emphasis should be placed on testing these models against observations.