



**Assessment of the Impacts of and Adaptations to Climate
Change in the Plantation Sector, with particular reference to
Coconut and Tea, in Sri Lanka.**

Project No. AS-12

**Progress Report for the period
July 01 to December 31, 2002**

submitted to

**Third World Academy of Sciences
Trieste, Italy**

and

**AIACC Project Office
START Secretariat
Washington, USA**

by

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14 January 2003

1. Project Summary

1.1 Title

Assessment of the Impacts of and Adaptations to Climate Change in the Plantation Sector, with particular reference to Coconut and Tea, in Sri Lanka.

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PROGRESS REPORT**A. Brief Summary**

Work on the development of climate change scenarios using SDSM and MAGIC/SCENGEN software was undertaken. The collection of climate, production and socio-economic data was continued and analysis of data was commenced. In the tea sector, yield and weather relationships have been established partially. Study on the enrichment of CO₂ was continued at two elevations. The data collected so far had shown that 25-40% increase in yield. Historic Data for socio-economic scenarios was completed for some agro-ecological regions.

In the tea sector, linear trend analyses for climate data were carried out on monthly and yearly basis for each agro-ecological region. Rainfall and maximum temperature were identified as significant climate variables on nut production in two agro-ecological regions and consequently two crop models were developed to estimate nut yield per hectare.

A workshop was organized for the training of team members in the use of an integrated assessment model developed by the International Global Change Institute in New Zealand with 3 scientists from IGCI serving as resource persons. The quality control of the mean temperature records for 130 years for the 15 main meteorological stations was completed. The quality control of the minimum and maximum temperature data for the same stations was also nearly completed.

B. Tasks performed and Outputs**1. General****1.1 Review Meetings**

The study teams met three times on July 29th, October 07th and November 26th in order to:

- Review the progress in the previous month/s and plan the work for the ensuing month,
- Brief by the participating members to non-participating members on the knowledge and information gathered at the overseas meetings attended by the members,

- Discuss the scope and the contents of the Training Workshop on Integrated Assessment Modeling, to be held in December.
- Coordinate the data collection and analysis exercise to be carried out by the 4 participating institutes.
- Compare notes on the results of data analysis carried out by team members.

The meetings were held in rotation at the CRI, Lunuwila, TRI at Talawakelle and NMRS at Polgolla, respectively.

1.2 Participation in Meetings

A contributed paper on “Effect of temporal scale aggregation on climate change studies” was presented by Sarath Peiris of CRI at the International Workshop on Regional Integrated Assessment of Climate Impacts held in Pascoli, Italy, on 16-20 September, 2002. His travel and subsistence costs were met from the Project funds.

1.3 Training Programmes Attended

Five team members attended a 5-day training programme on GIS applications conducted by the local representatives of Arcview Software, which was purchased for use in the computer at the Meteorological Department. The high cost prevented this software from being installed in other computers.

One member attended a training programme on the use of system software LINUX which was found necessary for use with regional climate modeling applications.

1.4 Development of a web site.

A website has been created giving the details of the project and presentations made by members at various occasions. Its URL is www.aiacc.slt.lk.

2. Data Collection

2.1 Meteorological Data

The required digitized data on monthly temperature (minimum and maximum) and rain fall were given to the three institutes from the data-base of the Department. These covered 22 stations for temperature and 99 for rain fall. In addition, daily values for temperature were given to the CRI for 3 stations in the coconut growing areas.

2.2 Coconut Sector

2.2.1 Climate Data

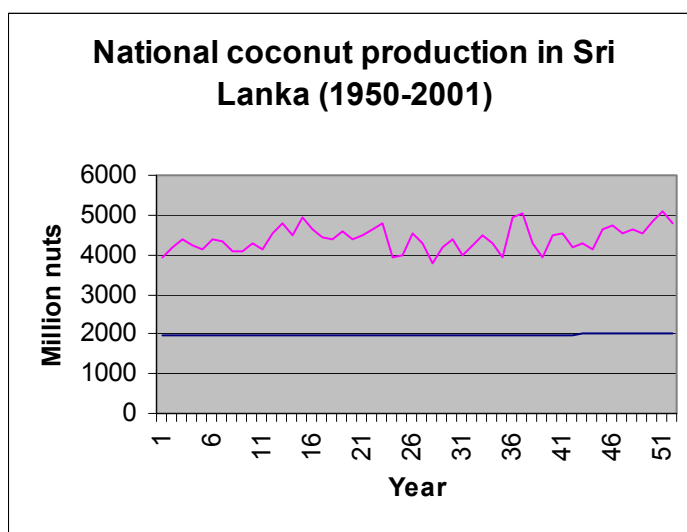
Programmes were developed to computerize daily precipitation and temperature (maximum & minimum) from 1932 – 2001 obtained from the Meteorology Department into a customized

format. Data were quality controlled. Precipitation data was obtained for 28 stations including of six agro-ecological regions. Air temperature (maximum and minimum) data were available for one location in each agro-ecological region.

Annual rain fall (in mm) within the coconut growing area (coconut triangle) from 1950 to 2001 was also worked out.

2.2.2 Nut Production Data

The national annual nut production data were obtained from 1950 to 2001. These are shown graphically below.



The collection of yield data for different agro-ecological regions separately was commenced. Collection of crop yield data from 1990 to 2001 in the Low Country Wet-Intermediate Region (ILI - 55 estates) and two Low country Wet Regions (WL3 & WL4 - 23 estates) were completed.

2.2.3 Soil physical parameters

To develop crop models, collection of soil physical parameters relevant to different land suitability classes (S1, S2, S3, S4 and S5) was commenced and following data collections were completed.

- Bulk density
- Rooting depth
- Water retention capacity
- Duration of water retention
- Total Nitrogen content
- Macro and micro porosity %
- Soil pH

The average values obtained for the above parameters are given below.

Soil Physical Properties of different land suitability classes (LSC)

LSC	Soil series	Bulk density (g/cm ²)	Rooting depth (m)	Water retention capacity (mm)	Duration of water retention (days)	Total N (%)	Mac. Porosity %	Micro porosity %	Soil pH
S1	Madampe	1.48	3	186.3	38	0.12	33.1	11.56	6.50
	Rathupasa	1.48	3	211.3	43	0.12	33.1	11.56	7.05
	Katunayake	1.48	3	166.3	35	0.10	33.1	11.56	4.77
S2	Borupan	1.49	3	285	53		31.45	12.6	
	Mavillu	1.49	2	238	44		31.45	12.6	
	Welikatiya	1.12	2	103	19	0.07	40.32	5.84	6.28
	Kalpitiya	1.12	2	53	10	0.05	40.32	5.84	5.51
	Ambakele	1.36	2	299.6	61	0.06	24.0	24.6	6.81
	Welipelessa	1.48	2	199.1	41		33.1	11.56	
	Kurunegala	1.55	1.5	92.8	19	0.10	24.5	17.65	5.94
	Melsiripura	1.36	3	307.5	63	0.15	24.0	24.6	5.46
	Pallama	1.48	2	193.4	40	0.11	33.1	11.56	5.48
S3	Gambura	1.49	3	260	48	0.07	31.45	12.6	6.08
	Wilpattu	1.49	3	256	47		31.45	12.6	
	Wariyapola	1.54	1.5	110.7	23	0.08	17.3	24.85	6.24
S4	Andigama	1.55	1	66	14	0.08	24.5	17.65	6.16
	Kuliyapitiya	1.55	1	56	11	0.14	24.5	17.65	5.61
	Maho	1.54	1.5	105.8	22	0.06	17.3	24.85	6.00
	Boralu	1.55	1	55	12	0.14	24.5	17.65	5.18
S5	Sudu	1.12	1	42	9	.03	40.32	5.84	6.77

2.2.4 Socio-Economic Parameters

Following data were collected from published sources.

- Annual national coconut production (million nuts) from 1950 to 2001
- Annual statistics of manufacture of kernel products (million nut equivalent) from 1971 to 2001
- Annual export volume of kernel products (million nut equivalent) from 1971 to 2001
- Annual export of fibre products (Mt) from 1975 to 2001

2.3 Tea Sector

2.3.1 Climate and Crop Data Collection

Collection of field data on crop productivity was completed. Monthly data on tea yield (productivity) and rainfall were collected from selected tea estates (25) representing all tea growing regions as listed below. Three tea fields (high, moderately and low yielding) planted during 1974-1978 were selected from each estate for data collection.

Agro-ecological Region	Name of Estates
Up country wet-zone (WU)	Moray, Helboda, St. Commbs and Park
Up country intermediate zone (IU)	Rangala, Pitakanda, Nonperil, Uva highland
Mid country wet zone (WM)	Hapugasthann, Endana, Kiriwanaganga, Enselwatte, Loolecondera, Hays, Pettigala
Mid country intermediate zone (IM)	Verellapathana, Ury
Low country wet zone (WL)	Halgolla, Miyanawita, Noragalla, Pelmadulla, Vogan, Hulandawa, Madampe, Yataderiya

2.3.2 Collection of Socio-economic Data

Primary data collection required to develop socio-economic scenarios, was completed in 4 Up- and Mid-country Ecological regions. A stakeholder survey was also carried out to gather experiences of climate change impact on tea cultivation and processing.

Summary of data collected is given below.

Type of Data	Estates					
	Uda Radella	Mool Oya	Hantane	Diyagama East	Liddesdale	Gouravilla
Rain Fall	1970-1975 /1982-2001	1978-2001	1986-2001	1966-2001	1963-2001	1978-2001
Sun Shine Hours	1994-1998			1988-2000	1992-2001	n.a.
Wet Days	1970-1975 /1982-2001	1978-2001	1986-2001		1970-2001	1978-2001
Land Use	1980-2001		1986-2001	1985-2001		
Green Leaf	1970-1975 /1982-2001	1967-2001	1986-2001	1966-2001	1977-2001	1978-2001
Bought Leaf	n.a		1986-2001	1966-2001	1977-2001	
Made Tea	1970-1975/ 1982-2001	1978-2001	1986-2001	1966-2001	1970-2001	1978-2001

Yd/ha Field wise(4 fields)			1986-2001		1981-2001	
Gross Out Turn	1970-1972 /1982-1998		1986-2001	1966-2001	1986-2001	1983-2001
Net Out Turn	n.a		1986-2001	1966-2001	1977-2001	1983-2001
C.O.P.	1984-2001	1995-2001	1986-2001	1983-2001	1981-2001	1978-2001
N.S.A.	1984-2001	1995-2001	1986-2001	1983-2001	1981-2001	1978-2001
Refuse Tea	1970-1975 /1982-2001		1986-2001	1966-2001		1978-2001
Made Tea-Grade wise	1970-1975 /1982-2001		1986-2001	1966-2001		1978-2001
Agro chemical usage			1994-2001	1977-2000	1992-2001	1978-2001
Fertilizer usage			1994-2001	1977-2000	1992-2001	1978-2001
Annual work force	1984-		1987-2001			1980-2001

In addition to above field data, a survey on stake-holder's views and experience on impacts of climate change on productivity and quality of tea was carried out. Stakeholder survey has uncovered that quality seasons have not been set during the past few years due to changes in weather pattern in tea growing areas incurring loss of profits

2.3.3 Experiment on CO₂ Enhancement

Two field experiments on the impact of CO₂ enhancement on crop productivity, one at TRI, Talawakelle in the Up country and other at TRI, Ratnapura in the Low country were carried out. Tea bushes in the field were exposed to enhanced CO₂ using open top chambers with CO₂ fed from cylinders. Treatments are: control (ambient CO₂), enhanced CO₂ (550-650 ppm) within chamber and ambient CO₂ within chamber. Tea bushes are harvested weekly and yields are recorded. Results collected so far, has shown that tea yield under enhanced CO₂ has been increased by around 38% in the low elevation where the ambient temperature is high, and by 25% in the high elevation where the ambient temperature is low. Further assessments are being carried out on rate of shoot growth. These results will be used for modeling the productivity of tea lands under different scenarios of climate change.

2.4 Quality Control of Data

This work focused on identifying the quality of data in the main 15 meteorology stations. Initial analysis was carried out on the quality of the mean temperature records by exploratory data analysis, correlation analysis, reconstruction of data based on related stations. Our work followed the procedures of global historical climate network. It was possible to identify a number of segments of the data record that had been contaminated by station relocation from this analysis. There are significant differences in warming trends with and without quality control. The preliminary results were reported at the Annual

Session of SLAAS last year. Work on similar procedures for minimum and maximum temperature data was nearly completed. The diurnal variability in warming trends is particularly important for plantation crops.

3. Data Analysis

3.1 Coconut Sector

The following preliminary analyses were done for two agro-ecological regions, LCWIR and LCWR in the coconut growing areas.

Analysis of long-term climate data applicable to coconut growing areas.

Trend analyses were done on yearly, monthly and seasonal basis for original data and for departures from the corresponding means over 1961 – 1990 for precipitation. There was a decreasing trend for annual rainfall in IL1 and WL4 and increasing trend for annual rainfall in WL3. Of the four seasons, significant decreasing trend for rainfall in IL1 was found during the first inter-monsoon period (March to April). There was an increasing trend in seasonal rainfall too in WL3. Of the four seasons, significant decreasing trend in WL4 was found during March to April and December to February. Quantification of decreasing or increasing rates was not done as trend analysis alone is not sufficient for rainfall.

The rates of annual increase of temperature variables on yearly and seasonal basis are shown in Table 1. All the coefficients in Table 1 are significant at least at the 5% level.

Table1. Rate of annual increase in °C/year

Temperature variable	Agro-ecological regions in low country (LC) in Sri Lanka				
	LCWIR	LCWR		LCDR	
	IL1	WL3	WL4	DL3	DL5
Maximum	0.017	0.018	0.018	0.026	0.018
Minimum	0.003	0.017	0.005	0.006	0.006
Mean	0.010	0.017	0.012	0.016	0.013
Diurnal	0.014	0.001	0.012	0.021	0.012

(LCWIR – low country wet intermediate, LCWR – low country wet regions, LCDR – low country dry region)

The temperature increase in all regions of coconut growing areas occurred significantly. The rate of increase in maximum air temperature is higher than that of minimum, mean or diurnal air temperatures. The rate of increase is the lowest in minimum temperature in all regions. The rate of mean air temperature is the highest in WL3 and it is as large as 1.7 °C/100 years.

The analysis has to be further continued to study the climate variability.

Development and application of crop models to determine the relationship between yield and climate factors

Compound climate indicators consist of rainfall and temperature in various months were developed to explain annual and monthly climate variability in LCWIR, but not yet tested by relating with other parameters affected due to climate change. Climate models were developed using some monthly rainfall & temperature variables of two preceding years to crop in order to explain annual yield variability in LCWIR and LCWR. Models explained about 60% of annual yield variability.

This work will be continued further to develop crop models for different regions and one for national using climate data and soil suitability classes for coconut.

Development of climate change scenarios for coconut growing areas jointly with climate scientists.

Four past crop production scenarios were developed using a simple statistical indicator based on 50 years past data (Table 2).

Table 2 Identified scenarios based on total national production

Scenarios	Criteria	Corresponding years	Mean yield (mln nuts)
I 'Low Yield'	$Y \leq 2206$	1950, 1954, 1957, 1958 1960 1973, 1974, 1977 1980, 1984, 1988 1991, 1993	2049
II 'Medium Low '	$2206 < Y \leq 2430$	1951, 1953, 1955, 1959 1967 1976, 1978, 1979 1981, 1983, 1987 1992	2314
III 'Medium High'	$2430 < Y \leq 2601$	1952, 1956 1961, 1963, 1966, 1968, 1969 1970, 1975 1982, 1985 1990, 1996, 1998	2513
IV 'High yield'	$2601 < Y$	1962, 1964, 1965 1971, 1972 1985, 1986 1994, 1995, 1997, 1999 2000, 2001	2820

Y = actual annual nut production in million nuts

The comparison of climate in coconut growing areas in each scenario will be investigated. Once the methodology to develop climate change scenarios was identified with climate scientists, climate change scenarios for coconut growing areas and consequently production scenarios will be identified during the next eight months.

Identification of socio-economic impact indicators sensitive to climate change.

The following were identified as socio-economic impact indicators sensitive to climatic change.

i) Employment in desiccated coconut (DC) mills

Average labor days used per Mt of DC was computed as 11 man-days + 7 women days. So, non production of each Mt of DC due to coconut shortage in drought-prone years will result in loosing employment of 11 man days + 7 women days.

ii) Of the expenses incurred by a household for food items, percentage expenditure on culinary coconut consumption by Sri Lankan population

When the coconut crop is in short supply in drought-prone years, consumers' cost of living increases significantly.

3.2 Tea Sector

1. Analysis of data collected from low high and mid-country estates and regression equations for yield and climate parameters were obtained. The parabolic response was seen. The equation is: $\text{Yield} = -508 + 63.6 \times \text{Temp} - 1.46 \text{ Temp}^2$

During data analysis, it was found that, there is a wider variation in crop productivity in relation to pruning year (tea bushes are pruned every 3-5 years depending on growth and elevation) and age of tea bushes that is not accounted for by the variation in the environmental factors. Hence, standardizing of data is necessary in establishing relationships between environmental factors and productivity. This is now being attended.

2. A dynamic physiological canopy tea model is under construction taking into account rainfall, radiation and temperature and leaf area .

Literature survey has been done to identify any suitable models for development of Socio-economic scenarios. The following table gives a summary of data collected.

4. Training Workshop on Integrated Assessment of Climate Change Impacts

A training workshop was conducted by 3 visiting scientists from the International Global Change Institute, University of Waikato, New Zealand during December 15-20 at Colombo. Fifteen members comprising 8 scientists and 7 research assistants attended the workshop. Its objectives were:

Objective 1: to build a *prototype SriLankaCLIM model*, by:

- specifying the data required from Sri Lanka for development of the prototype version (IGCI -- completed);

- determine the specific area and resolution required (Sri Lankan team responsibility, with IGCI advice)
- collecting the required data in appropriate format (Sri Lankan team responsibility);
- developing a prototype “shell” for a *SriLankaCLIM* model that includes: a data browser; an extreme event analyzer and a climate change scenario generator, as well as the capacities for spatial and site-specific analyses. This model version will provide the platform upon which *SriLankaCLIM* can be further developed with the inclusion of sectoral impact models. (This task will be accomplished by the country team working interactively with IGCI.).

Objective 2: to train the Sri Lanka team in *SriLankaCLIM* development, by:

- conducting a structured exercise on model development and maintenance using datasets provided by IGCI. The country team will learn how to: define the geographical area and spatial resolution; input climate time-series data for sites; input spatial climatologies; add or delete patterns of climate change from GCMs; and learn about the requirements for interfacing sectoral impact models.
- applying the skills of the country team to build the prototype SriLankaCLIM during the workshop (as in Obj. 1);

Objective 3: to determine the scope and logistics for further *SriLankaCLIM* development, especially with regard to sectoral impact models, by:

- conducting a training exercise using a fully-developed SimCLIM for another country. There are two reasons for conducting this exercise: to develop the skills of the country team in using the *SimCLIM* model system; and to create awareness of the range of potential developments for *SriLankaCLIM*;
- discussing the options for further model development and sectoral modelling in light of the priorities of the AIACC country team, the availability of data, and the team’s priorities and modelling capabilities;
- developing a “blueprint” for further *SriLankaCLIM* development and a Plan of Action, if appropriate at this stage.

Output of the Workshop:

The training workshop gave an opportunity to familiarize the use of climate analysis in decision-making and the use of GCM outputs to project future climate scenarios. However, it was observed that the *SimCLIM* or the prototype model, *SriLankaCLIM* does not have the facility to incorporate complex crop models, any economic models or Integrated Assessment Models.

The Slimclim was run with 30 years base line rainfall data and temperature data. Later GCM pattern was introduced to the base line data and a new projection was made. Preliminary indication was that optimum conditions for tea is more in the mountains and SouthWestern regions of the country becomes unsuitable with the climate change. This has

to be confirmed with more refined data. This indicates that SIMCLIM could be adopted for Sri Lanka tea growing area. For future integrated assessments, more refined data should be used..

All this workshop was referred to as Integrated Assessment, it was restricted to training on a software that dealt with using climate model outputs. Even for the climatic analysis, we found that this model was rather crude and did not provide realistic results. There was no methods of uncertainty analysis. The inputs needed for the model such as "downscaling patterns" do not exist. The training team refused to provide the source code for the model. Documentation of the model was not provided adequately and there was a black box feel to it. In addition, the model crashed over a dozen times during the training workshop. Unless, the trainers develop the model and debug it properly, it will be difficult to get realistic testable results. It was poorly developed. There was only speculation about economic and societal aspects. For our part, we found that this training workshop did not contribute commensurate with the cost of conducting the workshop and the time that was spent by 20 scientists on it.

C. Difficulties Encountered

1. Climate Data

- Difficulties were encountered in the process of gathering historical data from a large number of stations as most of the stations do not have computerized data. Almost all Agro-Meteorological stations commenced after 1975. Therefore they do not possess 30-year baseline data. In some stations there are breaks in data, some times with 10-year gaps. Also, most of the stations do not possess 100-year records.
- There were discontinuities in socio-economic data at estate level. The need for extra assistants was also identified for collecting field data and analysis.
- There was difficulty in accessing literature on previous work done as the journals covering the subject are not available in the country. We are ordering one journal but with their high cost, are unable to order several. Perhaps, AIACC could arrange to send content pages of more important journals devoted to climate change.

2. Coconut Sector

- In the process of accessing literature on previous work done and models developed etc.
- Downloading large-scale weather variables in order to derive statistical relationships with local weather variables.
- The correlations between soil physical parameters and coconut yield in different land suitability classes were not available
- The correlation between impact of CO₂ elevation and temperature increase on coconut yield is not available.

- Inadequate time spent on data analysis of the project due to expansion of institute's research advisory and extension work

3. Tea Sector

It was found during estate visits that some estate records on productivity were incomplete or missing. Further due to poor performance of some fields planted during 1974-1978, they had been abandoned or replanted few years ago. Usually, vegetatively propagated tea fields are replanted after 25-30 years. Under such circumstances, it was not possible to collect full range of data over a longer period of time for the purpose of standardizing and comparison of data. In order to minimize errors in establishing relationships, weekly data on crop productivity and daily met data were extracted from long-term field experiments at the Tea Research Institute, Talawakelle (up country) and Ratnapura (Low country).

D. Tasks within the next 8 months

1. Climate Scenarios

- Expected to get further training on SDSM and Sri Lanka Clim software's, which will be used in downscaling and scenario development.
- Expected to get training on GIS from University of Colombo.
- Expected to start scenario development by

Using baseline data collected and analyzed
 Downloading of NCEP reanalysis data and GCM outputs
 Downscaling GCM output to the Station level or to a fine grid

- Interpolation of temperature and rainfall data using Arc GIS software with the elevation dependency feature after adding some more stations to increase accuracy.

2. Coconut Sector

- Collection of yield data from estates in all agro-ecological regions will be completed within the next six months.
- Continue the analysis of rainfall and temperature data in more comprehensive manner to identify the climate variability and vulnerability of coconut growing regions separately.
- Compare climatologies among the identified four crop production scenarios.
- Develop crop models for other regions and for national level using climate variables.

- Improve the crop x climate models using simple monthly climate variables so that it can be used for SRILANKACLIM model.
- Develop a statistical downscaling method (SDM) .
- Continue the data collection on soil physical properties and water retention properties of five land suitability classes in different agro-ecological regions and develop the correlations with yield.
- Conduct an experiment to estimate the dry matter accumulation in coconut seedlings with doubling of atmospheric CO₂ concentration.
- Influence of climate variables (temperature and rainfall) on the level of mite infestation on coconut will be explored and the corresponding crop losses will be assessed.
- Trend of percentage contribution from coconuts to GDP will be analyzed.
- Arrange overseas training for three coconut scientists separately in different areas namely i) analysis of economic impacts on climate change, ii) crop - growth modeling and iii) climate variability & statistical downscaling.

3. Tea Sector

- Continuation of the field trial on CO₂ enhancement
- Exploring and Establishing empirical relationships between weather data and productivity of different tea growing regions
- Identification of limiting factors/constraints (especially in climatic factors) for tea production in different regions
- Prediction of tea productivity based on climate or development of crop models compatible with SriLankaCLIM.
- Collection of soil data in tea growing areas to be fed to SriLanka CLIM and Plant-Grow Model
- Calibrating Cropsyst and Ecosyst models and building a dynamic tea model and calibrating with field data.
- Data analysis to be performed in order to develop socio-economic scenarios for the Up and Mid country.
- Similar kind of historical data collection will be carried out in Agro-ecological regions in Uva and Low country.
- Stakeholder survey will be extended tea brokers and exporters in order to assess the impact on national economy due to the effects on seasonal quality tea production.

E. Anticipated Difficulties within the next 8 months**1. Climate Scenario Development**

Accessibility to the GCM outputs and NCEP data.

2. Coconut Sector

To download GCM outputs to suit the coconut growing regions.

3. Tea Sector

- Absence or weak relationships between weather data and crop productivity in all tea growing regions due to lack of data and wide variations.
- Difficulties in tea yield prediction based on climate in each and every tea growing region..
- Delays in access to the Plant-grow model to be modified for tea (This has to be revised and made compatible with Sri Lanka CLIM by the Training specialists led by Dr.Warrick) and other tea models such as Cuppa Tea model (Cranfield University, UK)
- Delays in acquiring digitized soil maps in agroecological regions.
- Inadequate time to be spent for data analysis of the project due to expansion of institute's research advisory and extension work

F. Presentations

A paper on “Effect of temporal scale aggregation on climate change studies” was presented by Sarath Peiris of CRI at the International Workshop on Regional Integrated Assessment of Climate Impacts held in Pascoli, Italy, on 16-20 September, 2002 (Abstract is given in Annex)

Several presentations were made by the team members at the Training Workshop on Integrated Assessment of Climate Change Impacts. These will be posted on the web shortly (www.aiacc.slt.lk).