IMPACT OF RAINFALL CHANGE ON THE AGRO-ECOLOGICAL REGIONS OF SRI LANKA

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ABSTRACT

Changes in future rainfall distribution for the agro-ecological regions of Sri Lanka were analyzed. The baseline period to compare future predictions was taken as 1970 to 2000. Downscaled climate change prediction grids were extracted from the UK Hadley Centre for Climate Prediction and Research Model (HadCM3). These grids were extracted for 2050. In the baseline period 76 stations of 147 showed decreasing trends in annual rainfall and 71 increasing trends. Thirty six of the 76 stations showing a decrease were in the wet zone. In the intermediate zone 17 stations showed increasing trends and in the dry zone 34 stations indicated increasing trends. Mean annual rainfall (MAR) for the baseline period for the whole country was 2094 mm/year while the projected value for 2050 is 2249 mm/year. The increase of MAR over Sri Lanka by 2050 compared to the baseline period is about 7%. The comparison of rainfall between the baseline period and 2050 showed that some areas of the dry zone will receive MAR of more than 1750 mm and could be classified and included into the intermediate zone by 2050. Further, the increase of MAR for 11 agro-ecological regions goes beyond the variability observed in the baseline data set.

INTRODUCTION

Water availability is a function of rainfall and is crucial to all aspects of human life, including agriculture and nature, and 84% of the world's available water resources are allocated to agriculture that is closely linked to food production (Droogers, 2004). Increasing global surface temperatures lead to changes in precipitation and atmospheric moisture that affect food production worldwide. It is now widely accepted that anthropogenic activities lead to increased greenhouse gas concentrations, which will lead to changes in climate (De Silva *et al.,* 2007). Over the past 100 years the earth has experienced climate change and this is expected to continue. The nature of the impacts of climate change will differ geographically depending on the exposure and development status across the regions and their ability to respond and adapt to the changes in the climate (IPCC, 2007).

There is ample evidence to suggest that Sri Lanka's climate has already changed (Chandrapala, 1996). Changes in rainfall and temperature are among these variables. These changes will have a significant impact on sectors such as water and agriculture and, therefore, on food production (Weeraratna and Weerasinghe, 2006). Being an agricultural based country, it is very important to analyse the magnitude of Sri Lanka's climate change and its effect on water resources and agriculture in both spatial and temporal contexts. Such analysis would help in making decisions on long term agricultural planning which is essential to maintain the self-sufficient status of its major crops. For instance, rice, a main crop in Sri Lanka is highly susceptible to variations of rainfall while other crops such as tea, rubber and coconut are also dependant on rainfall during different growth periods.

A number of studies have been conducted in Sri Lanka on climate change impacts on water resources and agriculture. Droogers (2004) showed that climate change will have an impact on water resources and, therefore, on food production in the *Walawe* river basin. According to his analysis, rainfall will be higher, temperatures will increase, evapotranspiration demands will be higher, and potential crop growth will rise due to elevated CO_2 levels. The total impact of these factors is that while long-term average yields and production will increase climate extremes will occur more frequently. De Silva *et al.,* (2007) showed that the wet season average rainfall for Sri Lanka will reduce by about 9% -17% by 2050 compared to the 1960-1990 baseline period and that average paddy water requirement will increase by 13%-23% by 2050. De Silva (2006) found that the changes in rainfall and temperature, together with other climatic factors, would increase the soil moisture deficit significantly in the dry zone areas in Sri Lanka. The study conducted by De Costa (2008) concludes that the temperature is increasing in all climatic zones of Sri Lanka. Other major studies on climate change can be found in Eriyagama *et al.,* (2010).

Therefore, to ensure food and environmental security in the coming decades Sri Lanka will require tools, methods, coping strategies and adaptations at every level of its food production and environment sustainability programs. Measuring impacts will require actual knowledge of the change of climate variables over the agro-ecological regions (Fig. 1.) as these regions represent uniform agro-climate, soil and terrain conditions that support a particular farming system where certain ranges of crops and farming practices find their best expression (Panabokke, 1996; Punyawardena, 2008). This research dwells upon the rainfall variability by a set of temporal dimensions up to 2050 across the agro-ecological regions of Sri Lanka.

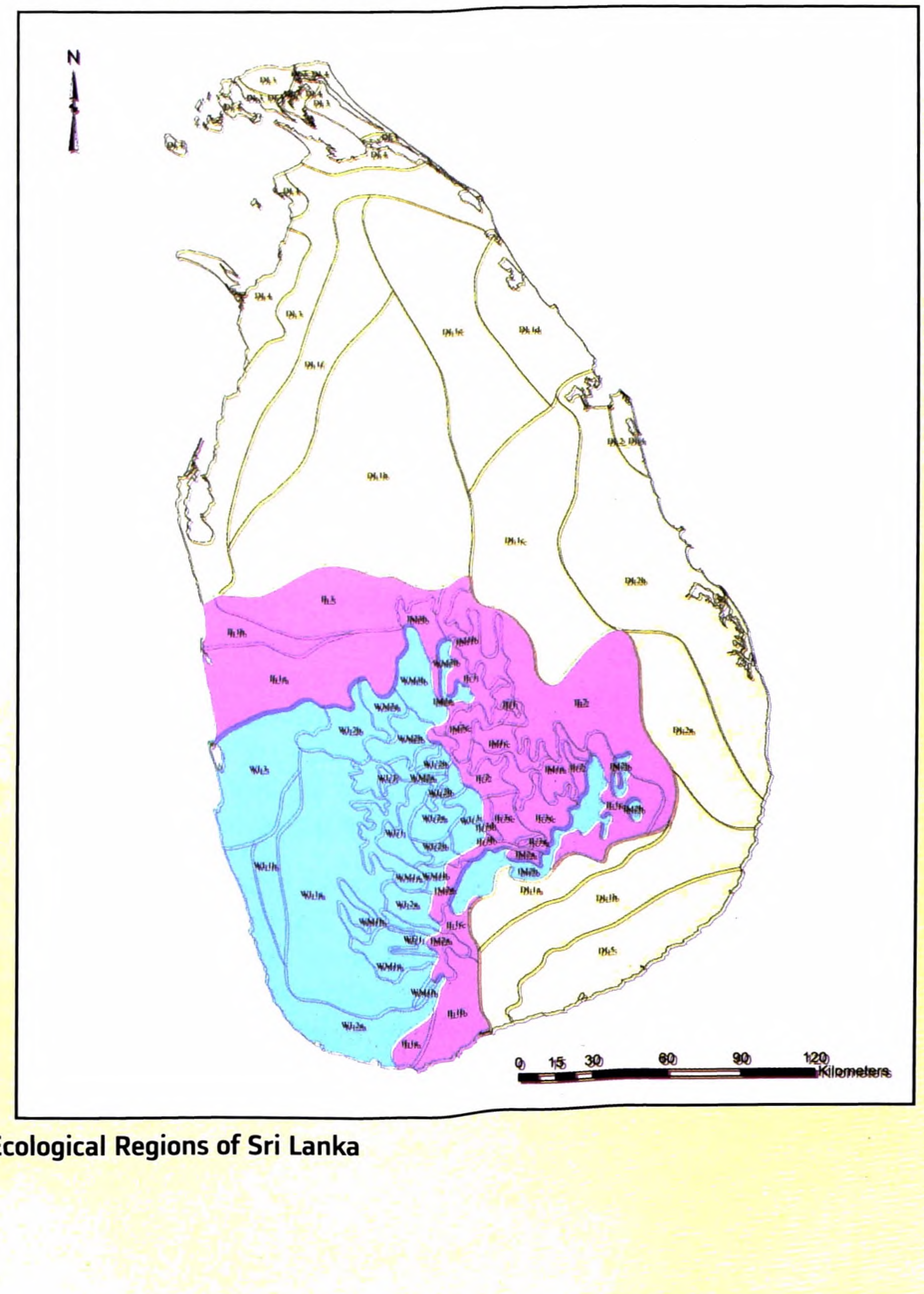

Fig. 1. Agro-Ecological Regions of Sri Lanka

METHODOLOGY

In this study the selected baseline period is 1971–2000 and rainfall data from 147 meteorological observation stations were used to compare climate change projections. Fig. 2 illustrates the spatial distribution of the rainfall stations used for the study. The criteria for selecting these stations were the availability of data for a continuous period of 30 years and the location of the stations across the country. Annual rainfall grids were interpolated based on the data collected from these stations and using simple Kriging (Goovaerts, 1999) interpolation method. Monthly climate change projections extracted from the outputs of the UK Hadley Centre for Climate Prediction and Research model (HadCM3) were applied to emission Scenario A1B. The digitized agro-ecological region map (Fig. 1), which comprises of 48 regions, based on the National Atlas of Sri Lanka (2007) was used.

RESULTS AND DISCUSSION

Current rainfall patterns (1971 – 2000)

Initially a simple trend analysis was carried out using data from 147 stations. In the baseline period (1971-2000), 76 of 147 stations showed decreasing trends in annual rainfall and 71 stations showed increasing trends (Table 1). In the wet zone 36 of the 57 stations (63%) indicated decreasing trends and the largest downward trend of 37.2 mm/year was found at the *Nakiyadeniya* station. In the intermediate zone 17 stations showed increasing trends. As shown in Table 1, 34 stations in the dry zone indicated

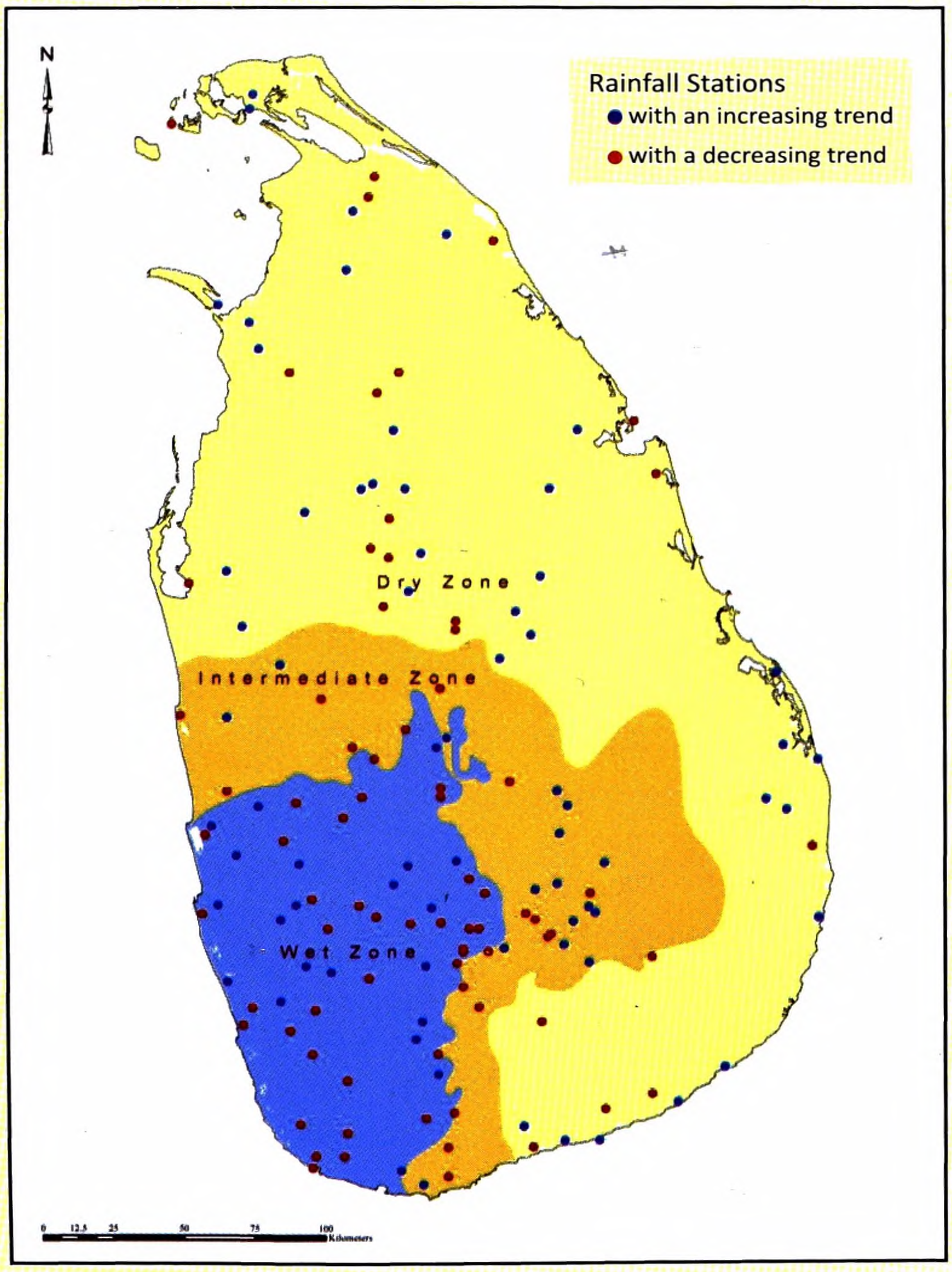

Fig. 2. Location of rainfall stations showing rainfall trends from 1970 to 2000.

increasing trends. The largest increase in rainfall of 15.1 mm/year was at *Palampoddar* in the dry zone. *Kantalai* (13.9 mm/year), *Jaffna* (13.1 mm/year), *Angamedilla* (11.4 mm/year), *Batticaloa* (10.1 mm/year), *Bakamuna* (9.6 mm/year) and, *Kalmunai* (8.3 mm/year) stations also showed increasing trends. Though these trends are not statistically significant, they indicated the direction of future rainfall trends.

In the dry zone, 34 of 56 stations (61%) showed increasing trends in the baseline period (Fig. 2). An increasing annual rainfall trend was found at the *Palampoddar* and *Jaffna* stations in the baseline period, which will change to a decreasing trend between 2020 and 2050. All other stations showed the same patterns observed in the baseline data.

1500 mm/year compared to the baseline period. This could be due to the errors in rainfall interpolation and the uncertainty of the rainfall projection.

The highest proportional increase of rainfall in 2050 is predicted to be in the Southern and South-Eastern parts of the country (*Kekenadura* (60%), *Mahawalatenna* (52%), *Ambalanthota* (40%), *Bata Ata* (32%) and *Yala* (31%). The highest proportional decrease of rainfall in 2050 is predicted to be in the dry region (*Jaffna* (11%) and *Vavuniya* (2%) and some parts of the wet zone (*Nawalapitiya* (28%) and *Canawarella* (27%))

Table 1. Results of the trend analysis for the rainfall stations in climatic regions

Climatic Zone	Increasing Trend of Rainfall		Increasing Trend of Rainfall		Total Number of Stations
	Number of Stations	%	Number of Stations	%	
Dry Zone	34	61	22	39	56
Intermediate Zone	16	47	18	53	34
Wet Zone	21	37	36	63	57
Total No. of Stations	71	48	76	52	147

Future rainfall

Mean annual rainfall for the baseline period for the whole country was 2094 mm while the projected values for 2050 is 2249 mm. The estimated MAR for the baseline period is slightly higher than the published value of 2000 mm (Madduma Bandara, 2000). The MAR over Sri Lanka will increase by 155 mm (7%) in 2050 compared to the baseline period.

The spatial patterns of the changes of total rainfall in 2050 compared to the baseline period are shown in Fig. 3. Total annual rainfall change over the country in 2050 will be within ± 500 mm over about 90% of the land area. In some small areas rainfall reduction will be more than

Rainfall in three major climatic zones and agro-ecological regions

Major climatic zones

Sri Lanka is divided into three major climatic zones namely dry, intermediate and wet zone. Dry zone is the area where MAR is less than 1750 mm while wet zone receives more than 2500 mm of MAR. An impact of climate change on rainfall in the major climatic zones of Sri Lanka is investigated and Fig. 4 presents the changes of climatic zone boundaries due to changes in rainfall in 2050.

The results presented in Fig. 4A suggest that there are some differences between currently used climatic zone boundaries and the boundaries

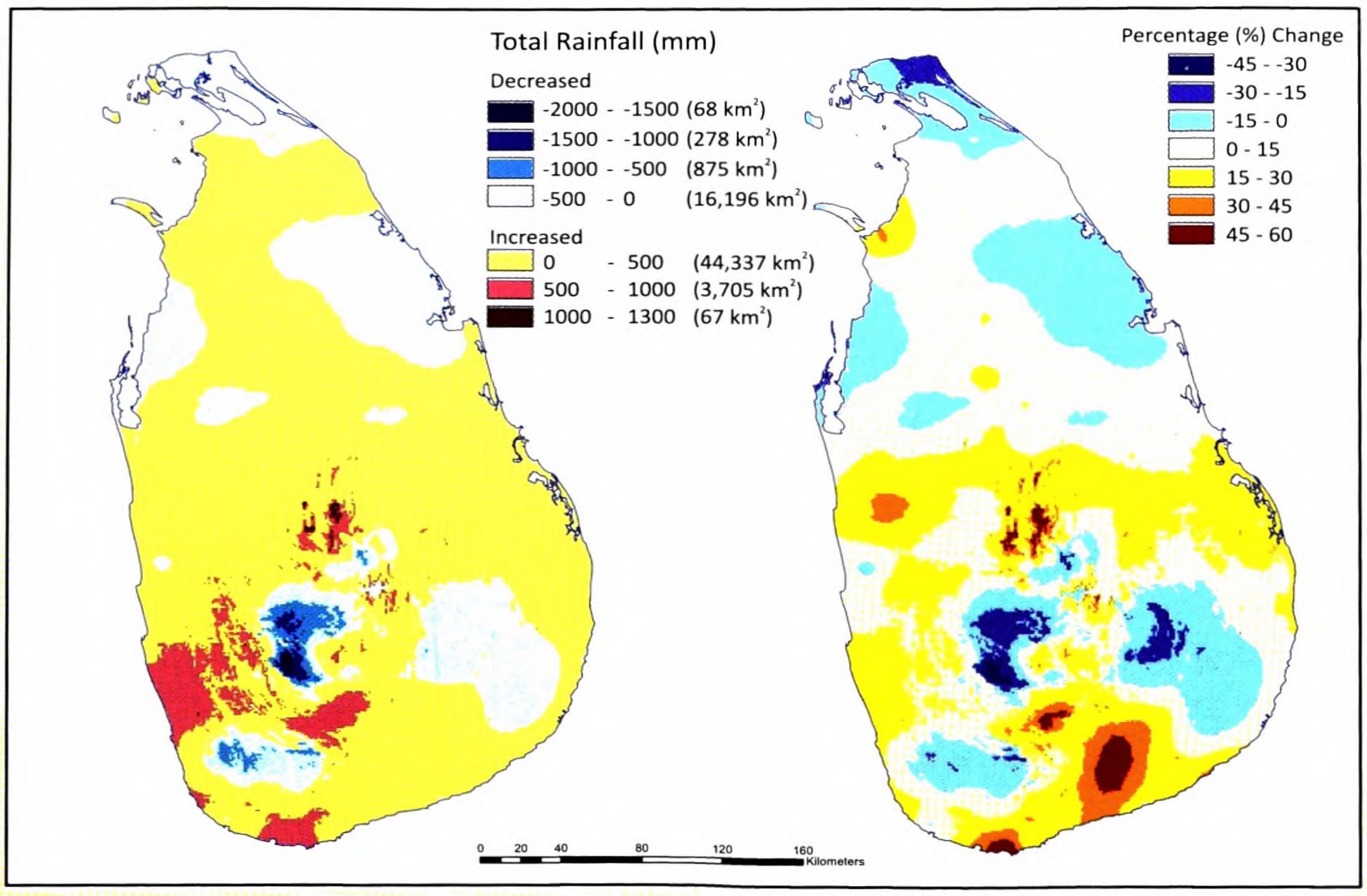

Fig. 3: Spatial patterns in changes of total rainfall in 2050 compared to baseline period (1970-2000)

demarcated during this study based on the data from the baseline period. However, for the comparison, the areas under current boundaries were used. Fig. 4B suggests that a substantial part of DL2a and DL2b regions would become the intermediate zone in 2050.

As shown in Fig. 4 and Table 2, the area extent under the wet zone by 2050 will be similar to the

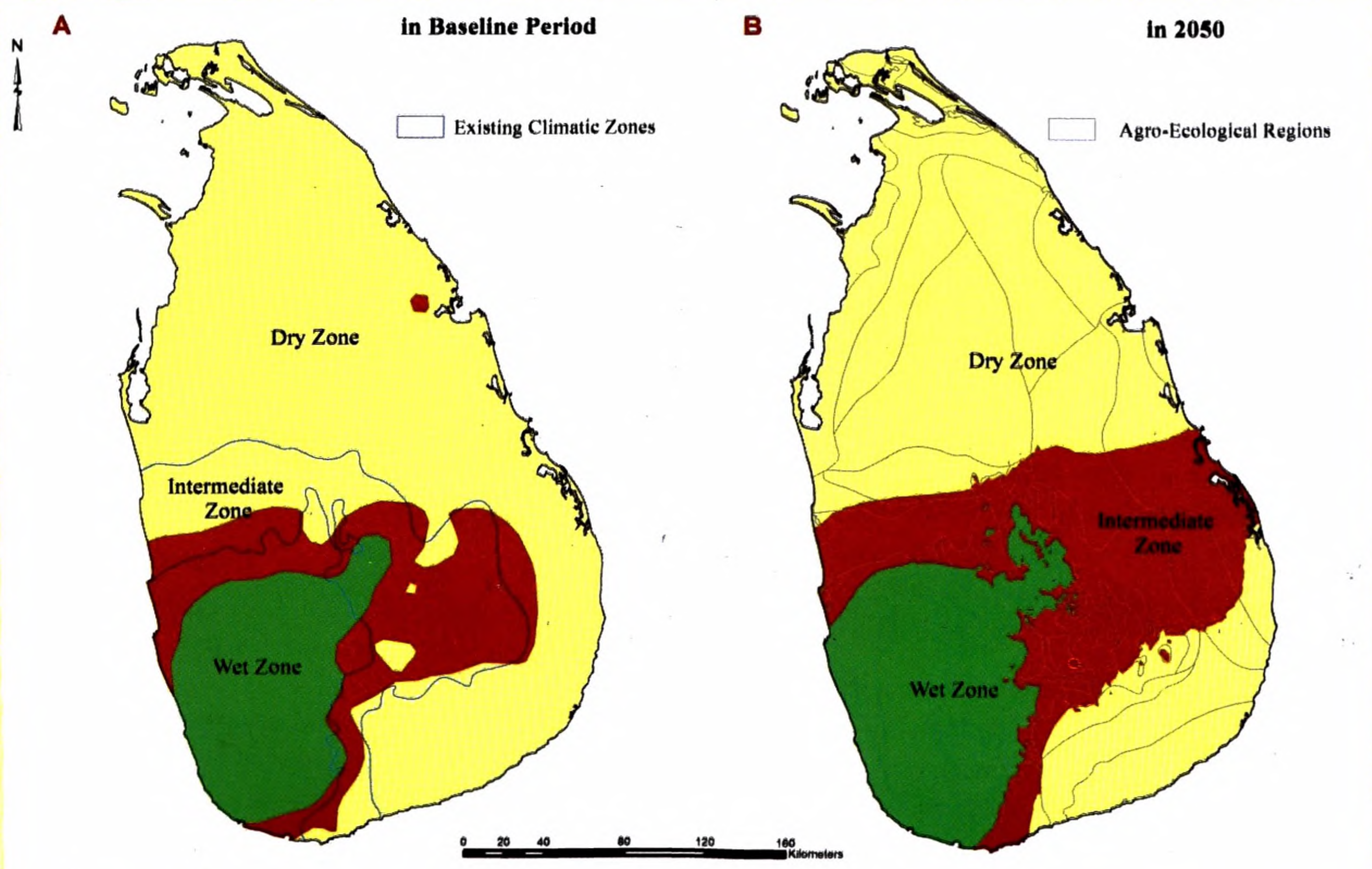

Fig. 4. Changes in climatic zone boundaries by 2050

Table 2. Current and projected areas (km^2) under three major climatic zones

Zone	Current	Baseline	2050	% change*
Dry	38,627	43,734	35492	-8.1
Intermediate	14,212	11,866	17312	21.8
Wet	12,696	10,278	12793	0.03

* Change of area compared to the current climatic zone map

present extent. Areas under the intermediate zone will increase by 21.8% while the dry zone will reduce by 8.1%. About 1639 km^2 currently under the wet zone will be in the intermediate zone by 2050 while about 5888 km^2 ha of area under the dry zone will be in the intermediate zone. About 1662 km^2 under the intermediate will be in the wet zone by 2050. Therefore, contrary to some studies (Imbulana *et al.,* 2006, Manawadu and Fernando, 2008), the area under the intermediate zone will increase by encroaching some areas in the current dry zone.

Agro-ecological regions

There are 13, 20 and 15 agro-ecological regions located in the current dry, intermediate and wet zones respectively (Fig. 1). Analysis of rainfall changes in agro-ecological regions revealed that 11 of the 48 agro-ecological regions, which represent 17% of the land area in the country, will experience rainfall reductions due to climate change (Table 3). These regions are WU1, DL3, DL4, DL1d, DL1e, IL1c, IM3c, IU2, WM2a, WU2b, WM1a and WM2a. The other 37 agro-ecological regions are expected to have increased rainfall in the future.

Further, the analysis revealed that two of the agro-ecological regions, DL2a and DL2b, currently identified as 'dry zone,' will receive MAR more than 1750 mm in 2050. This implies that these two regions could be classified under the 'intermediate zone,' in the future. These two regions are located in the eastern part of the country. Also, three regions in the intermediate zone, IM2a, IM3c, and IU1 will receive MAR more than 2500 mm by 2050 and could be classified as wet zone.

Table 3. Results of the trend test for agro-ecological regions

Climatic Regions	Number of AERs having		Total Number of AERs
	Increasing Trend of Rainfall	Decreasing Trend of Rainfall	
Dry Zone	10	3	13
Intermediate Zone	17	3	20
Wet Zone	10	5	15
Total Number of AERs	37	11	48

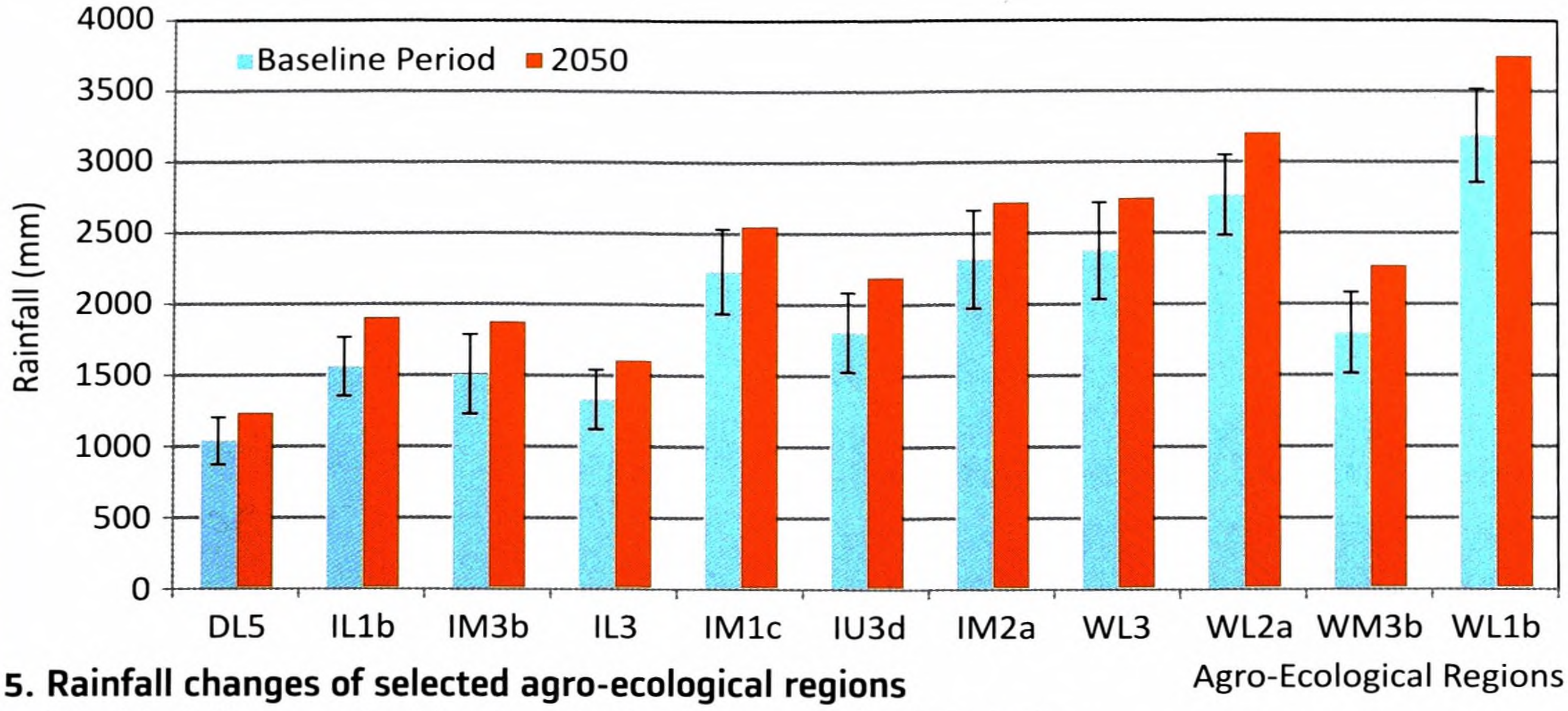

Fig. 5. Rainfall changes of selected agro-ecological regions
The black lines on the blue bars indicate the standard deviations.

Furthermore, to indicate the variability of rainfall during the baseline period, standard deviations of annual rainfall were estimated using the 30 year (1971 – 2000) data for all 48 agro ecological regions. Only 11 regions show that future rainfall by 2050 will exceed the limits of observed variability during the baseline period (Fig. 5). This suggests that out of the 37 regions that experience the increase of rainfall, only 11 regions would definitely be affected by climate change according to the climate change scenario used. In other regions, the projected rainfall will be within the variability found in the base line period.

MAR in IM3b, IL1b, and IL3 during the baseline period is less than 1750 mm, which indicates the dry conditions of these areas. This must be investigated since these regions are currently classified as the intermediate zone that receives more than 1750 mm of MAR. Among these 11 regions, three regions in the wet zone, WL2a, WM3b, WL1b, show a significant increase compared to the baseline period while the other six regions marginally exceed the upper limits of the baseline period.

CONCLUSIONS

The analyses revealed that MAR of Sri Lanka will increase by 155 mm, which is about 7%, in 2050 when compared with the baseline period (1970-2000). The highest proportional increase of rainfall in 2050 is predicted to be in the Southern and South-Eastern parts of the country. The dry zone area will reduce by 8.1% while the area under the intermediate zones will increase by 21.8% by 2050. Among the 48 agro-ecological regions, 11 agro-ecological regions were identified with a decreasing trend of rainfall patterns due to climate change. The rest of the agro-ecological regions displayed an increasing trend of rainfall in the future. Among the regions that have increasing patterns, 11 agro-ecological regions were recognized as mostly affected regions from increasing rainfall changes. Further, results of this study suggested that the areas under the current major climatic zones may change by 2050. Two agro-ecological regions currently identified as under the dry zone could be classified as intermediate zones while three zones in the current intermediate zone may move into the projected wet zone by 2050.

Since all models have inherent error bounds, Global Circulation Model (GCM) errors may have affected the model outputs and the study results. This study only uses the outputs from HadCM3 and A1B Emissions Scenario. Therefore, for a clear idea of the range of rainfall variation, outputs from other models need to be analyzed. The uncertainty bounds could be described with these results.

This study only evaluates the impacts of climate change on rainfall. These results should be analyzed with other aspects such as temperature and evapor-transpiration, which would help to estimate water availability and requirement for different crops under future climate projections.

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REFERENCES

Chandrapala, L. (1996). Long term trends of rainfall and temperature in Sri Lanka. Climate Variability and Agriculture, Abrol, Y. P., Gadgil, S. and Pant, G.B. (Eds.), Narosa Publishing House, New Delhi, 153-162.

De Silva, C. S. (2006). Impacts of climate change on potential soil moisture deficit and its use as a climate indicator to forecast irrigation need in Sri Lanka. In: Symposium Proceedings of the Water Professionals' Day 2006, Dayawansa, N. D. K. (Ed.), ...

De Silva, C. S., Weatherhead, E. K., Knox, J. W. and Rodriguez, D. J. A. (2007). Predicting the impacts of climate change, A case study of paddy irrigation requirements in Sri Lanka, Agric. Water Manag., 93: 19-29.

De Costa, W. A. J. M. (2008). Climate change in Sri Lanka: myth or reality? Evidence from long-term meteorological data, J. Nat. Sci. Found. of Sri Lanka, 36 (Special Issue): 63-88.

Droogers, P. (2004). Adaptation to climate change to enhance food security and preserve environmental quality: example for southern Sri Lanka. Agric. Water Manag., 66: 15–33.

Goovaerts, P. (1999). Geostatistics in Soil Science: state-of-the-art and perspectives, Geoderma, 89: 1–46.

Eriyagama, N., Smakhtin, V., Chandrapala, L. and Fernando, K. (2010). The Impact of Climate Change on Water Resources and Agriculture in Sri Lanka: A Review and Preliminary Vulnerability Mapping, Research Report 135, International Water Management Institute (IWMI), Colombo, Sri Lanka,

Imbulana, K. A. U. S., Wijesekera, N. T. S. and Neupane, B. R. (Eds.) (2006). Sri Lanka National Water Development Report, MAI & MD, UN-WWAP, UNESCO and University of Moratuwa, Sri Lanka, Paris and New Delhi.

International Panel for Climate Change (IPCC), Switzerland. (2007). [available at http://www.ipcc.ch/organization/organization_history.shtml] [viewed on 24/06/2012].

Maddumabandara, C. M. (2000). Water Resources of Sri Lanka in Natural Resources of Sri Lanka, National Science Foundation, Sri Lanka.

Manawadu, L. and Fernando, N. (2008). Climate Change in Sri Lanka, University of Colombo Review, J. the Uni. of Colombo, Sri Lanka, New Series; :1, No 02, 2007/2008

National Atlas of Sri Lanka. (2007). Second Edition, Department of Survey, Colombo, Sri Lanka.

Panabokke, C. R. (1996). Soils and Agro-Ecological Environments of Sri Lanka, Natural resources energy and Science Authority, Maitland Place, Colombo 07, Sri Lanka.

Punyawardena, B. V. R., (2008). Precipitation of Sri lanka and Agro-Ecological Regions, Agriculture Department of Sri Lanka, Agriculture Press, Gannoruwa, Sri Lanka.