Effect of Rainfall Abnormalities on Rice Yield in Hambanthota District, Sri Lanka

H.L.K. Sanjaya[1], Priyadarshana.T[2], T.M.N. Wijayaratna[3]

Department of Limnology
University of Ruhuna, Sri Lanka
Corresponding author's email: *hlksanjaya {at} yahoo.com*

Department of Limnology
University of Ruhuna, Sri Lanka

Department of Civil Engineering
University of Moratuwa, Sri lanka

ABSTRACT---- ***The sown area is continuously being increased in Hambanthota district; the rice production has not fulfilled its expected optimum yield. As the agriculture is mainly based on the rainfalls received to this region, the sentiment of the farmers on this matter is the shift of the crop season due to the climatic consequences. However, no proper scientific investigation has been done to see whether the rainfall pattern and intensity has changed. Neither future projection is available. Therefore, there is an urgent need to study the shifting the rainy seasons to re-determine the crop season in order to enhance the rice production in the district. It was collected available monthly rainfalls data for three stations called Hambanthota, Tissamaharama and Mamadala from 1869 to 2010. The recent data related to the rice production and cultivated area was obtained for last six years. Changes of the rainfall data were analyzed with the help of SPSS 16.0 and trends, percentage attainment of rainfalls during the Yala, and Maha seasons were calculated. It is clear that the expected yield has not been attained, though it receives 61.7%, 68.4% and 61.2% of the annual rainfall in Hambanthota, Tissamaharama and Mamadala respectively during the Maha season. The trend of mean annual rainfall moves along a steady line for next two decades. There is not a significant spatial variation (p>0.05) of the rainfalls among three different stations as well as monthly rainfall data over the last century in Hambanthota district. Since there is not a significant shift of rainy season, the reduction of expected rice yield cannot be introduced as a cause of an abnormality in rainfalls in the district.***

Keywords--- Rain fall distribution, Rice yield, Crop seasons, Climate change

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1. INTRODUCTION

Although global climate projections are available for most parts of the world and future trends have explained [1], within country projections for different climatic zones are not available for many tropical countries. For an example many studies projecting within country variations in climate in India has concluded that regional variations as significant and having profound effects on livelihood and nature [2], [3].

Sri Lanka is a tropical country, but due to topography and rainfall, three major climatic zones have been identified [4]. Among them, semi- arid zone is the most water scarce zone as the mean annual rainfall 1450mm/yr. [5] and the mean annual evapo-transpiration (1750mm/yr.) exceeds the annual rainfall. The dry zone covers 3/4 of the total area of the country while remaining the other part remains as the wet zone. 70% 0f the annual rainfall is received during the Maha season which is the North east monsoon and the other 30% is shared among Yala season (South west monsoon) and two inter monsoon seasons [5].

Hambanthota district is in southern province of Sri Lanka consist of 2609.3km^2 in land area. The estimated population is nearly 595877 and the population growth rate is about 1.17 % [6]. With the development and the population growth, the demand for agriculture production is being increased and the extent for paddy cultivation is increased. As the paddy cultivation is basically depended on received rainfalls to the region, the abnormalities of rainfalls due to the climatic changes will be an upcoming threat for the rice yield.

However, regional climatic projections have not been done specially for rainfall which is the key source of water for residents. Despite the increase in the extent of cultivated paddy land, the expected yields not been achieved. Anecdotal information suggests this is due to change in rainfall, both intensity and pattern. However, no proper scientific investigation has been done to see if rainfall pattern and intensity has changed. Neither future projection is available.

The North eastern monsoon brings heavy rain falls to the dry zone of the country including Hambanthota district from October to February. This is introduced as the Maha season that the maximum rice production is generated from the dry zone. The South western monsoon is conveyed relatively low rainfalls during May to September introduces as the Yala season (Yala kannaya) to the dry zone. The government introduced recently the third season as the "Meda Kannaya" from August to November as a solution for the inclement of rice production. Many studies have been done in Sri Lanka to predict the vulnerability of different areas due to climatic changes [7], [8], [9], and [10]. [11] reveals that, there would be an inclement of demand of water for irrigation purposes in "Maha kannaya" in 13% to 23% in next 40 years period as a result of climate change dry zone. Therefore, there is an urgent need for studying the impact of shifting the rainy season on the rice production in Hambanthota district and re-railing the crop season in order to proceed the cultivations without the water shortage within the corrected crop season.

2. METHODOLOGY

Three rainfall stations were selected from three distant places in Hambanthota district (**Figure 1**). Recent monthly rain fall data (1990-2010) were obtained from the Department of Meteorology for last twenty years and the rest were obtained from the book of Long-term hydro-meteorological data in Sri Lanka [12] from 1869 to 1990 in Hambanthota area. Monthly rain fall data for 111 year were obtained for Tissamaharama area and 51 years data for Mamadala area as the shortage of recent data. Data on cultivated area and the rice production from 2004 to 2010 were obtained from the paddy statistic of census and statistic department, Sri Lanka.

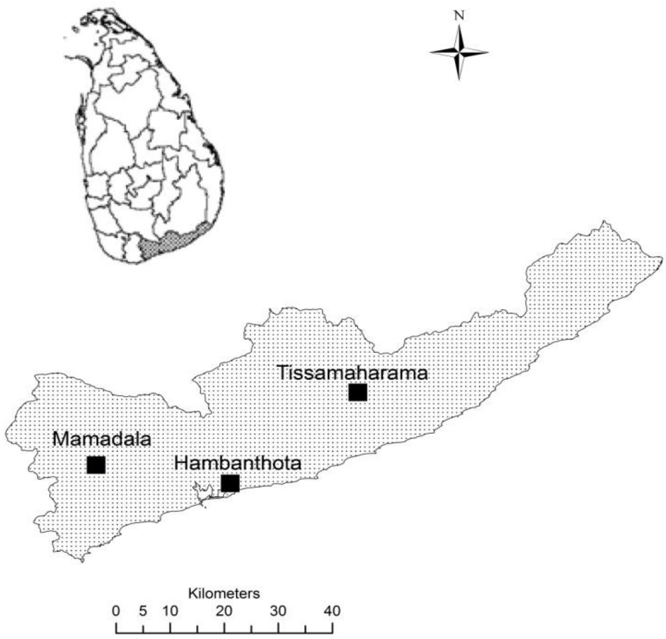

Figure 1: The three rain fall stations which were selected for the analysis of shifting the rainy seasons in Hambanthota district

The mean percentage receive of rainfalls were calculated for Yala and Maha season and the prediction of annual rainfalls for next 20 years in Hambanthota were done with the help of *ARIMA (101) (111)* model [13]. Rain fall prediction from 1990-2010 was done by *ARIMA (101) (111)* model and the predicted values and real values were compared to observe whether there is a significant difference in twenty years rainfall prediction. The monthly rainfall data were classified in to decades for the convenience of analysis. One-way ANOVA test was used to analyze the data for significant differences in received rainfalls in each decade with the help of SPSS 16.0. Annual rainfall, Maha and Yala rainfall also were separately considered for analysis to observe whether there is a significant shift of rainfalls. Further, the same test was done to observe whether there is a significant difference between three selected stations in terms of rainfall data from 1941 to 1990 this period has complete data set for all three stations. Daily rainfall data for 14610 days from 1951 to 1990 were analyzed to calculate the number of dry and wet days. The probability of occurrence of daily maximum rain fall and the return period also was calculated by using Weibul formula [14]. The return period and the probability occurrence of maximum rainfalls in Maha and Yala seasons were calculated by using above method

$$P_m = P(X \geq x_m) = \frac{m}{n+1} \text{ (Weibul formula)}$$

Where, *m* is the rank of an individual point after ranking largest to small and *n* is the total number of data points in the data series.

The relationship between probability and the return period is given as,

$$p = \frac{1}{T}$$

Where, p is the probability which was obtained from the Weibul formula and the T is the return period of a particular rainfall.

The probabilities of occurrence of maximum daily rainfall, Maximum annual rainfall and Maximum rainfall in Yala and maha seasons at least once during next 20 years were calculated by following "Bernoulli distribution".

$$f(x, n, p) = \frac{n!}{(n-x)!\,1!}(p^x)(1-p)^{n-x}$$

Where, *x* is the number of expected events, *n* is the number of predicted years; *p* is the probability of the event.

3. RESULTS

The average annual rainfall in Tissamaharama is about 1046mm/yr. and 68.4% of the rainfall is attained in Maha season. The other 31.6 % can be expected in Yala season. The mean annual rainfall in Hambanthota is 1021mm/yr. and the 61.7% of this rainfall is received during the Maha season and the other 38.3% is received in Yala season. Mamadala area is received 1066mm/yr. and 61.2% of the rainfall is received during the Maha season and the rest 38.2% is received in Yala season (**Figure 2**).

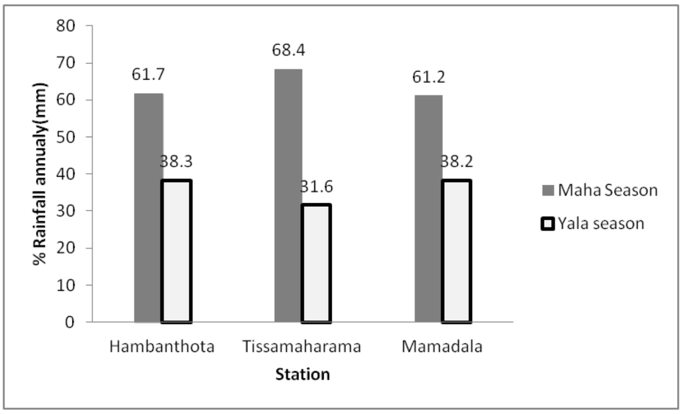

Figure 2: Percentage rainfall received during Yala and Maha season in Hambanthota, Tissamaharama and Mamadala.

According to the results of one way ANOVA test which was conducted for monthly, seasonal and annual, monthly average rainfall data (**Table 1**), it showed a significant difference (p<0.05) of rainfalls in January at Hambanthota. But, there was not a significant difference of rainfalls in Yala and Maha season, average monthly rainfall and annual rainfalls. However, there was a significant difference of Rainfalls in Yala season at Tissamaharama area (**Table 2**).

Table 1: One-way ANOVA table of comparing the annual rainfalls in Hambanthota, Tissamaharama and Mamadala.

ANOVA					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	12328.14	2	6164.068	0.092	0.913
Within Groups	9554367	142	67284.28		
Total	9566695	144			

Table 2: Significance at 0.05 probability level of ANOVA test which was conducted for monthly rainfall data at Mamadala, Hambanthota and Tissamaharama in Hambanthota District

	Significant value		
Rain fall(mm)	Hambanthota	Tissamaharama	Mamadala
Mar	0.17	0.29	0.64
April	0.36	0.36	0.65
May	0.15	0.11	0.14
Jun	0.99	0.55	0.47
Jul	0.09	0.12	0.26
Aug	0.07	0.20	0.22
Sep	0.23	0.57	0.33
Oct	0.80	0.93	0.16
Nov	0.54	0.39	0.76
Dec	0.14	0.50	0.62
Jan	0.04*	0.07	0.28
Feb	0.35	0.16	0.08
Yala	0.29	0.03*	0.23
Maha	0.24	0.50	0.22
Meda	0.29	0.82	0.18
Annual	0.17	0.22	0.11
Monthly average	0.07	0.22	0.14

*Significant at 5% probability level

Nevertheless, the rainfalls in Maha season, annual rainfall and average monthly rainfall did not show a significant disparity. When concern about the rainfalls in Mamadala area, the status is difference and there was not any significant difference of average monthly rainfalls, annual rainfalls, rainfalls in Yala and Maha season.

Table 3: Mean number of dry days during 1941 -1994 in each month and two cultivating seasons at Hambanthota.

Month/Season	Mean number of dry days
Mar	25
April	21
May	21
June	21
July	23
August	23
September	21
October	18
November	15
December	20
January	23
February	23
Maha season	120
Yala season	133

Other than October, November and December, the mean number of dry days is higher than 60% (**Table 3**).The recorded daily maximum rainfall in Hambanthota district from 1951 -1990 was 99.8mm. The number of dry days from 14610 days during this period was 10362 days and the number of wet das was 4228. When it is indicated as a percentage, dry days and wet days were 71% and 29% respectively. The probability of occurrence of 99.8mm daily rain fall was 0.02 and the probability of this event is 2 times during 100 years.

Table 4: The table of One-way ANOVA test which was conducted for analyzing the difference between forecasted and real rainfall values from 1990-2010 in Hambanthota.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1032.467	1	1032.467	0.045	0.832
Within Groups	886998.1	39	22743.54		
Total	888030.6	40			

The forecasted values from 1990 to 2010 were not significantly different from real rain fall values during this period and the prediction accuracy was good enough for 20 years. Last 20 year average rainfall was about 1037.5mm and the forecasted 20 year average was not shown much deviation and it was 1026mm (Figure 3).

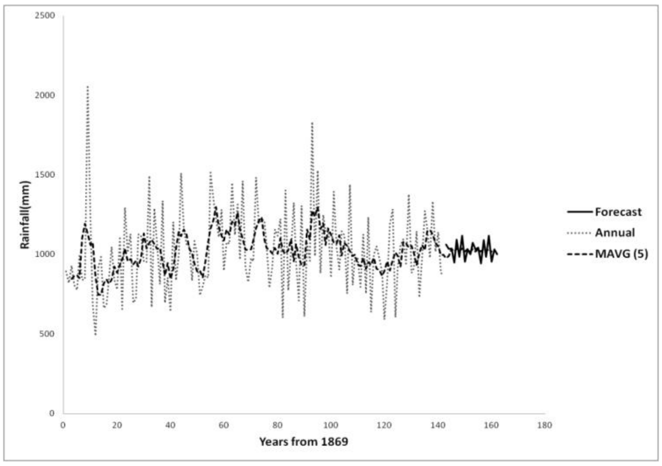

Figure 3: The forecasted, annual and 5 year moving average rainfalls in Hambanthota

4. DISCUSSION

Though it has been mentioned that the rainfall gain in Maha season is 70% of the total annual rainfall in dry zone of the country [5], the value was around 61% and only the rainfalls in Tissamaharama (68%) was closer to pre-introduced value. Yala season is received about 38% of total rainfall in Hambanthota and Mamadala while Tissamaharama is received about 31.6%. However, there was a significant similarity ($p=0.913$) of annual rainfalls among the three selected stations as the area does not show contrast topographical variations as it is mostly an undulating flat terrain [15]. Therefore, it is fair to forecast for one station and make the prediction for other two stations in the district.

Monthly rainfall data do not vary significantly ($p > 0.05$) within the stations overtime in the district, But there was a significant difference ($p<0.05$) in monthly rainfalls over 142 years at Hambanthota in January. Though January belongs to Maha season, it does not strong enough to make a significant difference of total rainfall in Maha season. The trend of rainfalls shows seasonal undulations of the annual rainfall data and it doesn't show a reducing trend even in the next couple of decades. In general, if the rainfalls which get during a particular month can be restricted for few days without much changes of total rainfall in that month. This may create an overland flow that is unable to retain in water storing structures making water shortage in the adjacent dry season. It was analyzed daily data from 1941 to 1994 to make sure whether this phenomenon is being happened in Hambanthota district. The recorded maximum daily rainfall during this period is 99.8mm and the number of dry days was 10362 out of 14610 days (71%). As the daily rainfalls are not concentrated in to certain group of days and even in November and December which the higher rainfalls receive to the district experienced more than 15 dry days (**Table 3**), it may not cause an unbearable overland flow.

According to the studies of historical irrigations, dry zone of the country including Hambanthota district reveals that there was a systematic and well organized ancient irrigation technology that can store water and utilize water for the sustainable development of the agriculture [4], [15],[16], [17], [18]. Only 653 small tanks are in functional stage out of 1410 small tanks in Hambanthota district which were successfully stored water in the history. Therefore a vast capacity has been missed out due to the omission of the value of small tanks [15]. Therefore, there is an urgent requirement for studies on the ancient irrigation system and its ability to retain excess water in the district.

In this sense it is clear that the problem is somewhere else than the anecdotal information which suggests that the reduction of expected rice yield is due to the shift of rainfall seasons compared to the past. Therefore, the reduction of expected rice is not due to the shift of rainy seasons since there is not a significant shift of the major crop seasons in the district.

5. ACKNOWLEDGEMENT

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6. REFERENCES

[1] Ottmar, E., Madruga, R.P., Sokona.Y, 2012. Renewable Energy Sources and Climate. 1st ed. USA: Cambridge University Press

[2] Lal, M., Sign, K., Rathore, L.S., Srinivasan, G., Saseendran, S.A., 1998. Vulnerability of rice and wheat yield in NW in India to future changes in climate. Agriculture and forest meteorology. 89, pp.101-114.

[3] Jalota, S.K, K., Harsimran, K., Samanprteet, B.B., Vashisht. 2013. Impact of climate change scenarios on yield, water and nitrogen balance and use efficiency of rice-wheat croping system. Agricultural water management. 116, pp.29-38

[4] Smarten, P.G., Jayakody, P., Molle, F., Jinapala, K. 2005. Small tank cascade systems in Walawe River Basin. Colombo, Sri Lanka: IWMI. 46p. (Working paper 92)

[5] Amarasinghe, U. A., Mutuwatta, L. and Sakthivadivel, R. 1999. Water scarcity variations within a country: A case study of Sri Lanka. Research Report 32. Colombo, Sri Lanka: International Water Management Institute.

[6] Census of population and housing 2012. Population of Sri Lanka by district. Department of census and statistics, Colombo.

[7] Chandrapala, L. 1996a. Calculation of areal precipitation of Sri Lanka on district basis using Voronoi Tessalation Method. Proceedings of National Symposium on Climate Change, Central Environmental Authority, Colombo, Sri Lanka, March 7-8, 1996.

[8] Chandrapala, L. 1996b. Long term trends of rainfall and temperature in Sri Lanka. In: Climate variability and agriculture, eds., Abrol, Y. P., Gadgil, S., Pant, G. B. (eds). New Delhi, India: Narosa Publishing House.

[9] Jayathilake, H.M., Chandrapala, L., Basnayake, B.R.S.B. and Dharmaratne, G.H.P. 2005, Water Resources and Climate Change Proceedings, Workshop on Sri lanka National Water Development Report, eds. Wijesekera, N.T.S., Imbulana, K.A.U.S. and Neupane, B., World Water Assessment Program. Paris, France.

[10]Peiris, T.S.G., Wijerathna, M., Ranasinghe, C.S., Ananda Kumaraswamy, A., Fernando, M.T.N., Jayakody, A., Rathnasiri, J. 2004. Impact of Climate change on Coconut and Tea industry in Sri Lanka. Paper presented at the 2nd AIACC Regional workshop for Asia and Pacific, Manila, Philippines.

[11]De Silva, C. S.; Weatherhead, E. K.; Knox, J. W.; Rodriguez-Diaz, J. A. 2007. Predicting the impacts of climate change – a case study of paddy irrigation water requirements in Sri Lanka. Agricultural Water management 93(1-2):19-29.

[12]Nakgava, K., Edgawa, H., Nakamura, V., Aoki, M., 1995. Long-term hydro-meteorological data in Sri Lanka; Data book of Hydrological cycle in humid, Tropical ecosystems, Part I, Japan; University of Tsukuba.

[13]Momani, P.E.N.M., "Time Series Analysis Model for Rainfall Data in Jordan: Case Study for Using Time Series Analysis", American Journal of Environmental Sciences, vol. 5, no. 5, pp. 599-604, 2009.

[14]Haan, C. T. 1994. Statistical Methods in Hydrology. Iowa State University Press. Ames.

[15]Panabokke, C. R., R. Sakthivadivel; A. D. Weerasinghe. 2002. Evolution, present status and issues concerning small tank systems in Sri Lanka. Colombo, Sri Lanka: International Water Management Institute.

[16]Sakthivadivel, R., N. Fernando, and J. D. Brewer. 1997. Rehabilitation planning for small tanks in cascades: A methodology based on rapid assessment. Research Report 13. Colombo, Sri Lanka: International Irrigation Management Institute.

[17].Nimal P.De Silva,D.L.O. Mendis, V.E.A. Wikramanayaka, 1995. Scientific principles seen in ancient artifacts and monumental structures. Science education series.

[18].Basnayake, H.T, 2005. Purana lankawe jala shistacharaya. 2nd ed. colombo,10: samanthi publishers