Recent Changes of Rainfall Regime of *Hakwatuna Oya* Watershed of Sri Lanka

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**ABSTRACT:** This study was conducted to verify farmers’ claim, which was also verified by a field survey, that the availability of water in the *Hakwatuna Oya* irrigation scheme in Sri Lanka has decreased due to variability of rainfall in the watershed area as a result of climate change. Daily rainfall data of 10 selected stations representing “Hakwatuna Oya” watershed over a 50 year period (1961-2010) were used in this study. The linear regression analysis was used to study the annual trend of rainfall during the study period from 1961-2010. The variability of rainfall during recent decades (1991-2000, 2001-2010) and the most recent 20-year period (1991-2010) was compared with the base period of 1961-1990, recommended by the World Meteorological Organization (WMO) for climate studies, using Coefficient of Variation (CV %), student t-test and confidence interval at 95 percent. The results showed that there was no significant trend of annual rainfall over the last 50 years. In relation to the four rainfall seasons, there was no significant variability of rainfall during the last two decades compared to the base period, except for few stations. However, the rainfall variability of South West Monsoon (SWM), Yala and Maha seasons displayed significant differences in mean rainfall for Siyabalangamuwa rainfall station, which is the closest to the *Hakwatuna Oya* scheme in the Intermediate zone. The mean rainfall during post 1990 period was lower than the base period during SWM and Yala season whereas it has increased during Maha season.

**Keywords:** Climate change, rainfall variability, *Hakwatuna Oya*

**INTRODUCTION**

Rainfall in Sri Lanka displays a distinctive characteristic of high temporal as well as spatial variation (Punyawarden, 2007). A major share of rainfall to Sri Lanka is accounted by monsoonal, convectional activities and formation of weather systems in the Bay of Bengal (Punyawarden, 2005). Additionally, it is also governed by the northward and southward migration of the Inter Tropical Convergence Zone (ITCZ) during the year (Jayewardena et al., 2005). The two wind regimes, the South West Monsoon (SWM) occur during the period of May to September and the North East Monsoon (NEM) during the period of December to January influence the seasonal rainfall of the island (Kankanam et al., 2007). During the period between two monsoons, the ITCZ lies on or near to Sri Lanka and enhances the regional convections forming low level disturbances, depressions and vortices in the Bay of Bengal and the Arabian sea. This process has an influence in the locality providing ample

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rainfall to the entire island during the months of October to November, in a season identified as the Second Inter Monsoon (SIM). When the ITCZ is not active, convective activities due to intensive heating of the land governs the rainfall in this period (Chandrapala, 1995; Punyawardena et al., 2004; De Silva et al., 2006; Punyawardena, 2007). During the months from March to April, a rainfall season recognized as the First Inter Monsoon (FIM) produces high intensity rains mainly due to thunderstorms resulting from convection activities (Punyawardena et al., 2004; Punyawardena, 2007).

Sri Lanka being predominantly agricultural country, has two main cropping seasons associated with rainfall. The SIM and NEM rainfall seasons together forms the major cultivation season known as Maha (September – February) and the FIM and SWM collectively forms the minor cultivation season recognized as Yala (March – August) (Zubair, 2002; Chithranayana and Punyawardena, 2007). The major rice growing areas of the country are located in the Dry zone (DZ) and the Intermediate zone (IZ). Many Agro-Ecological Regions (AER) in both DZ and IZ do not have a proper Yala season and are most vulnerable to droughts thus high variability of rainfall will have negative impacts on the rain fed, as well as irrigated paddy cultivation (Chithranayana and Punyawardena, 2013).

Researchers have observed that there is no significant trend in Sri Lanka’s mean annual rainfall (MAR) during the last century except higher variability (Jayawardene et al., 2005; Chandrapala, 1995). Few other studies on the prediction of the future climate of Sri Lanka suggests an increase in annual average rainfall across the country while a decrease in rainfall in the Dry areas of the country (Punyawardena et al., 2013; De Silva, 2007).

This study was conducted in response to many stakeholders, including farmers, in the Hakwatuna Oya irrigation scheme who complains, which was also verified during a field survey, that the “availability of water for cultivation has decreased during recent years”. The water for cultivation in the above scheme comes from two sources, i.e. rainfall and irrigation water issues from the Hakwatuna Oya reservoir. It was hypothesized that this could be due to two reasons; firstly due to rainfall variation as a result of climate change and secondly due to anthropogenic activities. This paper attempts to find the validity of the first possibility by investigating the trends and variation in the rainfall received in the Hakwatuna Oya watershed and its neighbouring areas in the recent decades compared to the past. The findings would be useful in deriving long term strategies to address this water scarcity issue.

**MATERIALS AND METHODS**

Daily rainfall values of selected ten rainfall stations representing Hakwatuna Oya watershed in the agro ecological regions (AER) of WM3b, IL1a, IL3 and DL1b over a 50 year period (1961-2010) was used in the study. The normal ratio method (Linsley et al., 1982) using three neighbouring stations, was used to estimate the missing rainfall data of each data series. The selected rainfall stations are given in Figure 1 and Table 1. The daily rainfall values were converted to annual rainfall, four seasonal rainfalls (i.e. FIM, SWM, SIM, NEM), and two growing seasons (i.e. Yala and Maha).

Linear regression analysis with the significance test at 5% probability was used to study the annual trend of rainfall during the study period from 1961 to 2010. The variability of rainfall during recent time frames (1991/00, 2001/10, 1991/10) was compared with the base period of 1961/90 using Coefficient of Variance (CV).
This base period has been stipulated by the World Meteorological Organization (WMO) for comparative studies of climate change analysis and, hence was used for this study. A two sample student t-test was conducted to find the significant difference of cumulative rainfall of different time periods against the base period assuming equal variances. The annual rainfall events during last two decades were plotted against the confidence interval (CI) of rainfall received during the base period. The dry years, (i.e. rainfall below the lower CI) and wet years (i.e. rainfall above the upper CI) were obtained to find whether farmers have experienced more dry years compared to wet years or vice versa during the recent decades.
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The same analysis was also conducted for two growing seasons as well as for four rainfall seasons.

Table 1. Selected rain gauge stations of the study

| AER  | Station     | Station No | Latitude | Longitude |
|------|-------------|------------|----------|-----------|
| WM3b | Matale      | 1          | 7.47 N   | 80.62 E   |
| IL1a | Bathalagoda | 2          | 7.52 N   | 80.45 E   |
|      | Kurunegala  | 3          | 7.47 N   | 80.35 E   |
| IL3  | Mediyawa    | 4          | 7.88 N   | 80.28 E   |
|      | Siyabalangamuwa | 5   | 7.95 N   | 80.45 E   |
|      | Wariyapola  | 6          | 7.63 N   | 80.25 E   |
| DL1b | Kalawewa    | 7          | 8.00 N   | 80.53 E   |
|      | Kandalama   | 8          | 7.87 N   | 80.68 E   |
|      | Mahailluppallama | 9    | 8.60 N   | 80.27 E   |
|      | Maradankadawala | 10  | 8.13 N   | 80.57 E   |

RESULTS AND DISCUSSION

Annual Rainfall
The linear trend of annual rainfall over 50 years in the stations surrounding the Hakwatuna Oya watershed shows no significant trend for the observed time period (Table 2).

Annual Rainfall Variability
The CV (%) for annual rainfall calculated for the selected stations surrounding Hakwatuna Oya watershed for the 1961/90 base period and the next 10 year and 20 year periods are displayed in Table 3 and the annual mean values are given in Table 4.

Table 2. Linear trend of 50 years annual rainfall

| AER  | Station         | 1961-2010 |
|------|-----------------|-----------|
|      |                 | R²        | p        |
| WM3b | Matale          | 0.000     | 0.987    |
| IL1a | Bathalagoda     | 0.028     | 0.244    |
|      | Kurunegala      | 0.042     | 0.153    |
| IL3  | Mediyawa        | 0.003     | 0.689    |
|      | Siyabalangamuwa | 0.066     | 0.071    |
|      | Wariyapola      | 0.032     | 0.217    |
| DL1b | Kalawewa        | 0.018     | 0.348    |
|      | Kandalama       | 0.020     | 0.328    |
|      | Mahailluppallama| 0.025     | 0.277    |
|      | Maradankadawala | 0.031     | 0.223    |

The annual rainfall shows a decreased variability in comparison with the base period CV% during the most recent decade (1991/00) for all stations. When compared with the base period, 1991/10 period shows a similar pattern with reduced variability in all the climatic zones with the exception of Bathalagoda, and Wariyapola stations, which shows an increased variability.
Table 3. Coefficient of variability of annual rainfall

| AER   | Station              | CV %   |
|-------|----------------------|--------|
| WM₂b  | Matale               | 15     |
| IL₁a  | Bathalagoda          | 15     |
|       | Kurunegala           | 16     |
| IL₂   | Mediyawa             | 26     |
|       | Siyabalangamuwa      | 23     |
|       | Wariyapola           | 17     |
| DL₁b  | Kalawewa             | 18     |
|       | Kandalama            | 19     |
|       | Mahalluppallama      | 17     |
|       | Maradankadawala      | 15     |

Confidence Interval of Annual Rainfall

Figure 2 presents the confidence interval (CI) of annual rainfall of the base period in stations surrounding Hakwatuna Oya watershed. A total of 7 out of 10 stations had more number of years of extreme events under the lower limit of the confidence interval (LCI) resulting in drought conditions.

Table 4. Mean rainfall and t-stat values of mean annual rainfall

| Time period | Station    | 1961/90 | 1991/00 | 2001/10 | 1991/00 | 2001/10 | 1991/10 |
|-------------|------------|---------|---------|---------|---------|---------|---------|
|             | Matale     | 1762    | 1772    | 1760    | 1766    | -0.066  | 0.010   | -0.038  |
|             | Bathalagoda| 1699    | 1583    | 1620    | 1602    | 1.252   | 1.686   | 1.211   |
|             | Kurunegala | 2103    | 1972    | 1970    | 1971    | 1.009   | 0.981   | 1.277   |
|             | Mediyawa   | 1224    | 1412    | 1426    | 1419    | -1.662  | -1.773  | -1.778  |
|             | Siyabalangamuwa| 1280 | 1300    | 1124    | 1212    | -0.173  | 1.415   | 0.789   |
|             | Wariyapola | 1690    | 1634    | 1713    | 1673    | 0.529   | -0.230  | 0.205   |
|             | Kalawewa   | 1299    | 1314    | 1327    | 1320    | -0.133  | -0.249  | -0.253  |
|             | Kandalama  | 1445    | 1369    | 1501    | 1435    | 0.601   | -0.451  | 0.101   |
|             | Mahalluppallama| 1399 | 1401    | 1383    | 1392    | -0.020  | 0.131   | 0.072   |
|             | Maradankadawala| 1351 | 1376    | 1285    | 1330    | -0.192  | 0.563   | 0.230   |

Rainfall Variability During Rainfall Seasons

First Inter Monsoon (FIM)

The CV (%) of seasonal rainfall for the FIM season (March- April) for the selected stations for 1961/90 base period and the recent years are given in Table 5. During the periods of 1991/10 and 1991/00, a decreased variability is displayed in all regions except for Matale, Siyabalangamuwa and Wariyapola. Comparison of the base period with the most recent 10-year period (2001/10) generally showed a decrease in variability in all regions, except Bathalagoda, Kurunegala, Kalawewa and Maradankadawala, which displayed an increased variability. Table 6 displays the mean rainfall values of FIM season in all 10 stations. Statistical comparisons indicated a significant difference in mean rainfall received by three
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stations, namely Matale and Mediyawa for the 2001/10 period and Kandalama for the 1991/00 period when compared to the base period.

Figure 2. Annual rainfall for years 1991-2010 in relation to the confidence interval of the base period of 1961-1990
Table 5. Coefficient of variability of first inter monsoon

| AER  | Station          | CV %  |
|------|------------------|-------|
|      | 1961/90 | 1991/10 | 1991/00 | 2001/10 |
| WM1,b | Matale      | 55     | 40     | 41     | 27     |
| IL1a  | Bathalagoda  | 35     | 41     | 38     | 40     |
| ILJ   | Kurunegala   | 35     | 37     | 28     | 42     |
|       | Mediyawa     | 51     | 38     | 30     | 33     |
|       | Siyabalangamuwa | 53  | 55     | 61     | 43     |
|       | Wariyapola   | 44     | 39     | 44     | 32     |
| DL1b  | Kalawewa     | 49     | 60     | 56     | 54     |
|       | Kandalama    | 44     | 53     | 43     | 39     |
|       | Mahalluppallama | 48  | 46     | 35     | 44     |
|       | Maradankadawala | 42  | 49     | 40     | 52     |

Table 6. Mean rainfall and t-stat values of First Inter Monsoon

| Station          | Mean (mm) | t-Stat |
|------------------|-----------|--------|
| Time period      | 1961/90  | 1991/00 | 2001/10 | 1991/10 |
| Matale           | 230      | 217     | 350*    | 284     | 0.302   | -2.72*  | -1.515  |
| Bathalagoda     | 312      | 245     | 323     | 284     | 1.7365  | -0.25   | 0.875   |
| Kurunegala      | 401      | 375     | 446     | 410     | 0.527   | -0.815  | -0.236  |
| Mediyawa        | 251      | 256     | 384*    | 320     | -0.117  | -2.83*  | -1.896  |
| Siyabalangamuwa | 240      | 156     | 266     | 211     | 1.912   | -0.576  | 0.816   |
| Wariyapola      | 341      | 295     | 396     | 346     | 0.865   | -1.023  | -0.099  |
| Kalawewa        | 228      | 174     | 284     | 229     | 1.377   | -1.261  | -0.029  |
| Kandalama       | 247      | 160*    | 314     | 237     | 2.37*   | -1.631  | 0.311   |
| Mahalluppallama | 257      | 188     | 283     | 235     | 1.683   | -0.577  | 0.635   |
| Maradankadawala | 259      | 210     | 268     | 239     | 1.294   | -0.208  | 0.618   |
| t-critical      | 2.024    | 2.024   | 2.01    |

Values and t-stats indicated in bold face and with an asterisk indicate a significant difference compared to the base period.

South West Monsoon (SWM)

As shown in Table 7, the rainfall variability of SWM during last 20-year period has increased compared to the base period except in Matale and Wariyapola. However, according to the mean seasonal rainfall values and the statistical analysis, only three stations located in the IZ i.e. Siyambalangamuwa, Kurunegala and Bathalagoda displayed a significant difference in mean seasonal rainfall (Table 8).
Table 7. Coefficient of variability of South-West monsoon

| AER   | Station            | CV % | 1961/90 | 1991/00 | 1991/00 | 2001/10 |
|-------|--------------------|------|---------|---------|---------|---------|
| WM₁b  | Matale             | 34   | 29      | 28      | 27      |
| IL₃a  | Bathalagoda        | 25   | 35      | 29      | 40      |
|       | Kurunegala         | 26   | 31      | 31      | 27      |
| IL₃   | Mediyawa           | 35   | 51      | 44      | 46      |
|       | Siyabalamanguwala  | 39   | 62      | 45      | 69      |
|       | Wariyapola         | 27   | 19      | 23      | 10      |
| IL₃b  | Kalawewa           | 49   | 58      | 54      | 64      |
|       | Kandalama          | 39   | 55      | 49      | 63      |
|       | Mahallahuppalama   | 37   | 42      | 34      | 50      |
|       | Maradankadawala    | 44   | 62      | 60      | 68      |

Table 8. Mean rainfall and t-stat values of South West monsoon

| Station           | Mean (mm) | Time period | t-Stat |
|-------------------|-----------|-------------|--------|
|                   | 1961/90   | 1991/00     | 2001/10| 1991/00 | 2001/10 | 1991/10 |
| Matale            | 600       | 629         | 507    | 568     | -0.397   | 1.327    | 0.582   |
| Bathalagoda       | 590       | 506         | 401*   | 453*    | -0.216   | 3.39*    | 3.09*   |
| Kurunegala        | 717       | 693         | 552*   | 623     | 0.339    | 2.53*    | 1.722   |
| Mediyawa          | 266       | 332         | 199    | 266     | -1.679   | 1.947    | 0.001   |
| Siyabalamangamuwa| 248       | 270         | 138*   | 204     | -0.585   | 3.16*    | 1.407   |
| Wariyapola        | 508       | 493         | 448    | 470     | 0.314    | 1.343    | 1.083   |
| Kalawewa          | 238       | 217         | 172    | 194     | 0.485    | 1.583    | 1.311   |
| Kandalama         | 233       | 210         | 175    | 193     | 0.673    | 1.641    | 1.438   |
| Mahallahuppalama  | 269       | 245         | 226    | 235     | 0.287    | 0.703    | 0.657   |
| Maradankadawala   | 245       | 258         | 229    | 244     | -0.287   | 0.356    | 0.043   |
| t-critical        |           |             |        | 2.024   | 2.024    | 2.01     |

Values and t-stats indicated in bold face and with an asterisk indicate a significant difference compared to the base period.

Second Inter Monsoon (SIM)

As observed in the SWM, the variability during SIM (October-November) has increased in the IZ, while it has decreased in the DZ (Table 9). None of the stations displayed statistical differences in mean values during all time periods considered (Table 10).
Table 9. Coefficient of variability of second inter monsoon

| AER    | Station         | CV %     |     |     |     |     |
|--------|-----------------|----------|-----|-----|-----|-----|
|        |                 | 1961/90  | 1991/10 | 1991/00 | 2001/10 |
| WM₁b   | Matale          | 36       | 35   | 33   | 39   |
| IL₁a   | Bathalagoda     | 30       | 46   | 35   | 52   |
|        | Kurunegala      | 32       | 39   | 32   | 46   |
| IL₃    | Mediyawa        | 43       | 46   | 38   | 53   |
|        | Siyabalangamuva | 40       | 37   | 35   | 41   |
|        | Wariyapola      | 28       | 40   | 40   | 43   |
| DL₁b   | Kalawewa        | 32       | 36   | 40   | 31   |
|        | Kandalama       | 41       | 31   | 37   | 24   |
|        | Mahalluppallama | 38       | 34   | 37   | 33   |
|        | Maradankadawala | 40       | 30   | 29   | 32   |

Table 10. Mean rainfall and t-stat values of second inter monsoon

| Mean (mm) | Station     | Time period | t-Stat |
|-----------|-------------|-------------|--------|
|           |             | 1961/90 | 1991/00 | 2001/10 | 1991/00 | 2001/10 | 1991/10 |
|           | Matale      | 562     | 539     | 535     | 537     | 0.325   | 0.375   | 0.45    |
|           | Bathalagoda | 532     | 527     | 644     | 585     | 0.089   | -1.423  | -0.875  |
|           | Kurunegala  | 686     | 649     | 711     | 680     | 0.465   | -0.274  | 0.086   |
|           | Mediyawa    | 477     | 530     | 582     | 556     | -0.715  | -1.23   | -1.211  |
|           | Siyabalangamuwa | 484 | 547     | 506     | 527     | -0.892  | -0.308  | -0.757  |
|           | Wariyapola  | 590     | 599     | 570     | 585     | -0.137  | 0.286   | 0.09    |
|           | Kalawewa    | 455     | 535     | 485     | 510     | 1.325   | -0.558  | -1.175  |
|           | Kandalama   | 510     | 512     | 480     | 496     | -0.019  | 0.432   | 0.263   |
|           | Mahalluppallama | 512 | 561     | 535     | 548     | -0.673  | -0.329  | -0.646  |
|           | Maradankadawala | 485 | 481     | 440     | 460     | 0.065   | 0.681   | 0.495   |
|           | *t*-critical |          | 2.024   | 2.024   | 2.01    |

North East Monsoon (NEM)

The results for the NEM (December - February) as shown in Table 11, indicate an increased variability in the AERs of WM₁b and IL₁a during the last 20 year period (1991/10), whilst AERs in IL₃ and DL₁b displayed a decreased variability. During the 1991/00 decade, all stations displayed an increased variability compared to the base period except for Matale, Kalawewa and Maradankadawala, which shows a decreased variability. When CV % of the last 10 year time period were compared to the base period, an increased variability could be seen in WM₁b and IL₁a AERs whilst a general decreasing variability could be observed in IL₃ and DL₁b regions. Statistical comparisons indicated no difference in mean rainfall received during the time periods considered.

The variability during the NEM is the highest compared to other three rainfall seasons as the average CV% of all 10-rainfall stations during the base period of NEM is 61%, when compared to FIM (46%), SWM (36%), and SIM (36%). However, in the recent decades the variability of the NEM (55%) and FIM (41%) has decreased whilst SWM and SIM variability displayed an increase with CV values of 46% and 39%, respectively.
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Table 11. Coefficient of variability of North East monsoon

| AER   | Station               | CV %       |       |       |       |       |
|-------|-----------------------|------------|-------|-------|-------|-------|
|       |                       | 1961/90    | 1991/10 | 1991/00 | 2001/10 | 2001/10 |
| WM₁b  | Matale                | 58         | 60     | 53     | 70     |       |
| IL₁a  | Bathalagoda           | 47         | 69     | 58     | 72     |       |
| IL₁a  | Kurunegala            | 58         | 64     | 65     | 67     |       |
| IL₃   | Mediyawa              | 61         | 60     | 74     | 43     |       |
|       | Siyabalangamuwa      | 74         | 71     | 79     | 47     |       |
|       | Wariyapola            | 70         | 62     | 76     | 48     |       |
| DL₀b  | Kalawewa              | 64         | 49     | 60     | 40     |       |
|       | Kandalama             | 56         | 57     | 59     | 57     |       |
|       | Mahalluppallama       | 59         | 59     | 62     | 55     |       |
|       | Maradankadawala       | 60         | 56     | 58     | 55     |       |

Table 12. Mean rainfall and t-stat values of North East monsoon

| Mean (mm)          | Time period | t-Stat |
|--------------------|-------------|--------|
|                    | 1961/90     | 1991/00 | 2001/00 | 1991/10 | 2001/10 | 1991/10 |
| Matale             | 369         | 401     | 395     | 398     | -0.415  | -0.309  | -0.451   |
| Bathalagoda        | 272         | 231     | 321     | 276     | 0.88    | -0.833  | -0.073   |
| Kurunegala         | 298         | 269     | 266     | 268     | 0.456   | 0.495   | 0.605    |
| Mediyawa           | 231         | 287     | 278     | 283     | -0.954  | -0.941  | -1.170   |
| Siyabalangamuwa   | 247         | 320     | 228     | 274     | -0.991  | 0.307   | -0.500   |
| Wariyapola         | 251         | 273     | 283     | 278     | -0.326  | -0.528  | -0.539   |
| Kalawewa           | 380         | 358     | 478     | 418     | 0.259   | -1.158  | -0.572   |
| Kandalama          | 451         | 504     | 587     | 545     | -0.549  | -1.367  | -1.185   |
| Mahalluppallama    | 355         | 428     | 361     | 394     | -0.882  | -0.071  | -0.616   |
| Maradankadawala    | 357         | 434     | 375     | 404     | -0.946  | -0.235  | -0.755   |
| t-critical         | 2.024       | 2.024   | 2.01    |

Rainfall variability during growing seasons
Yala Season

Table 13 and 14 presents the coefficient of Variation (CV %) and the mean values of the rainfall during Yala Season (March - August) for the selected stations. A decreased variability could be observed in WM₁b and IL₃ AERs in the decade of 1991/00, whereas IL₁a and DL₀b showed an overall increased variability. For the most recent decade, all stations except Bathalagoda, Siyabalangamuwa, Kalawewa and Kandalama displayed a decreased variability when compared with the base period. The observations for the 20 year time period were similar to that of the 1991/00 decade, where a decreased variability could be observed in WM₁b and IL₃ AERs and IL₁a and DL₀b showed an overall increased variability. Statistical comparisons between the base period and all the other tested periods indicated a difference in mean rainfall in Siyabalangamuwa during all time periods considered whereas Kalawewa, station showed a difference in mean rainfall between base period and the recent decade.
Table 13. Coefficient of variability of Yala season

| AER   | Station             | CV %  |
|-------|---------------------|-------|
| WM<sub>b</sub> | Matale             | 35    | 22 | 25 | 21   |
| IL<sub>a</sub> | Bathalagoda        | 26    | 28 | 30 | 27   |
|         | Kurunegala         | 26    | 24 | 22 | 23   |
| IL<sub>b</sub> | Mediyawa           | 33    | 27 | 27 | 29   |
|         | Siyabalangamuwa   | 42    | 37 | 44 | 32   |
|         | Wariyapola         | 29    | 23 | 27 | 20   |
| DL<sub>b</sub> | Kalawewa           | 31    | 43 | 48 | 35   |
|         | Kandalama          | 32    | 42 | 41 | 38   |
|         | Mahalluppallama    | 33    | 28 | 30 | 26   |
|         | Maradankadawala    | 34    | 37 | 32 | 41   |

Maha Season

During Maha season (September–February) all stations except Siyabalangamuwa, Kalawewa, and Maradankadawala displayed an increased variability during the 1991/10 time period, and all stations displayed an increased variability during the 1991/00 decade except Matale, Siyabalangamuwa, and Maradankadawala.

Table 14. Mean rainfall and t-stat values of Yala season

| Mean (mm)            | 1961/90 | 1991/00 | 2001/10 | 1961/90 | 1991/00 | 2001/10 | t-Stat |
|----------------------|---------|---------|---------|---------|---------|---------|--------|
| Station              |         |         |         |         |         |         |        |
| Matale               | 684     | 716     | 713     | 715     | -0.396  | -0.362  | -0.508 |
| Bathalagoda          | 785     | 787     | 742     | 765     | -0.027  | 0.577   | 0.339  |
| Kurunegala           | 979     | 976     | 811     | 894     | 0.033   | 1.927   | 1.243  |
| Mediyawa             | 455     | 519     | 517     | 518     | -1.169  | -1.118  | -1.468 |
| Siyabalangamuwa     | 645     | 350*    | 361*    | 355*    | 3.24*   | 3.18*   | 4.41*  |
| Wariyapola           | 721     | 667     | 729     | 698     | 0.731   | -0.118  | 0.412  |
| Kalawewa             | 365     | 341     | 498*    | 420     | 0.510   | -2.80*  | -1.315 |
| Kandalama            | 404     | 316     | 439     | 377     | 1.870   | -0.676  | 0.660  |
| Mahalluppallama      | 440     | 384     | 358     | 410     | 1.648   | 0.592   | 1.475  |
| Maradankadawala      | 426     | 375     | 408     | 392     | 0.979   | 0.313   | 0.808  |
| t-critical           |         |         |         |         | 2.024   | 2.024   | 2.01   |

Values and t-stats indicated in bold face and with an asterisk indicate a significant difference compared to the base period

In 20 year time period, an increased variability could be observed in all stations except Bathalagoda, Siyabalangamuwa, Kalawewa and Maradankadawala. The statistical comparisons of the distribution of rainfall during Maha season between the base period and the next 10-year and 20-year periods as given in Tables 15 and 16.
Recent Changes of Rainfall Regime

Table 15. Coefficient of variability (CV %) of Maha season

| AER   | Station            | CV % Maha 1961/90 | CV % Maha 1991/00 | CV % Maha 2001/10 |
|-------|--------------------|-------------------|-------------------|-------------------|
| WM3b  | Matale             | 29                | (30)        | 24                | 36                |
| IL4a  | Bathalagoda        | 26                | 32                | 32                | 25                |
| IL3   | Kurunegala         | 25                | 34                | 31                | 31                |
|       | Mediyawa           | 32                | 41                | 40                | 44                |
|       | Siyabalangamuwa   | 51                | 38                | 40                | 34                |
|       | Wariyapola         | 24                | 28                | 31                | 27                |
| IL2b  | Kalawewa           | 35                | 30                | 35                | 27                |
|       | Kandalama          | 29                | 37                | 38                | 37                |
|       | Mahalluppalama     | 29                | 33                | 34                | 34                |
|       | Maradankadawala    | 33                | 28                | 31                | 25                |

Table 16. Mean rainfall and t-stat values of Maha season

| Mean (mm)                  | Station          | Time period | t-Stat | t-critical |
|---------------------------|------------------|-------------|--------|------------|
|                           |                  | 1961/90     | 1991/00| 2001/10    | 1991/00 | 2001/10    | 1991/10 |
|                           | Matale           | 1078        | 1069   | 1074       | 1072    | 0.074      | 0.03    | 0.065    |
|                           | Bathalagoda      | 996         | 957    | 1319*      | 1138    | 0.398      | -3.22*  | -1.629   |
|                           | Kurunegala       | 1125        | 971    | 1303       | 1137    | 1.464      | -1.529  | -0.123   |
|                           | Mediyawa         | 770         | 887    | 927        | 907     | -1.156     | -1.456  | -1.563   |
|                           | Siyabalangamuwa | 679         | 945*   | 777        | 861     | -2.06*     | -0.821  | -1.863   |
|                           | Wariyapola       | 969         | 993    | 968        | 980     | -0.25      | 0.015   | -0.150   |
|                           | Kalawewa         | 912         | 923    | 1022       | 973     | -0.996     | -0.985  | -0.684   |
|                           | Kandalama        | 1037        | 1069   | 1118       | 1094    | -0.266     | -0.659  | -0.564   |
|                           | Mahalluppalama   | 953         | 1028   | 1063       | 994     | -1.013     | -0.387  | -0.864   |
|                           | Maradankadawala  | 921         | 1008   | 904        | 956     | -0.778     | 0.155   | -0.418   |

Values and t-stats indicated in bold face and with an asterisk indicate a significant difference compared to the base period

CONCLUSIONS

There were no conclusive significant trends of rainfall during the last two decades of 1991 to 2010 compared to the base period of 1961-1990, defined by the WMO for climate studies, in 10 selected rainfall stations around the Hakwatuna Oya watershed. The number of dry years has slightly increased compared to wet years during last two decades, especially in the IZ, where the command area of irrigation system is located.

In relation to the four rainfall seasons, there was no significant variability of rainfall during last two decades compared to the base period, except for few stations. However, the rainfall variability of SWM, Yala and Maha seasons displayed a statistical difference in mean rainfall for Siyabalangamuwa rainfall station, which is the closest to the Hakwatuna Oya scheme in the IZ. The mean rainfall during post 1990 period was lower than the base period during SWM and Yala season whereas it has increased during Maha season.
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