RAIN FALL ANALYSIS - Standardized Precipitation Index (SPI)

Station Name:	**Millawana-Estate**
Type:	**Precipitatiom**
Data Interval:	**Daily**
Unit:	**Millimeters**
Period	**1960/01/01 to 2018/12/31**

appVersion(4) = "0.99.7251.32800"

$Project := [\text{"Millawana Estate"}]$

$t_{start} := \text{time}(0)$

1. Select period

$t1 := \text{time}(0)$

Assume 30 day month

Input Matrix. You can extend or reduce the size of matrix

$$input_1 := \begin{bmatrix} \text{"3 Months"} & 3 \cdot 30 \\ \text{"4 Months"} & 4 \cdot 30 \\ \text{"6 Months"} & 6 \cdot 30 \\ \text{"9 Months"} & 9 \cdot 30 \\ \text{"12 Months"} & 12 \cdot 30 \\ \text{"18 Months"} & 18 \cdot 30 \end{bmatrix}$$

Select Period

- [x] 3 Months
- [x] 4 Months
- [x] 6 Months
- [x] 9 Months
- [x] 12 Months
- [ ] 18 Months

nn_day

Output

$$nn\_day = \begin{bmatrix} 90 \\ 120 \\ 180 \\ 270 \\ 360 \end{bmatrix}$$

For use in results

$$months := \frac{nn\_day}{30} = \begin{bmatrix} 3 \\ 4 \\ 6 \\ 9 \\ 12 \end{bmatrix}$$

2. Import rainfall data from EXCEL file

NOTE : SMATH treats blanks in EXCEL as zeros. Hence, in case of missing data, first use a suitable method to fill in such gaps.

MyDirectory := DocumentDirectory("") = "F:\0001. Training ID\0001. IRESH Irrig. Dept\"

MyFile := concat(MyDirectory, "rainfall_KalaOyaBAsin.xlsx")

$RF\_DATA := \text{importData}_{XLSX}(MyFile, \text{"Sheet1"}, \text{"B3"}, \text{"B21552"})$

Read daily rainfall data file. Define correct cell range (in this case B3:B21552

$\text{rows}(RF\_DATA) = 21550$ $\text{cols}(RF\_DATA) = 1$ $n_{DATA} := \text{length}(RF\_DATA) = 21550$

$\text{time}(0) - t1 = 0.72\ \text{s}$

3. Find 'n' day totals for a a single duration

Program 4: Finds 'p' day Avg. of an Array : Super Fast:

$t1 := \text{time}(0)$

$$period_{tot} := \text{round}\left(\frac{n_{DATA}}{360}\right)\ \text{yr}$$

$$period_{tot} = 60\ \text{yr}$$

Program 1: To find "p" day TOTAL.

$$n\_day\_Tot(q, p) := \left| \begin{array}{l} q := \text{eval}(q) \\ j := \left[1 .. \text{trunc}\left(\frac{\text{rows}(q)}{p}\right) \right] \\ \text{eval}\left(PT_j := \sum_{n=1+(j-1)\cdot p}^{j \cdot p} q_n \right) \\ PT \end{array} \right.$$

Only to demonstrate how Program 1 works

$n\_day := nn\_day_1 = 90$

Apply Program 1 with appropriate variables

$$X := n\_day\_Tot(RF\_DATA, n\_day) = \begin{bmatrix} 557.36 \\ 549.82 \\ 992.27 \\ 848.58 \\ 634.75 \\ 457.57 \\ 705.05 \\ 878.01 \\ 395.09 \\ \vdots \end{bmatrix}$$

$\max(X) = 1643.35$ $\min(X) = 17.6$

$n := \text{rows}(X) = 239$

$$\frac{\text{rows}(RF\_DATA)}{n\_day} = 239.4444$$

$$n_{bal} := \left(\frac{\text{rows}(RF\_DATA)}{n\_day} - n\right) \cdot n\_day = 40$$

$$n \cdot n\_day + n_{bal} = 21550$$

$\text{time}(0) - t1 = 0.28\ s$

4. Find 'n' day totals for multiple durations

Program 2: For a range of 'p' day totals of vector 'A' .
Calls Program 1 repeatedly for each 'nn_day' array element.

$$nn\_day\_total(A, p) := \left| \begin{array}{l} j := [1..\text{rows}(p)] \\ \text{eval}\left(B_j := n\_day\_Tot\left(A, p_j\right)\right) \end{array} \right.$$

Input Array

$$nn\_day = \begin{bmatrix} 90 \\ 120 \\ 180 \\ 270 \\ 360 \end{bmatrix}$$

$t1 := \text{time}(0)$

Calls Program 2

$XX := nn\_day\_total(RF\_DATA, nn\_day)$

Input Array passed to Program 2 to find XX

$\text{time}(0) - t1 = 1.01\ s$

$$X = \begin{bmatrix} 557.36 \\ 549.82 \\ 992.27 \\ 848.58 \\ 634.75 \\ 457.57 \\ 705.05 \\ 878.01 \\ 395.09 \\ 456.94 \\ 225.98 \\ 919.66 \\ 897.09 \\ 505.92 \\ 284.32 \\ \vdots \end{bmatrix}$$

Compare

$$XX_1 = \begin{bmatrix} 557.36 \\ 549.82 \\ 992.27 \\ 848.58 \\ 634.75 \\ 457.57 \\ 705.05 \\ 878.01 \\ 395.09 \\ 456.94 \\ 225.98 \\ 919.66 \\ 897.09 \\ 505.92 \\ 284.32 \\ \vdots \end{bmatrix} \qquad XX_2 = \begin{bmatrix} 966.21 \\ 1082.64 \\ 899.18 \\ 726.71 \\ 1054.48 \\ 894.19 \\ 600.02 \\ 350.72 \\ 1046.91 \\ 1118.93 \\ 555.27 \\ 1313.66 \\ 543.19 \\ 567.52 \\ 671.38 \\ \vdots \end{bmatrix}$$

$\text{rows}(XX) = 5$

$\text{cols}(XX) = 1$

$\text{Max}(XX_1) = 1643.35$ $\text{Min}(XX_1) = 17.6$ $\text{rows}(XX_1) = 239$ $\text{rows}(XX_2) = 179$

$$\overrightarrow{\text{Max}(XX)} = \begin{bmatrix} 1643.35 \\ 2163.81 \\ 2185.43 \\ 2646.56 \\ 2987.86 \end{bmatrix} \qquad \overrightarrow{\text{Min}(XX)} = \begin{bmatrix} 17.6 \\ 23 \\ 287.14 \\ 711.64 \\ 1125.56 \end{bmatrix} \qquad \overrightarrow{\text{rows}(XX)} = \begin{bmatrix} 239 \\ 179 \\ 119 \\ 79 \\ 59 \end{bmatrix}$$

5. Find logarithms of a single XX vector

No zeros or -ve values in XX

$\overrightarrow{\mathrm{Min}(XX)} = \begin{bmatrix} 17.6 \\ 23 \\ 287.14 \\ 711.64 \\ 1125.56 \end{bmatrix}$

$t1 := \mathrm{time}(0)$

{rogram 3: To deal with zero values. for "ln(X)"

$$LNX(M) := \left| \begin{array}{l} j := [1..\mathrm{rows}(M)] \\ \mathrm{eval}\left(B_j := \begin{cases} 0 & \text{if } M_j = 0 \\ \ln(M_j) & \text{otherwise} \end{cases} \right) \end{array} \right.$$

$LNX(XX_1) = \begin{bmatrix} 6.32 \\ 6.31 \\ 6.9 \\ 6.74 \\ 6.45 \\ 6.13 \\ 6.56 \\ 6.78 \\ 5.98 \\ 6.12 \\ 5.42 \\ 6.82 \\ \vdots \end{bmatrix}$ $LNX(XX_2) = \begin{bmatrix} 6.87 \\ 6.99 \\ 6.8 \\ 6.59 \\ 6.96 \\ 6.8 \\ 6.4 \\ 5.86 \\ 6.95 \\ 7.02 \\ 6.32 \\ 7.18 \\ \vdots \end{bmatrix}$

$\overrightarrow{\mathrm{rows}(LNX(XX))} = \begin{bmatrix} 239 \\ 179 \\ 119 \\ 79 \\ 59 \end{bmatrix}$

6. Find logarithms of an array of XX vectors

Program 4: Calls Program 3.
Vectorize function used

$all\_LNX := \mathrm{eval}\left(\overrightarrow{LNX(XX)}\right)$

Calls Program 3

$all\_LNX_1 = \begin{bmatrix} 6.32 \\ 6.31 \\ 6.9 \\ 6.74 \\ 6.45 \\ 6.13 \\ 6.56 \\ 6.78 \\ 5.98 \\ 6.12 \\ 5.42 \\ 6.82 \\ 6.8 \\ 6.23 \\ 5.65 \\ 7.17 \\ \vdots \end{bmatrix}$ $all\_LNX_2 = \begin{bmatrix} 6.87 \\ 6.99 \\ 6.8 \\ 6.59 \\ 6.96 \\ 6.8 \\ 6.4 \\ 5.86 \\ 6.95 \\ 7.02 \\ 6.32 \\ 7.18 \\ 6.3 \\ 6.34 \\ 6.51 \\ 6.24 \\ \vdots \end{bmatrix}$

$\overrightarrow{\mathrm{rows}(all\_LNX)} = \begin{bmatrix} 239 \\ 179 \\ 119 \\ 79 \\ 59 \end{bmatrix}$

$\mathrm{time}(0) - t1 = 0.17\ \mathrm{s}$

6. Find Means of XX array and Means of LNX arrays

$t1 := \text{time}(0)$

$$All\_XX_{mean} := \text{eval}\left(\overrightarrow{\text{Mean}(XX)}\right) = \begin{bmatrix} 490.32 \\ 653.04 \\ 977.54 \\ 1452.48 \\ 1934.61 \end{bmatrix}$$

$$All\_LNX_{mean} := \text{eval}\left(\overrightarrow{\text{Mean}(all\_LNX)}\right) = \begin{bmatrix} 5.97 \\ 6.32 \\ 6.81 \\ 7.24 \\ 7.54 \end{bmatrix}$$

7. Gamma PDF and CDF

$$A := \overrightarrow{\ln\left(All\_XX_{mean}\right) - All\_LNX_{mean}} = \begin{bmatrix} 0.22 \\ 0.16 \\ 0.08 \\ 0.04 \\ 0.03 \end{bmatrix}$$

$$\alpha := \text{eval}\left(\overrightarrow{\frac{1}{4 \cdot A} \cdot \left(1 + \sqrt{1 + 4 \cdot \frac{A}{3}}\right)}\right) = \begin{bmatrix} 2.42 \\ 3.25 \\ 6.43 \\ 12.09 \\ 16.64 \end{bmatrix}$$

$$\beta := \text{eval}\left(\overrightarrow{\frac{All\_XX_{mean}}{\alpha}}\right) = \begin{bmatrix} 202.64 \\ 200.65 \\ 151.91 \\ 120.09 \\ 116.24 \end{bmatrix}$$

Eqn for Gamma function PDF

$$g(x, j) := \frac{1}{\beta_j^{\alpha_j} \cdot \text{Gamma}\left(\alpha_j\right)} \cdot x^{\alpha_j - 1} \cdot e^{-\frac{x}{\beta_j}}$$

Eqn. 1

$$\overrightarrow{\frac{1}{\beta}} = \begin{bmatrix} 0.0049 \\ 0.005 \\ 0.0066 \\ 0.0083 \\ 0.0086 \end{bmatrix}$$

Eqn for Gamma function CDF

$$G(x\_val, j) := \frac{1}{\beta_j^{\alpha_j} \cdot \text{Gamma}\left(\alpha_j\right)} \cdot \int_0^{x\_val} x^{\alpha_j - 1} \cdot e^{-\frac{x}{\beta_j}}\, d\, x$$

Eqn. 2

Some Examples

$$\overrightarrow{\beta^{\alpha}} = \begin{bmatrix} 381413.15 \\ 31153938.77 \\ 1.09 \cdot 10^{14} \\ 1.42 \cdot 10^{25} \\ 2.37 \cdot 10^{34} \end{bmatrix} \qquad \alpha - 1 = \begin{bmatrix} 1.42 \\ 2.25 \\ 5.43 \\ 11.09 \\ 15.64 \end{bmatrix} \qquad \overrightarrow{\text{Gamma}(\alpha)} = \begin{bmatrix} 1.26 \\ 2.56 \\ 256.29 \\ 50346333.06 \\ 7.73 \cdot 10^{12} \end{bmatrix}$$

$g\left(X_1, 1\right) = 0.0011 \qquad g\left(X_2, 1\right) = 0.0011$

$g\left({XX_1}_1, 1\right) = 0.0011$

$\text{time}(0) - t1 = 0.05\ s$

7.1 PDF

$t1 := \mathrm{time}(0)$

Ptogtam 5

$PDF(x\#, n\#) := \left| \begin{array}{l} j := [1..\mathrm{rows}(x\#)] \\ \mathrm{eval}\left(B_j := g\left(x\#_j, n\#\right)\right) \end{array} \right.$

Program 6: Calls Program 5

$All\_PDF(x\#) := \left| \begin{array}{l} j := [1..\mathrm{rows}(x\#)] \\ \mathrm{eval}\left(B_j := PDF\left(x\#_j, j\right)\right) \end{array} \right.$

$$A1 := PDF\left(XX_1, 1\right) = \begin{bmatrix} 0.0011 \\ 0.0011 \\ 0.0003 \\ 0.0005 \\ 0.0009 \\ 0.0013 \\ 0.0007 \\ 0.0004 \\ 0.0014 \\ 0.0013 \\ 0.0015 \\ 0.0004 \\ 0.0004 \\ 0.0012 \\ \vdots \end{bmatrix} \quad X = \begin{bmatrix} 557.36 \\ 549.82 \\ 992.27 \\ 848.58 \\ 634.75 \\ 457.57 \\ 705.05 \\ 878.01 \\ 395.09 \\ 456.94 \\ 225.98 \\ 919.66 \\ 897.09 \\ 505.92 \\ 284.32 \\ 1300.52 \\ \vdots \end{bmatrix} \quad XX_3 = \begin{bmatrix} 1107.18 \\ 1840.85 \\ 1092.31 \\ 1583.07 \\ 852.02 \\ 1145.63 \\ 1403.02 \\ 1584.85 \\ 685.67 \\ 1096.42 \\ 904.84 \\ 1503.01 \\ 1129.55 \\ 1197.32 \\ 806.25 \\ 846.36 \\ \vdots \end{bmatrix} \quad X - XX_1 = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ \vdots \end{bmatrix}$$

$\sum A1 = 0.2561$

$Ans1 := \mathrm{eval}(All\_PDF(XX))$

$$Ans1_1 = \begin{bmatrix} 0.0011 \\ 0.0011 \\ 0.0003 \\ 0.0005 \\ 0.0009 \\ 0.0013 \\ 0.0007 \\ 0.0004 \\ 0.0014 \\ 0.0013 \\ 0.0015 \\ \vdots \end{bmatrix} \quad Ans1_2 = \begin{bmatrix} 0.0005 \\ 0.0004 \\ 0.0006 \\ 0.0009 \\ 0.0004 \\ 0.0007 \\ 0.0012 \\ 0.0012 \\ 0.0004 \\ 0.0004 \\ 0.0012 \\ \vdots \end{bmatrix}$$

$\sum Ans1_1 = 0.2561$

$\sum Ans1_2 = 0.1607$

$$\overrightarrow{\mathrm{rows}(Ans1)} = \begin{bmatrix} 239 \\ 179 \\ 119 \\ 79 \\ 59 \end{bmatrix}$$

$\mathrm{time}(0) - t1 = 0.22\ \mathrm{s}$

7.2 CDF

Program 7

$$CDF(x\#, n\#) := \left| \begin{array}{l} j := [1..\mathrm{rows}(x\#)] \\ \mathrm{eval}\left(B_j := G(x\#_j, n\#)\right) \end{array} \right.$$

Program 8: Calls Program 7

$$All\_CDF(x\#) := \left| \begin{array}{l} j := [1..\mathrm{rows}(x\#)] \\ \mathrm{eval}\left(B_j := CDF(x\#_j, j)\right) \end{array} \right.$$

$t1 := \mathrm{time}(0)$ $\quad G := All\_CDF(XX)$ $\quad \mathrm{time}(0) - t1 = 5.32\ \mathrm{s}$

$$CDF(X, 1) = \begin{bmatrix} 0.6618 \\ 0.6538 \\ 0.9257 \\ 0.8738 \\ 0.736 \\ 0.5441 \\ 0.7912 \\ 0.8866 \\ 0.4583 \\ 0.5433 \\ 0.2003 \\ 0.9026 \\ 0.8942 \\ 0.6043 \\ 0.2901 \\ 0.9776 \\ 0.4763 \\ 0.2802 \\ \vdots \end{bmatrix}$$

Compare

$$G_1 = \begin{bmatrix} 0.6618 \\ 0.6538 \\ 0.9257 \\ 0.8738 \\ 0.736 \\ 0.5441 \\ 0.7912 \\ 0.8866 \\ 0.4583 \\ 0.5433 \\ 0.2003 \\ 0.9026 \\ 0.8942 \\ 0.6043 \\ 0.2901 \\ 0.9776 \\ 0.4763 \\ 0.2802 \\ \vdots \end{bmatrix}$$

$t1 := \mathrm{time}(0)$

8. Calculation of SPI values and Probabilities

Program 9: Returns Inv. Cumulative Normal Distribution values

$$F_{inv.normal} := \overrightarrow{\mathrm{ICDF}_{Normal}(G)}$$

Extract 2 nd column of ICDF

$$Z := \overrightarrow{\mathrm{col}(F_{inv.normal}, 2)}$$

$$F_{inv.normal\,1} = \begin{bmatrix} 0.6618 & 0.4175 \\ 0.6538 & 0.3956 \\ 0.9257 & 1.4444 \\ 0.8738 & 1.1445 \\ 0.736 & 0.631 \\ 0.5441 & 0.1108 \\ 0.7912 & 0.8107 \\ 0.8866 & 1.2084 \\ 0.4583 & -0.1048 \\ 0.5433 & 0.1088 \\ 0.2003 & -0.8406 \\ 0.9026 & 1.2965 \\ 0.8942 & 1.2491 \\ 0.6043 & 0.2644 \\ 0.2901 & -0.5531 \\ & \vdots \end{bmatrix}$$

$$Z_1 = \begin{bmatrix} 0.4175 \\ 0.3956 \\ 1.4444 \\ 1.1445 \\ 0.631 \\ 0.1108 \\ 0.8107 \\ 1.2084 \\ -0.1048 \\ 0.1088 \\ -0.8406 \\ 1.2965 \\ 1.2491 \\ 0.2644 \\ -0.5531 \\ \vdots \end{bmatrix} \qquad Z_2 = \begin{bmatrix} 0.9357 \\ 1.1734 \\ 0.7904 \\ 0.3806 \\ 1.1175 \\ 0.7793 \\ 0.0365 \\ -0.8224 \\ 1.1023 \\ 1.2441 \\ -0.0966 \\ 1.6007 \\ -0.1338 \\ -0.0595 \\ 0.2357 \\ \vdots \end{bmatrix}$$

$$\overrightarrow{\mathrm{rows}(Z)} = \begin{bmatrix} 239 \\ 179 \\ 119 \\ 79 \\ 59 \end{bmatrix}$$

$$\overrightarrow{\sum Z} = \begin{bmatrix} 0.1317 \\ 0.4357 \\ -0.0602 \\ -0.0506 \\ -0.0022 \end{bmatrix}$$

$\mathrm{time}(0) - t1 = 0.17\ \mathrm{s}$

$t1 := \mathrm{time}(0)$

Program 10: Rounding data to 2 decimals.
Jean's method revised: Very handy

$Rounded(data) := \left| \begin{array}{l} \text{"collects index list"} \\ j := [1 .. \mathrm{rows}(data)] \\ a_j := \mathrm{eval}\left(\overrightarrow{\mathrm{round}(P := data_j, 2)}\right) \end{array} \right.$

Rounding necessary as the Condition Matrix has 2 decimals. See 8.1 below

$ZZ := Rounded(Z)$ $\mathrm{rows}(ZZ) = 5$ $\mathrm{time}(0) - t1 = 0.05\ s$

$$ZZ_1 = \begin{bmatrix} 0.42 \\ 0.4 \\ 1.44 \\ 1.14 \\ 0.63 \\ 0.11 \\ 0.81 \\ 1.21 \\ -0.1 \\ 0.11 \\ -0.84 \\ 1.3 \\ \vdots \end{bmatrix} \quad ZZ_2 = \begin{bmatrix} 0.94 \\ 1.17 \\ 0.79 \\ 0.38 \\ 1.12 \\ 0.78 \\ 0.04 \\ -0.82 \\ 1.1 \\ 1.24 \\ -0.1 \\ 1.6 \\ \vdots \end{bmatrix}$$

$\mathrm{rows}(ZZ_1) = 239$

$\mathrm{rows}(ZZ_2) = 179$

$$\overrightarrow{\mathrm{rows}(ZZ)} = \begin{bmatrix} 239 \\ 179 \\ 119 \\ 79 \\ 59 \end{bmatrix}$$

After rounding

$$\overrightarrow{\sum ZZ} = \begin{bmatrix} 0.16 \\ 0.47 \\ -0.05 \\ -0.07 \\ 0.02 \end{bmatrix}$$

Before rounding

$$\overrightarrow{\sum Z} = \begin{bmatrix} 0.1317 \\ 0.4357 \\ -0.0602 \\ -0.0506 \\ -0.0022 \end{bmatrix}$$

8..1 Condition Matrix to calculate SPI & Probabilities

Condition Matrix $t1 := \mathrm{time}(0)$

Program 11: All conditions in a Matrix, where each element represents a specific condition

$$All\_Conds(x) := \begin{bmatrix} x \geq 2.0 \\ 1.5 \leq x \leq 1.99 \\ 1.0 \leq x \leq 1.49 \\ -0.99 \leq x \leq 0.99 \\ -1.49 \leq x \leq -1.0 \\ -1.99 \leq x \leq -1.5 \\ x \leq -2.0 \end{bmatrix}$$

Program 12: SPI for a single vector

$SPI\_Single(x\#) := \left| \ \mathrm{eval}\left(\sum \overrightarrow{All\_Conds(x\#)}\right) \right.$

First vector of ZZ $AA := ZZ_1$

For a Single Array (ZZ1)

$\mathrm{appVersion}(3) = \text{"0.99.7251"}$

Program 13: For AA, find number of occurences satisfying each condition (TRUTH TABLE)

$$SPI1 := SPI\_Single(ZZ_1) = \begin{bmatrix} 5 \\ 13 \\ 24 \\ 161 \\ 22 \\ 9 \\ 5 \end{bmatrix} \qquad \sum SPI1 = 239$$

Program 14: Probability vector for AA

$$Pr1 := \frac{SPI1}{\sum SPI1} \cdot 100 = \begin{bmatrix} 2.1 \\ 5.4 \\ 10 \\ 67.4 \\ 9.2 \\ 3.8 \\ 2.1 \end{bmatrix} \qquad \sum Pr1 = 100$$

For a Nested Array (ZZ)

$t1 := \mathrm{time}(0)$

Program 15: Find All SPI vectors using Vectorize fumction: Very handy

$$S1 := \overrightarrow{SPI\_Single(ZZ)}^{T} = \begin{bmatrix} \begin{bmatrix} 5 \\ 13 \\ 24 \\ 161 \\ 22 \\ 9 \\ 5 \end{bmatrix} & \begin{bmatrix} 3 \\ 9 \\ 17 \\ 126 \\ 13 \\ 6 \\ 5 \end{bmatrix} & \begin{bmatrix} 3 \\ 4 \\ 14 \\ 79 \\ 12 \\ 4 \\ 3 \end{bmatrix} & \begin{bmatrix} 4 \\ 1 \\ 7 \\ 53 \\ 9 \\ 4 \\ 1 \end{bmatrix} & \begin{bmatrix} 0 \\ 5 \\ 5 \\ 39 \\ 5 \\ 5 \\ 0 \end{bmatrix} \end{bmatrix}$$

Program 16: Sum of each SPI vector

$$S2 := \overrightarrow{\sum S1} = \begin{bmatrix} 239 & 179 & 119 & 79 & 59 \end{bmatrix}$$

$\mathrm{time}(0) - t1 = 0.16\ s$

Program 17: Similarly, find All Probability vectors

$$P1 := \overrightarrow{\frac{S1}{S2}} \cdot 100 = \begin{bmatrix} \begin{bmatrix} 2.1 \\ 5.4 \\ 10 \\ 67.4 \\ 9.2 \\ 3.8 \\ 2.1 \end{bmatrix} & \begin{bmatrix} 1.7 \\ 5 \\ 9.5 \\ 70.4 \\ 7.3 \\ 3.4 \\ 2.8 \end{bmatrix} & \begin{bmatrix} 2.5 \\ 3.4 \\ 11.8 \\ 66.4 \\ 10.1 \\ 3.4 \\ 2.5 \end{bmatrix} & \begin{bmatrix} 5.1 \\ 1.3 \\ 8.9 \\ 67.1 \\ 11.4 \\ 5.1 \\ 1.3 \end{bmatrix} & \begin{bmatrix} 0 \\ 8.5 \\ 8.5 \\ 66.1 \\ 8.5 \\ 8.5 \\ 0 \end{bmatrix} \end{bmatrix}$$

Program 18: Sum of each Prob vector

$$P2 := \overrightarrow{\sum P1} = \begin{bmatrix} 100 & 100 & 100 & 100 & 100 \end{bmatrix}$$

Program 19:Add headers to S1 & S2

$$S1S2 := \overrightarrow{\mathrm{stack}(\text{"S:'SPI"}, S1, S2)} = \begin{bmatrix} \begin{bmatrix} \text{"S:'SPI"} \\ 5 \\ 13 \\ 24 \\ 161 \\ 22 \\ 9 \\ 5 \\ 239 \end{bmatrix} & \begin{bmatrix} \text{"S:'SPI"} \\ 3 \\ 9 \\ 17 \\ 126 \\ 13 \\ 6 \\ 5 \\ 179 \end{bmatrix} & \begin{bmatrix} \text{"S:'SPI"} \\ 3 \\ 4 \\ 14 \\ 79 \\ 12 \\ 4 \\ 3 \\ 119 \end{bmatrix} & \begin{bmatrix} \text{"S:'SPI"} \\ 4 \\ 1 \\ 7 \\ 53 \\ 9 \\ 4 \\ 1 \\ 79 \end{bmatrix} & \begin{bmatrix} \text{"S:'SPI"} \\ 0 \\ 5 \\ 5 \\ 39 \\ 5 \\ 5 \\ 0 \\ 59 \end{bmatrix} \end{bmatrix}$$

Program 20: Add headers to P1 & P2

$$P1P2 := \overrightarrow{\mathrm{stack}(\text{"S:'Pr"}, P1, P2)} = \begin{bmatrix} \begin{bmatrix} \text{"S:'Pr"} \\ 2.1 \\ 5.4 \\ 10 \\ 67.4 \\ 9.2 \\ 3.8 \\ 2.1 \\ 100 \end{bmatrix} & \begin{bmatrix} \text{"S:'Pr"} \\ 1.7 \\ 5 \\ 9.5 \\ 70.4 \\ 7.3 \\ 3.4 \\ 2.8 \\ 100 \end{bmatrix} & \begin{bmatrix} \text{"S:'Pr"} \\ 2.5 \\ 3.4 \\ 11.8 \\ 66.4 \\ 10.1 \\ 3.4 \\ 2.5 \\ 100 \end{bmatrix} & \begin{bmatrix} \text{"S:'Pr"} \\ 5.1 \\ 1.3 \\ 8.9 \\ 67.1 \\ 11.4 \\ 5.1 \\ 1.3 \\ 100 \end{bmatrix} & \begin{bmatrix} \text{"S:'Pr"} \\ 0 \\ 8.5 \\ 8.5 \\ 66.1 \\ 8.5 \\ 8.5 \\ 0 \\ 100 \end{bmatrix} \end{bmatrix}$$

Program 21 : Very useful feature to bring relevant matrices together

$$All\_SP := \overrightarrow{\mathrm{augment}(S1S2, P1P2)}$$

$$All\_SP = \begin{bmatrix} \begin{bmatrix} \text{"S:'SPI"} & \text{"S:'Pr"} \\ 5 & 2.1 \\ 13 & 5.4 \\ 24 & 10 \\ 161 & 67.4 \\ 22 & 9.2 \\ 9 & 3.8 \\ 5 & 2.1 \\ 239 & 100 \end{bmatrix} & \begin{bmatrix} \text{"S:'SPI"} & \text{"S:'Pr"} \\ 3 & 1.7 \\ 9 & 5 \\ 17 & 9.5 \\ 126 & 70.4 \\ 13 & 7.3 \\ 6 & 3.4 \\ 5 & 2.8 \\ 179 & 100 \end{bmatrix} & \begin{bmatrix} \text{"S:'SPI"} & \text{"S:'Pr"} \\ 3 & 2.5 \\ 4 & 3.4 \\ 14 & 11.8 \\ 79 & 66.4 \\ 12 & 10.1 \\ 4 & 3.4 \\ 3 & 2.5 \\ 119 & 100 \end{bmatrix} & \begin{bmatrix} \text{"S:'SPI"} & \text{"S:'Pr"} \\ 4 & 5.1 \\ 1 & 1.3 \\ 7 & 8.9 \\ 53 & 67.1 \\ 9 & 11.4 \\ 4 & 5.1 \\ 1 & 1.3 \\ 79 & 100 \end{bmatrix} & \begin{bmatrix} \text{"S:'SPI"} & \text{"S:'Pr"} \\ 0 & 0 \\ 5 & 8.5 \\ 5 & 8.5 \\ 39 & 66.1 \\ 5 & 8.5 \\ 5 & 8.5 \\ 0 & 0 \\ 59 & 100 \end{bmatrix} \end{bmatrix}$$

$MTH := months^{T} = [\,3\;\;4\;\;6\;\;9\;\;12\,]$

$months = \begin{bmatrix} 3 \\ 4 \\ 6 \\ 9 \\ 12 \end{bmatrix}$

Program 22 : Create header for Months

$hd1 := \overrightarrow{\text{concat}(\text{num2str}(MTH), \text{" M"})} = [\,\text{"3 M"}\;\;\text{"4 M"}\;\;\text{"6 M"}\;\;\text{"9 M"}\;\;\text{"12 M"}\,]$

$t1 := \text{time}(0)$

$\text{time}(0) - t1 = 0.17\ \text{s}$

Description of SPI definitions & ranges

Des :=

"S:'RF"	"S:'Period'/'Category"
"S:'mm"	"S:'Wet'/'Dry"
"2.0+"	"Extremely Wet"
"1.5 to 1.99"	"Very Wet"
"1.0 to 1.49"	"Moderately Wet"
"-0.99 to +0.99"	"Near Normal"
"-1.0 to -1.49"	"Moderately Dry"
"-1.5 to -1.99"	"Severely Dry"
"≤ -2.0"	"Extremely Dry"
"Σ"	"Total"

Des := [Des] =

"S:'RF"	"S:'Period'/'Category"
"S:'mm"	"S:'Wet'/'Dry"
"2.0+"	"Extremely Wet"
"1.5 to 1.99"	"Very Wet"
"1.0 to 1.49"	"Moderately Wet"
"-0.99 to +0.99"	"Near Normal"
"-1.0 to -1.49"	"Moderately Dry"
"-1.5 to -1.99"	"Severely Dry"
"≤ -2.0"	"Extremely Dry"
"Σ"	"Total"

Click on dotted region & Drag to rigth to view entire expression

Program 23 : Stack with "hd1"

$All\_SP2 := \overrightarrow{\text{stack}(hd1, All\_SP)} =$

"3 M"	"3 M"	"4 M"	"4 M"	"6 M"	"6 M"	"9 M"	"9 M"	...
"S:'SPI"	"S:'Pr"	"S:'SPI"	"S:'Pr"	"S:'SPI"	"S:'Pr"	"S:'SPI"	"S:'Pr"	
5	2.1	3	1.7	3	2.5	4	5.1	
13	5.4	9	5	4	3.4	1	1.3	
24	10	17	9.5	14	11.8	7	8.9	
161	67.4	126	70.4	79	66.4	53	67.1	
22	9.2	13	7.3	12	10.1	9	11.4	
9	3.8	6	3.4	4	3.4	4	5.1	
5	2.1	5	2.8	3	2.5	1	1.3	
239	100	179	100	119	100	79	100	

$All\_SP3 := \text{augment}(Des, All\_SP2) =$

"S:'RF"	"S:'Period'/'Category"	...
"S:'mm"	"S:'Wet'/'Dry"	
"2.0+"	"Extremely Wet"	
"1.5 to 1.99"	"Very Wet"	
"1.0 to 1.49"	"Moderately Wet"	
"-0.99 to +0.99"	"Near Normal"	
"-1.0 to -1.49"	"Moderately Dry"	
"-1.5 to -1.99"	"Severely Dry"	
"≤ -2.0"	"Extremely Dry"	
"Σ"	"Total"	

$\text{time}(0) - t1 = 0.02\ \text{s}$

SPI Analysis

	RF	Period / Category	3 M	3 M	4 M	4 M	6 M	6 M	9 M	9 M	12 M	12 M
	mm	Wet / Dry	SPI	Pr	SPI	Pr	SPI	Pr	SPI	Pr	SPI	Pr
Millawana Estate	**2.0+**	**Extremely Wet**	**5**	**2.1**	**3**	**1.7**	**3**	**2.5**	**4**	**5.1**	**0**	**0**
	1.5 to 1.99	**Very Wet**	**13**	**5.4**	**9**	**5**	**4**	**3.4**	**1**	**1.3**	**5**	**8.5**
	1.0 to 1.49	**Moderately Wet**	**24**	**10**	**17**	**9.5**	**14**	**11.8**	**7**	**8.9**	**5**	**8.5**
	-0.99 to +0.99	**Near Normal**	**161**	**67.4**	**126**	**70.4**	**79**	**66.4**	**53**	**67.1**	**39**	**66.1**
	-1.0 to -1.49	**Moderately Dry**	**22**	**9.2**	**13**	**7.3**	**12**	**10.1**	**9**	**11.4**	**5**	**8.5**
	-1.5 to -1.99	**Severely Dry**	**9**	**3.8**	**6**	**3.4**	**4**	**3.4**	**4**	**5.1**	**5**	**8.5**
	≤ -2.0	**Extremely Dry**	**5**	**2.1**	**5**	**2.8**	**3**	**2.5**	**1**	**1.3**	**0**	**0**
	Σ	**Total**	**239**	**100**	**179**	**100**	**119**	**100**	**79**	**100**	**59**	**100**

All_SP3

$\mathrm{time}(0) - t_{start} = 10.2\ \mathrm{s}$