# 8 The Methodological Approaches in Physical Geography

K. W. G. Rekha Nianthi, A. K. Wickramasooriya, Lalitha Dissanayake, C. S. Hettiarachchi, and R. M. G. N. Rajapaksha


**Abstract**

Physical geography is the branch of natural science which deals with the study of processes and patterns in the natural environment such as the atmosphere, hydrosphere, lithosphere, biosphere, in the geosystem. This chapter considers some selected methodological approaches for hydrology, climatology, geomorphology and biogeography. The hydrology section of this chapter recommended to apply the most suitable method to estimate missing precipitation. Three methods are introduced as a simple arithmetic mean method, normal ratio method and inverse distance method. The methods of estimating missing precipitation, which are described in this subsection, are very useful for researchers who engaged with hydrological and climatological research utilizing precipitation data in gauging stations facing difficulties to collect continuous precipitation due to unavailability of data. The techniques of climate section are devoted to discuss the selected statistical techniques that are vastly applicable in many climate-related assessments. Time series analysis plays a significant role in analysing and modelling climatological data. There are several software packages that support time series data analysis. Out of them R is a widely used statistical package that provides an environment for statistical analysis and the production of clear graphics in time series analysis. Four main components frequently perform in a time series analysis are trends, seasonality, cycles and irregular fluctuations. All are applicable to climate data and result in meaningful outputs. The geomorphological section introduced how to derive the particle size distribution of soils. There are some advantages; of the sieving method in particle sizing, it is fast and easy handling of the instrument, accurate and reproducible, a time-saving method and the cost of the instrument is lower than other methods, but it works only with dry particles. Biogeography is a discipline with a long intellectual heritage that considers where and why different types of organisms occur over the face of the globe. In Biogeographical survey methods measuring Biodiversity is one of the main tasks.



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## 8.1 Introduction

Physical geography is the branch of natural science which deals with the study of processes and patterns in the natural environment such as the atmosphere, hydrosphere, biosphere and geosphere, as opposed to the cultural or built environment, the domain of human geography. Physical geography can be divided into several branches. This chapter considers hydrology, climatology, geomorphology and biogeography selected techniques which are more important to the undergraduate and postgraduate studies. The early studies in geomorphology are the founder for pedology one of two main branches of soil science. In this chapter, soil geography is also considered special for the distribution of soil across the terrain. The hydrology mainly concerns with the amount and quality of water moving and accumulating on the land surface and the soils and rocks near the surface and the hydrological cycle. It encompasses water in river, lakes, aquifers and to a glacier. Climatology is the study of the climate scientists defined as the weather conditions average over a long period of time. Climatology examines both the nature of micro and macroclimates and the natural and anthropogenic influences on them. Geomorphology concerns the surface of the earth and the processes by which it is shaped in the present and past form. This geomorphology has several subfields that deal with specific landforms of various environments. Biogeography is the science which deals with geographic patterns of species distribution and the process that results in these patterns. This chapter considers some selected methodological approaches for the above-mentioned four subjects.

## 8.2 The Selected Methodological Approaches in Hydrology

### 8.2.1 Introduction

Precipitation is one of the main parameters considered in climatological and hydrological studies. However, sometimes researchers may find it difficult to complete their research without having continuous precipitation data records at gauging stations. There are various reasons for not having continuous precipitation data at gauging stations, i.e. malfunctioning of precipitation gauges and other related instruments, gauges are damaged due to the effect of natural hazards and are not replaced for a long period, the absence of people in charge of reading and record of rain gauge stations, not available continuous precipitation data at gauging stations.

The researchers are interested to complete their research even though with the lack of precipitation data, and they use many alternative precipitation estimating methods to find missing precipitation at gauging stations. In that case, it is necessary to use the most suitable method to calculate the accurate missing precipitation, otherwise it will affect the analysis of their research. Thus, this sector addresses the appropriate methods which can be used to calculate missing precipitation data and understand their strengths and weaknesses.

### 8.2.2 Objective

The main objective of this section is to identify the different methods which can be applied to estimate missing precipitation at a station using available precipitation data at stations in and around that station. Further, this section explains the best method and conditions to be satisfied to estimate the most accurate missing precipitation data.

### 8.2.3 Methods

The sample data set of ten rain gauging stations which include national grid coordinations, the average annual precipitation data and available precipitation data are considered to explain different methods that could be applied for estimating missing precipitation of a station. There are three methods commonly use to estimate or calculate missing precipitation of a rain gauge station. These three methods are Simple arithmetic mean method, Normal ratio method and Inverse distance method.

#### 8.2.3.1 Simple Arithmetic Mean Method

The simple arithmetic mean method can be applied when there is a similar normal annual precipitation that can be observed in all rain gauging stations considered for estimating the missing precipitation. Therefore, first it has to be checked whether the normal annual precipitation of all stations considered for the estimation of missing precipitation are within the 10% of the normal annual precipitation of the station of the missing precipitation to be estimated. If this condition is satisfied, simple arithmetic mean method could be utilized to estimate missing precipitation of the station 'X', i.e. $P_x$ (Chow et al. 1988) and arithmetic mean of precipitation could be calculated using number of nearby stations (n) and precipitation of ith station ($P_i$) which are given in the following equation (Tabios and Salas 1985).

$$P_x = \frac{1}{n}\sum_{i=1}^{i=n} P_i$$

#### 8.2.3.2 Normal Ratio Method

When the normal annual precipitation is not similarly distributed in rain gauging stations consider the estimate of missing precipitation, i.e. normal annual precipitation of stations do not fall within 10% normal annual precipitation of the missing station, normal ratio method could be used. The missing precipitation of station 'X', i.e. $P_x$ could be calculated using no of surrounding stations (m), precipitation of rain gauges used for estimation ($P_i$), normal annual precipitation of X station ($N_x$) and normal annual precipitation of surrounding stations ($N_i$) as mentioned in the following equation (Singh 1994).

$$P_X = \frac{1}{m}\sum_{i=1}^{m}\left[\frac{N_X}{N_i}\right]P_i$$

#### 8.2.3.3 Inverse Distance Method

When the normal annual precipitation data of gauging stations are not available and distances to gauging stations from the station with missing precipitation or (x,y) coordinates of all stations are available, inverse distance method could be used to estimate the missing precipitation of the station. The equation used to estimate missing precipitation of station 'X' i.e. $P_X$ using this method is given below (Lam 1983) which includes precipitation of each station use for the estimation ($P_i$), distance from each location to station with missing precipitation (di) and the number of surrounding stations (N).

$$P_X = \frac{\sum_{i=1}^{N}\left[\frac{P_i}{d_i^2}\right]}{\sum_{i=1}^{N}\left[\frac{1}{d_i^2}\right]}$$

If the distances are known from the station with missing precipitation, directly those distances could be assigned for the above equation. However, if distances are unknown and if the coordinates of each station are known, distances in metres could be calculated using the following equation.

$$d_{1,2} = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$$

where $d_{1,2}$ is the distance between station 1 and station 2 and ($x_1$, $y_1$), ($x_2$, $y_2$) are coordinates of station 1 and station 2, respectively. However, $d_{1,2}$ has to be divided by 1000 to convert distance into km.

### 8.2.4 Procedure

Three methods of estimating missing precipitation explained in the above could be understood by the following examples. To explain procedure of three methods following sample data set could be used (Table 8.1). Assume that the researcher needs precipitation data of all ten stations on 01 September 2020. However, this data is not available in stations $S_2$, $S_5$ and $S_8$. Therefore, he/she could use the most suitable method out of three methods introduced in the above to estimate missing precipitation data. The researcher should consider the following criteria to estimate missing precipitation of station $S_2$, $S_5$ and $S_8$.

#### 8.2.4.1 Estimate of Missing Precipitation at $S_2$ Station

The coordinations are missing at station $S_2$ and therefore, distances from $S_2$ station to other stations cannot compute. Thus, inverse distance method cannot apply to estimate missing precipitation. The normal annual precipitation of station $S_2$ is 104.8 mm and 10% of it is 10.48 mm. To check whether the normal annual precipitation of other stations are within 10% of the normal annual precipitation of $S_2$ station, the following calculations could be done.

$$\text{Maximum normal annual precipitation} = 104.8\ \text{mm} + 10.48\ \text{mm or } 115.28\ \text{mm}$$

$$\text{Minimum normal annual precipitation} = 104.8\ \text{mm} - 10.48\ \text{mm or } 94.32\ \text{mm}$$

All available normal annual precipitation of stations are within 94.32 mm and 115. 28 mm. Therefore, simple arithmetic mean method could be used to calculate the missing precipitation at station $S_2$, i.e. $P_{S2}$ as mentioned below

$$P_{S_2} = (22.4 + 8.9 + 3.8 + 18.7 + 7.3 + 18.6 + 20.5)\text{mm}/7 = 14.31\ \text{mm}$$

**Table 8.1** Sample data set of rain gauging station

| Station Name | X-Coordination | Y-Coordination | Normal annual precipitation (mm) | Precipitation on 01/09/2020 |
|---|---|---|---|---|
| $S_1$ | 156,956 | 345,284 | 111.8 | 22.4 |
| $S_2$ | Not available | Not available | 104.8 | Not available |
| $S_3$ | 166,868 | 336,500 | 108.4 | 8.9 |
| $S_4$ | 167,000 | 334,025 | 106.6 | 3.8 |
| $S_5$ | 172,358 | 347,480 | Not available | Not available |
| $S_6$ | 157,880 | 346,890 | 105.6 | 18.7 |
| $S_7$ | 167,040 | 334,562 | 96.3 | 7.3 |
| $S_8$ | Not available | Not available | 114.5 | Not available |
| $S_9$ | 170,060 | 340,568 | 111.7 | 18.6 |
| $S_{10}$ | 167,895 | 334,674 | 98.7 | 20.5 |

#### 8.2.4.2 Estimate of Missing Precipitation at $S_5$ Station

The normal annual precipitation at station $S_5$ is missing and also it is needed to estimate the missing precipitation on 01 September 2020 at station $S_5$. As the normal annual precipitation at station $S_5$ is missing, it is not possible to check whether all station's normal average precipitation is within 10% of the normal average precipitation of $S_5$ station. Therefore, inverse distance method has to be used to calculate the missing precipitation of $S_5$ station ($P_{S5}$). However, as only coordinates are given in the table, distances to other stations from station $S_5$ have to be calculated using the following equation.

$$d_{1,2} = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$$

Example: distance between S5 and S1 stations could be calculated as

$$d_{S_5,S_1} = \sqrt{(172358 - 156956)^2 + (347480 - 345284)^2} \Big/ 1000 \text{ km}$$
$$= 15.6 \text{ km}$$

Similarly, distances between other stations and station $S_5$ can be calculated and are shown in Table 8.2.

Precipitation on 01 September 2020 at station $S_5$, i.e. $P_{S5}$ could be calculated as follows:

$$P_{S_5} = \frac{\left\{ \begin{array}{c} \left(22.4/15.6^2\right) + \left(8.9/12.3^2\right) + \left(3.8/14.5^2\right) + \left(18.7/14.5^2\right) \\ + (7.3/14.0^2) + (18.6/7.3^2) + (20.5/13.6^2) \end{array} \right\} \text{mm}}{\left\{ \begin{array}{c} (1/15.6^2) + (1/12.3^2) + (1/14.5^2) + (1/14.5^2) \\ + (1/14.0^2) + (1/7.3^2) + (1/13.6^2) \end{array} \right\}}$$

$$P_{S_5} = 15.25 \text{ mm}$$

#### 8.2.4.3 Estimate of Missing Precipitation at $S_8$ Station

The normal annual precipitation at station $S_8$ is 114.5 mm. As there is no information about coordinates of this station, it is not possible to apply inverse distance method to calculate missing precipitation. Therefore, suitable method out of simple arithmetic mean method or normal ration method could be used. The 10% of the normal annual precipitation at station $S_8$ is 11.45 mm.

Maximum normal annual precipitation
$= 114.5$ mm $+ 11.45$ mm or 125.95 mm

Minimum normal annual precipitation
$= 114.5$ mm $- 11.45$ mm or 103.05 mm

Normal annual precipitation of all stations are not within the range of 10% of the normal annual precipitation of the station $S_8$. For example stations $S_7$ and $S_{10}$ received precipitation 96.3 mm and 98.7 mm respectively which are not in the range 125.95 mm and 103.05 mm. Therefore, simple arithmetic mean method could not apply to estimate precipitation on 01 September 2020 at station $S_8$, and therefore, normal ratio method has to be used. Based on normal ratio method missing precipitation at station S8 could be calculated as follows:

$$P_{S_8} = \frac{1}{7} \times \left( \begin{array}{c} \frac{114.5}{111.8} \times 22.4 + \frac{114.5}{108.4} \times 8.9 + \frac{114.5}{106.6} \times 3.8 \\ + \frac{114.5}{105.6} \times 18.7 + \frac{114.5}{96.3} \times 7.3 + \frac{114.5}{111.7} \times 18.6 + \frac{114.5}{98.7} \times 20.5 \end{array} \right)$$

$$P_{S_8} = \frac{108.23}{7} \text{ mm}$$

$$P_{S_8} = 15.46 \text{ mm}$$

### 8.2.5 Advantages and Disadvantages

The methods of estimating missing precipitation which are described in this subsection are very useful for researchers who engaged with climatological and hydrological research utilizing precipitation data in many gauging stations and face difficulties to collect continuous precipitation due to unavailability of data. However, as these methods are used to estimate missing precipitation, it is recommended to apply the most suitable method to estimate missing precipitation otherwise, it will affect the outcome of the research or study.

**Table 8.2** Distances between $S_5$ station and other stations

| Station | $S_1$ | $S_2$ | $S_3$ | $S_4$ | $S_5$ | $S_6$ | $S_7$ | $S_8$ | $S_9$ | $S_{10}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Distance from the station $S_5$ (km) | 15.6 | – | 12.3 | 14.5 | – | 14.5 | 14.0 | - | 7.3 | 13.6 |

## 8.3 The Selected Methodological Approaches in Climatology

### 8.3.1 Introduction

Field of climatology focuses on study of the atmosphere and weather patterns in a particular area over the period. The term weather describes status of the atmosphere for short term or various temporal scales. Climate is defined as averages of atmospheric or weather conditions in a particular area over a longer period. Commonly assessed climate variables are atmospheric temperature, precipitation, wind direction and speed, atmospheric pressure and humidity. Analysis of climate is important to quantify risks and trends of climate-related disasters as well as predict the future weather and climate status to minimize economic and social losses and adapt to the climate variations. Weather forecasting plays grate importance from a farmer to top-level policy-makers and planners since majority of the economic activities are directly or indirectly climate related or dependent. There are different aspects in quantification of climate data. Frequently analysed climate parameters are mean or average values, minimum and maximum, Coefficient of variance, range, standard deviation, and standard error, etc. of climate variables as descriptive statistics. However, selection of statistical methods is mainly depending on the objective/s of the study. Most climate studies are focused on spatial and temporal variations, trend analysis, seasonal variations, likelihood of occurrence of storms or flood peaks in an area and weather forecasting through statistical models.

Climate data can be analysed either subjectively in experience or objectively dealing with long-term reliable data series. Climate data are collected in meteorological stations by experienced climatologist in specific time intervals as specified for each climate variable. Rainfall data are usually collected on daily basis. All daily records are stored in electronically or manually in climate databases. Interested person can be accessed the official database and purchase either daily data or monthly mean or data as required. Modern world is highly depending on climate change impacts. Awareness of climate variations and changes is vital to plan future activities and minimize or get rid of climate change impacts. Reliable climate and weather assessments are purely depending on mathematical and statistical techniques.

### 8.3.2 Objective

This section has devoted to explain the statistical techniques that are vastly applicable in many climate-related assessments.

### 8.3.3 Methods

Time series analysis plays a significant role in analysing and modelling climatological data (Collischonm et al. 2005). There are several software packages that support to time series data analysis. Out of them R is a widely used statistical package that provides an environment for statistical analysis and the production of clear graphics in time series analysis. Four main components frequently perform in a time series analysis are trends, seasonality, cycles, and irregular fluctuations. All are applicable to climate data and result in meaningful outputs.

### 8.3.4 Procedures

There are prerequisite tests need to perform before the data series bring into the analysis to acquire some compulsory conditions in time series analysis. Further climate data series are depending on long-term data series; there might be a chance to having missing data and abnormal data in a series due to instrumental errors or other reasons. Therefore, to achieve reliable output, it is essential to follow correct statistical tests and procedures to analysis of climate data towards specific objective.

### 8.3.5 Homogeneity and Normality Testing

Testing of homogeneity of the data is essential for analysing climate data series to check instrumental, reading or data processing errors. Climate data analysis is indeed homogeneous data series unless it hides the true climatic signals specially trends, detect change points and forecasting. Normal distribution of the data series can be detected by the normal or Gaussian frequency distribution. Histograms, scatter plots, or probability– probability (P–P) or quantile–quantile (Q–Q) plots, Skewness and kurtosis are common statistical tests that can be used to assess normal distribution. None-normal data series need to transform the data series as required to get the series nearly normal. Transformed data also need to represent the same physical processes as the original data as well transformed data should safeguard the thorough conclusions. The most common data transformation methods are the square root, cube root, logarithmic and inverse transformations.

### 8.3.6 Missing Values

Climate data analysis are depending on continuous long-term data series. There might be a chance to loss some data in such long-term data series due to different reasons. To reach a reliable outcome of any analysis is essential to identify and replace the lost data before taking the data in to the analysis. Estimation allows an observed value to be compared to its neighbours in both time and space. Data estimation to be realistic and consistent when using essential applications of statistics and mean time need to consider physical properties of the system being considered. In some cases, the estimation of a missing value can be performed by a simple process, such as by computing the average of the values observed on both sides of the gap. Complex estimation methods are also used, considering correlations with other elements. These methods include weighted averages and linear regressions.

### 8.3.7 Time Series Plot and Moving Average Plot

General time series plots illustrate natural behaviour of the data series over the years. Most instances general time series plots are not enough to assess seasonality, cyclic patterns or trends exist in the time series. Therefore, further analysis methods are required to assess seasonal, cyclic and trend analysis. Especially lengthier time series data sets show noise and shield the true patterns.

As per the time series plots in Fig. 8.1, there is no clear trend of increasing or decreasing of

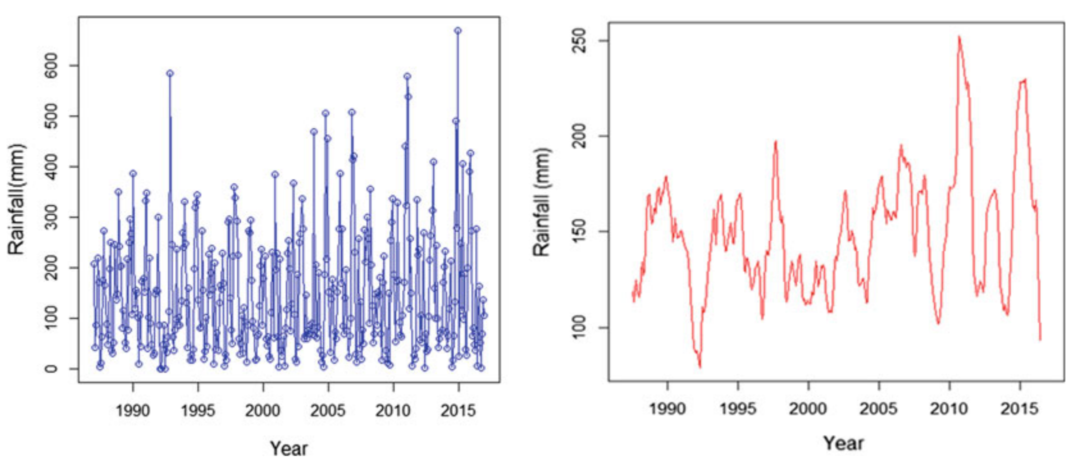



**Fig. 8.1** General Time series plot and moving average plot illustrating monthly mean rainfall distribution over 1987–2016

rainfall during 1987–2016 period, but it visualizes that a seasonality pattern showing small and huge hikes representing rainfall fluctuations over the period. The expanded plots further visualize huge hikes are restricted towards year ends.

Smoothing is a technique that is used to reduce random fluctuations or noise in a time series and results in sharp clear pattern of the original data series. Moving average is one of the smoothing techniques that are commonly used for time series analysis and time series forecasting. Moving Average smoothers, the data by averaging consecutive observations in a series. The average plot shows clear random fluctuations than in general time series plot.

### 8.3.8 Decomposition

Method of Decomposition provides useful information about the time series as decomposition transforms an original time series into multiple different time series as trend component, random component, and seasonality component either additively or multiplicatively (Fig. 8.2). There are four components are shown separately in Fig. 8.2 within four panels. First panel illustrates observations that depict the behaviour of rainfall variation in the original data series over the time. The second panel illustrates trend component. According to this example, there is no visual trend pattern. Overall trend throughout the period is not increased or decreased over time. Third panel shows seasonal component. There is a clearly identified seasonal component illustrated in panel 3. The residual component shown in the bottom panel that is leftovers when the seasonal and trend-cycle components have been subtracted from the data series. Fairly random behaviour is shown in residuals over the period. Further decomposition analysis gives in figure, whether the seasonality and the trend are true or false.

### 8.3.9 Trend Analysis

Trends are the long-term underlying movements representing growth or decline in a time series over an extended period. Either smooth continuous curve or a straight line represents the trend

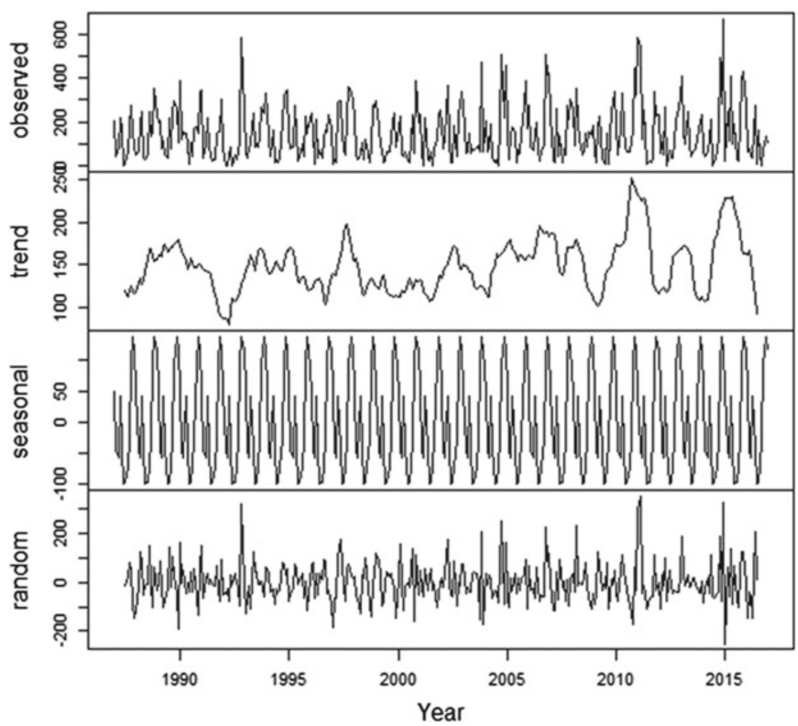



**Fig. 8.2** Time Series decomposition plot showing rainfall behaviour during 1987–2017

in a graph that is captured using time series regression, double exponential smoothing, moving average methods and Mann–Kendall trend test.

### 8.3.10 Mann–Kendall Trend Test

The Mann–Kendall trend test is completely nonparametric. Before applying the Mann–Kendall test to the time series, need to be investigated whether the time series data are serially correlated (Wickramaarachchi et al. 2020). If they are serially correlated need to be used the Mann–Kendall test in conjunction with block bootstrapping method in order to account for the serial correlation and if they are not serially correlated they could apply the Mann–Kendall test without performing block bootstrapping.

Examining the autocorrelation (ACF) and partial autocorrelation (PACF) plots for the time series data set suggests that the autocorrelation and partial autocorrelation present in this series are significant. If most of the vertical spikes in the ACF and PACF plots fall out of the horizontal band defined by the blue dotted lines indicates presence of significant autocorrelations (Fig. 8.3).

Once the Mann–Kendall test is performed the resulting Tau value is inside the 95% confidence interval levels, we can conclude that trend of time series is not significant and if Tau value is out of the limits of confidence interval then the trend is significant. Sign of the Tau value indicates the direction of the trend. Magnitude of the trend can be estimated by Sens' slope estimation test. The used time series data are not shown significant trend (Fig. 8.4).

### 8.3.11 Time Series Forecasting Using ARIMA Model

#### 8.3.11.1 ACF & PACF Analysis

There are different climate forecasting methods. The Box-Jenkins **A**uto **R**egressive **M**oving **A**verage (ARIMA) models possess many desirable features allowing the analyst to depend only on historical data series to forecast future events without depending on other related time series data. There are few steps behind to build up the ARIMA model. Seasonality, trend components as well correlations are need to remove by converting the data series as stationary if it is a non-stationary series. There are several conditions that must be satisfied for the stationarity of a series. They are the mean, and the variance of the series should not be time dependent and the covariance of time series and lagged time series should depend only on the difference of the time. Differencing is the technique that is commonly used to remove non-stationarity in a data series. If the series is non-stationary due to non-constant mean, then the lag differencing can be performed. This differencing technique results in three parameters as p, d and q. Plots of Auto

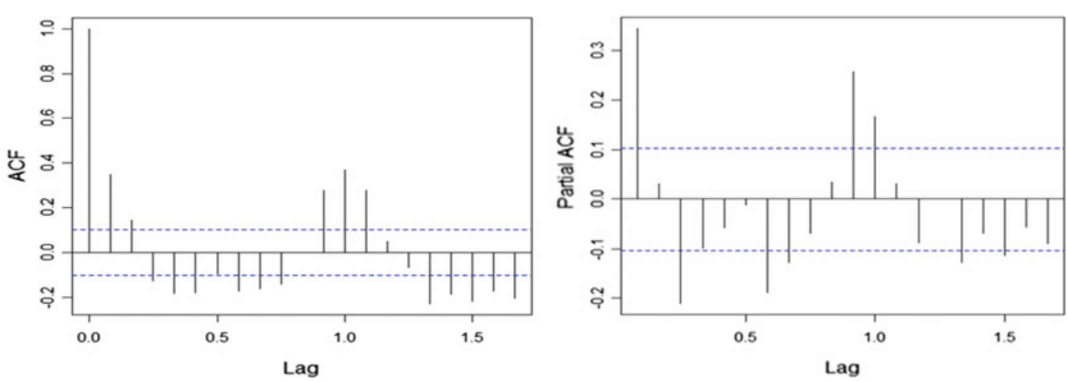



**Fig. 8.3** ACF and PACF Plots showing autocorrelations

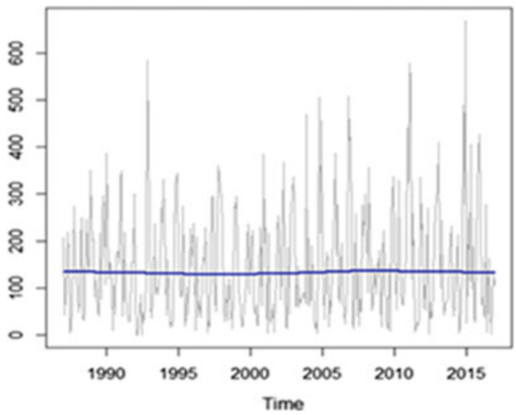



**Fig. 8.4** Trend plot

Correlation Function (ACF) and Partial Auto Correlation Function (PACF) result in the parameters p,d,q. ACF Plot is used to get Moving Average (MA) parameter (q, Q), PACF Plot is used to get Auto Regressive (AR) parameter (p, P) (Meher and Jha 2013).

In ACF and PACF plots, lag represents the years and single spike represents a month in a year. Within one lag there are 12 spikes are displayed. Horizontal blue lines are indicated critical lines. Spikes within the critical lines indicate that absence of autocorrelations and spikes extending beyond the critical line signifies the presence of significant autocorrelations (Fig. 8.5a).

The ACF plot showing in illustrates a significant spike at lag 4 for MA parameter and the sinusoidal curve indicates that seasonality of annual (m = 12) and PACF plot indicates a significant spike at lag 1 for AR parameter. Therefore, the rainfall data series used in this example is non-stationary because it shows seasonal effects as revealed by the ACF and PACF plots and needs to transform it into a stationary series by adjusting the seasonality.

Figure 8.5b illustrates the seasonality adjusted ACF and PACF plots. As per Fig. 8.6, ACF and PACF plots have not shown significant spikes. Most autocorrelations and partial autocorrelations are within the critical level. Hence can be confirmed that the original rainfall data series have converted to stationary data series and the data series is now capable to apply in ARIMA modeling.

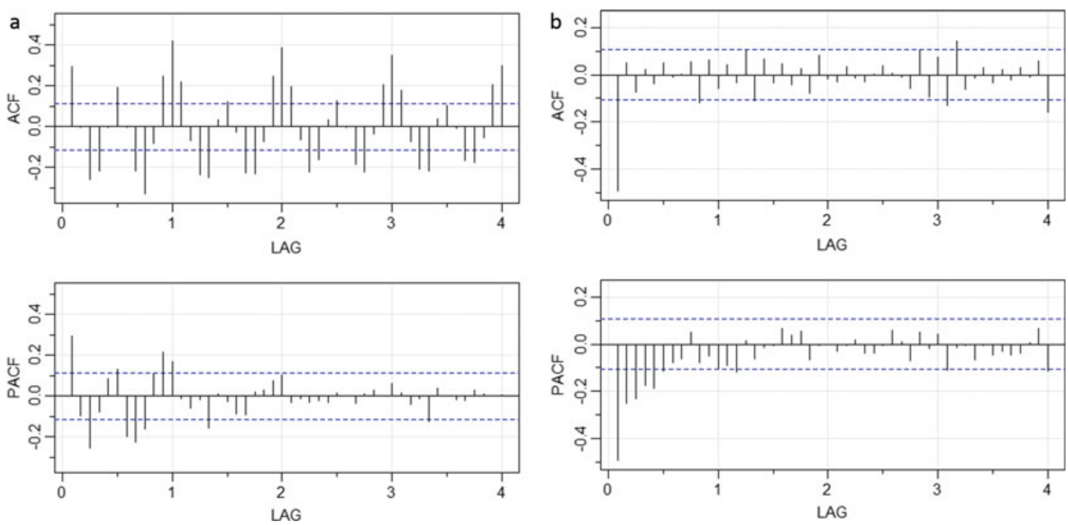



**Fig. 8.5** **a** ACF and PACF plots and **b** Seasonality adjusted ACF and PACF plots

### 8.3.12 Ljung-Box Test and Augmented Dickey-Fuller Test (ADF Test)

Stationarity of data can be assessed by the Ljung-Box test statistics. The Augmented Dickey-Fuller Test (ADF test) is another confirmation test that is used to confirm the conversion of data series into a stationary series. As per the ADF test results, we have enough evidence to reject null hypothesis since p-value is less than 0.05. The tested data series has seasonality adjusted and converted to stationary series and applicable for the ARIMA modelling. The data series that contains seasonal component must be modelled as a Seasonal ARIMA model. Seasonal ARIMA model is a combination of non-seasonal ARIMA model and seasonal ARIMA model. If the data series is separated into two parts such as seasonally adjusted component and seasonal component due to the existence of seasonality, then the ARIMA model used in both components can be identified as SARIMA model. The SARIMA model is denoted by SARIMA (p,d,q) (P,D,Q)s, where first bracket and second bracket denote the seasonally adjusted and seasonal factor series respectively. As per the results of the Ljung-Box test, associated p-value is greater than 0.05 confirms the acceptance of null hypothesis which said that 'the model does not exhibit lack of fit'. Therefore, the developed model is fine and better forecasts the future rainfall. Pattern visible in the residuals time plots, lag spikes of the frequency in the ACF plots and the Gaussian shape of the parametrically measured residuals all suggested that there is no correlation and models are capable of capturing future variation of the rainfall (Fig. 8.6).

Stationary series use to fit the SARIMA model and then the statistical programme fits all the possible models as a result. The Akaike Information Criterion (AIC) is mostly used to choose the best model out of many resulted models, best model will be a model that has lowest AIC value. When the most appropriate model selects, the model parameters can be estimated using the least squares method. The diagnostic checking of the residuals from the fitted model is the next stage of the process, usually by correlation analysis with the aid of ACF plots. If the residuals are correlated, the model will need to be revisited. Further, inspecting the normal probability plot and the histogram of residuals are the common test that can be performed to assess fitness of the ARIMA model and to check the behaviour of the residuals of the fitted model, respectively. As per the results of the Ljung-Box test, if associated p-value is greater than 0.05 it confirms the not rejection of null hypothesis which is 'the model does not exhibit lack of fit' and in other words model is fine. Pattern visible in the residuals time plot, lag spikes of the frequency in the ACF plot, and the Gaussian shape of the parametrically measured residuals (Fig. 8.7) all suggest no correlation or model is capable of capturing variation of the rainfall using this time series data.

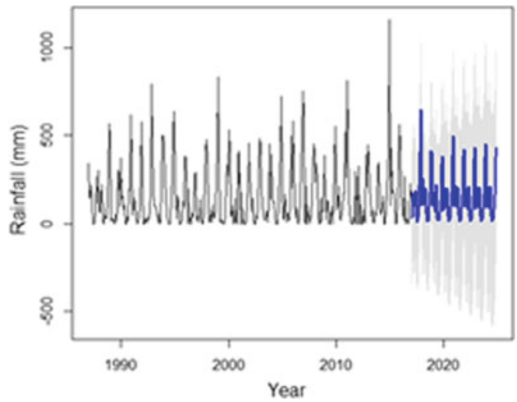



**Fig. 8.6** Time series forecast plot

### 8.3.13 Advantages of Climate Data Analysis

Climate information are relevant for several fields. Agriculture, Aquaculture, Food processing industries, construction designers, management of public finances, assets, insurance needs and health and much more different fields depend on understanding of future climate. Potential climate models are useful tool to predict the climate variations in future. Reliable analysis and modelling techniques are essential to provide

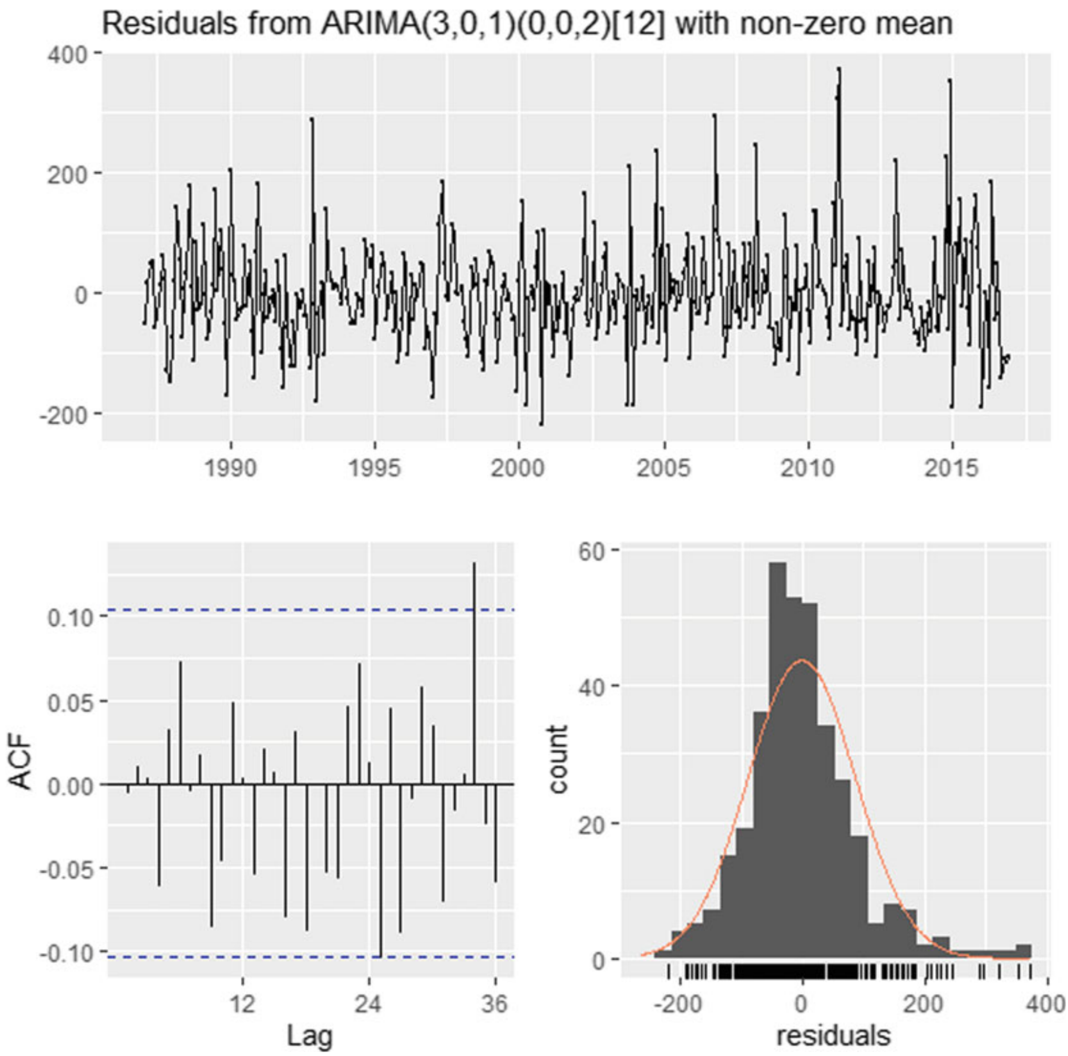



**Fig. 8.7** Pattern visible in the residuals from ARIMA models

information to parties who rely on the climate conditions in their business.

## 8.4 The Methodological Approaches in Geomorphology

### 8.4.1 Introduction

In the last two decades, the management of land surface has developed into the form of a multi-functional procedure built upon the holistic base that unites scientific knowledge Lehotský and Grešková (2007). The section methodological approaches in geomorphology present a review of the methodology of soil texture analysis based on key techniques. The term 'texture' refers to the degree of coarseness or fineness of the mineral matter in the soil. It is determined by the proportion of sand, silt and clay particles Waugh (2006).

### 8.4.2 Objectives

The purpose of the analysis is to derive the particle size distribution of soils. Soil tests are conducted for several purposes such as agricultural, engineering (geotechnical), geochemical or as an ecological investigation. Soils supply most of the mineral nutrition for plants through the plant's root system. Therefore, the most widely conducted soil tests are to estimate the plant nutrients for the purpose of determine fertilizer recommendations in agriculture. In agriculture, soil tests are generally referred to as the 'analysis of a soil sample'. This field and laboratory soil sample tests are basically for determining physical properties of soil such as soil colour, consistency, moisture, porosity, bulk density and particle density, structure and texture. In addition to that, this also constitutes for measuring some chemical properties; particularly the soil pH and salinity.

### 8.4.3 Method

Soil test is comprised of four steps: Collection of a representative soil sample, Laboratory analysis of the soil sample, Interpretation of analytical results and recommendations based on interpreted analytical results. Soil sampling is the critical first step in a soil testing. Laboratory testing will utilize the analysis procedures which appropriate for determining soil conditions. Lab tests frequently include professional interpretation of results and recommendations. This method is constituting those four steps that relates to the above main physical and chemical properties of soil. The records of soil properties are useful for determining the soil management strategies and maintaining soil fertility for the ecological balance. Soil texture analysis is used to measure proportions of various sizes of the soil particles. The three major groups of soil particles are sand, silt and clay. These three groups are commonly referred to as the soil separates and soil texture is defined as the relative proportions of each class. The size measured in the particles are depending upon system use to define soil particle size classification. U.S. Department of Agriculture (USDA), World Reference Base for Soil Resources (WRB) and several other researchers and research institutions have introduced soil particle size classifications (Table 8.3).

According to this classification, particles less than 2 mm belong to sand, silt and clay. These fine grain particles are much more important in chemical reactions, release of nutrient elements and retention of soil moisture than a large volume of coarse gravel or sand. And also, soil texture is important to identify soil's responses to environmental and management conditions such as drought or calcium requirements. There are different methods to identify soil texture. 'Feel method' is a way to determine soil texture by rubbing soil between fingers. 'Separation by sedimentation' is depends upon *Stokes' Law*. 'Sieve analysis' is used to assess the particle size distribution and particularly it is used for coarse grain fraction. 'Pipet method' is often used as the standard to which other methods are compared and it is used for defining fine grain fraction which is less than 0.063 mm diameter. Generally, the grain size distribution is combined method of

**Table 8.3** Soil particle size classifications (USDA & WRB)

| Name of soil separate | Diameter limits (mm) (USDA classification) | Diameter limits (mm) (WRB classification) |
|---|---|---|
| Clay | Less than 0.002 | Less than 0.002 |
| Silt | 0.002–0.05 | 0.002–0.063 |
| Very fine sand | 0.05–0.10 | 0.063–0.125 |
| Fine sand | 0.10–0.25 | 0.125–0.20 |
| Medium sand | 0.25–0.50 | 0.20–0.63 |
| Coarse sand | 0.50–1.00 | 0.63–1.25 |
| Very coarse sand | 1.00–2.00 | 1.25–2.00 |

*Source* Soil Survey Field and Laboratory Methods Manual (2009) this mechanical sieve and pipet analysis. The Hydrometer method is predominant method which is associated with this laboratory test.

### 8.4.4 Procedure

See Figs. 8.8 and 8.9.

### 8.4.5 Determination of Soil Texture by Using Hydrometer Method

This method is used to determine sand, silt and clay concentrations without separating them. Hydrometer method is similar to pipet method except for the manner of determining the concentration of solids in suspension (Fig. 8.10; Table 8.4).

### 8.4.6 Discussion

Results are reported as percentages of the mineral fraction, 42.5% sand, 42.5% silt and 15% clay. Soil texture is based on the USDA textural triangle. This soil sample indicates 'loam' texture according to this soil texture triangle. Loam soils generally contain more nutrients, moisture and humus than sandy soils. It has better drainage and infiltration of water and air than silty soils. And also, it can be easier to till than clay soils. This soil can be basically recommended for the plant growth. In addition to the fine grain texture, this soil sample indicated small amount of coarse grain soil particles and considerable higher amount of fine grain particles. These fine grain particles are much more important in chemical reactions, release of nutrient elements and retention of soil moisture than a large volume of coarse gravel or sand. It is further important in determining the fertility and tillage characteristics of soils that is used as one of the primary characteristics for classifying soil horizons and soil profiles. This soil sample is representing the loam (Fig. 8.11).

### 8.4.7 Advantages and Disadvantages

The advantages of the sieving method in Particle Sizing: The analysis includes fast and easy handling of the instrument. The results of particle sizing are accurate and reproducible. It is a time-saving method, and the cost of the instrument is lower than other methods. The disadvantages of the sieving method in Particle Sizing: It works only with dry particles. The minimum limit of measurement is 50 µm, and there is a possibility of further reduction in size, which can cause errors.

Acquired representative soil sample put in oven until it become constant weight. In here, soil sample is in the metal cylinder and it put to oven keep with tray. It's weight record in 1st day as 726. 51g (weight with tray). Second day it shows constant value as 726.04g. Therefore, weight of the dry soil is 168.98 g (without weight of tray and metal cylinder).

| | | | |
|---|---|---|---|
| Weight of Dry soil (without tray and metal cylinder) | = weight of dry soil (with tray and metal cylinder) | - | (weight of tray + weight of metal cylinder) |

Weight of dry soil (without tray and metal cylinder) = 726.04g – (235.25g+321.81g)

= 168.98g

**Fig. 8.8** Method of drying soil sample

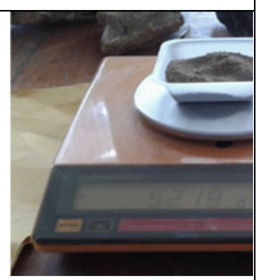
| | | |
|---|---|---|
| Step 1 | Crush the soil sample which is in metal cylinder and put it into bowl.<br><br>Then it crushes further by using small pestle. (Specially to note that, gravels and stones are not toughly crush; due to those are want to separate as coarse grain soil particle) |  |
| 2 | Then this soil sample put into 2 mm diameter sieve and sifts well. (It will help to grain size separate). Sieve will keep soil particles which more than 2 mm diameter (coarse grain soil).<br><br>Coarse grain soil particles (>2 mm diameter) |  |
| 3 | Fine grain soil particles (< 2 mm diameter) are drop onto the paper<br><br>Fine grain soil particle (<2 mm diameter) |  |
| 4 | Then we can measure the weight of fine and coarse grain soil samples. -In here, weight of coarse grain soil particles is 19.13 g.-Total weight of fine grain particles is 149.85 g. 50 g of fine grain soil particles should separate for the 'hydrometer method of soil analyses. |  |
| 5 | In here weight of measuring cup is 2.19 g. Therefore weight should take as 52.19 g.  %0 g of fine grain soil sample put into the beaker. Weight of remain fine grain soil sample is 99.85 g (after the separate 50 g soil sample for hydrometer analysis). |  |

**Fig. 8.9** Steps for fine and coarse grain size separation by using Sieve

| | | |
|---|---|---|
| 1 | First, take 50 g of separated fine grain soil sample beaker, then Prepare a solution of sodium hexametaphosphate. In here, 25 g of sodium hexametaphosphate take for soak soil sample. Then, soil sample soak overnight in this sodium hexametaphosphate solution. It will chemically separate the soil sample. |  |
| 2 | Then, soil mixture should pour into the cylinder by adding distilled water as the cylinder fill up to the volume of 1 liter. |  |
| 3 | Next hydrometer reading taken after the five hours and 55 minutes. Hydrometer reading at that time (4.00 p.m) was 0.1g/L. |  |
| 4 | Then put hydrometer into the cylinder.<br>Hydrometer reading at that time indicated as 0.8g/L. [hydrometer reading at 9.05 a.m. (50 sec after to fill up cylinder)] |  |

**Fig. 8.10** Steps for hydrometer analysis

**Table 8.4** Calculations for soil texture analysis

| Temperature corrections |
|---|
| Add 0.2 units to the readings of the sample due to it in above 67 In here, temperature was 26 (88). Therefore should add 0.2 unit to the readings |
| Percent Clay:<br>% clay = Corrected hydrometer reading at 5 h, 55 min. * 100/ wt. of sample<br>= (0.1 + 0.2 g/L)*100/50 g<br>= 15% |
| Percent Silt:<br>% silt = Corrected hydrometer reading at 50 s. * 100/ wt. of sample−% clay<br>= (0.8 + 0.2 g/L)* 100/50 g−15%<br>= 42.5% |
| Percent Sand:<br>% sand = 100%−% silt−% clay<br>= 42.5% |

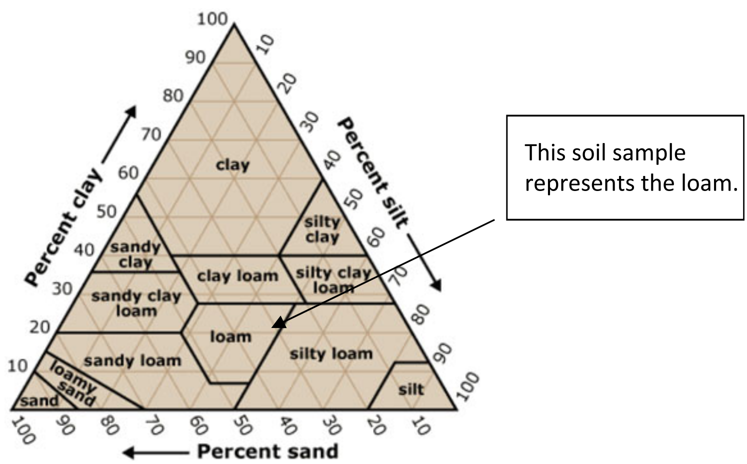



**Fig. 8.11** Soil texture analysis: the use of a triangular Graph. *Source* Waugh (2006)

## 8.5 The Methodological Approaches in Biogeography

### 8.5.1 Introduction

Biogeography is the study of the distribution of species and ecosystems in geographic space and through geological time. Organisms and biological communities often vary in a regular fashion along geographic gradients of latitude, elevation, isolation and habitat area. Biological diversity is a central theme of Biogeographical theory and has been the subject of many discussions. Currently, researchers have developed a large number of parameters for the measurement of biodiversity as an indicator of the state of ecological systems, with practical applicability for purposes of conservation, management and environmental monitoring (Magurran 1988).

### 8.5.2 Objectives

There are large number of parameters that are used to measure the biodiversity, for example, measuring Genetic Diversity, Species Diversity, Taxonomic Diversity, Patterns in Time, Dimensionless Patterns, etc. This chapter is mainly focused on measuring Species Diversity.

### 8.5.3 Methodology

There are two main aspects in Species Diversity namely, Species Richness and Species Abundance. Species richness is the number of species in an area; often the only information available depends on baseline taxonomic data. Species abundance is relative commonness of species, or evenness; requires baseline ecological data.

### 8.5.4 Procedure

Although there are several methods used to measure the Species Diversity below-mentioned methods are used commonly.

#### 8.5.4.1 Simpson's Diversity (D)

Used to measure mainly Species Richness.

$$D = \frac{N(N-1)}{\sum n(n-1)}$$

D = Diversity, N = Total number of organisms of all species found, n = Number of individuals of a particular species

#### 8.5.4.2 Shannon-Weiner Index (H)

$$\mathbf{H} = \sum -(\mathbf{P_i} * \ln \mathbf{P_i})$$

H = the Shannon diversity index, $P_i$ = fraction of the entire population made up of species i.

S = numbers of species encountered, $\sum$ = sum from species 1 to species S.

$$\text{For this community, } N = 32 + 18 + 12 = 62$$

$$D = \frac{N(N-1)}{\sum n(n-1)}$$

$$D = \frac{62 \times 61}{(32 \times 31) + (18 \times 17) + (12 \times 11)} = \frac{3782}{1430} = 2.64$$

**Table 8.5** Example 01

| Species | No.of Individuals |
|---|---|
| *Vigna mungo* | 32 |
| *Glycine max* | 18 |
| *Vigna radiata* | 12 |

**Table 8.6** Example 02

| Plant Species | $N_i$ | $P_i$ | ln $P_i$ | $-(P_i$*ln $P_i)$ |
|---|---|---|---|---|
| *Artocarpus nobilis* | 96 | 0.96 | −0.041 | 0.039 |
| *Dipterocarpus zeylanicus* | 1 | 0.01 | −4.61 | 0.046 |
| *Mangifera zeylanica* | 1 | 0.01 | −4.61 | 0.046 |
| *Syzygium rotundifolium* | 1 | 0.01 | −4.61 | 0.046 |
| *Shorea stipularis* | 1 | 0.01 | −4.61 | 0.046 |

$$\begin{aligned}\text{Shannon} - \text{Weiner Index (H)} \\ &= (0.039 + 0.046 + 0.046 + 0.046 + 0.046) \\ &= 0.223\end{aligned}$$

### 8.5.5 Advantages and Disadvantages

If Simpson's Diversity is high the area may be a stable ancient site. Low Simpson's Diversity may suggest pollution, recent colonization or agricultural management. The Shannon index is sensitive to the presence of rare species, and the Simpson's index is more responsive to the dominant species.

## References

Chow VT, Maidment DR, Mays LW (1988) Applied hydrology. Mc Graw Hill Book Company. ISBN 0-07-010810-2.
Collischonn W, Haas R, Andreolli I, Tucci CEM (2005) Forecasting river Uruguay flow using rainfall forecasting from a regional weather predicted model, J hydrol305(1–4):87–98
Lam NS (1983) Spatial interpolation methods review. Am Cartogr 10:129–149
Lehotský M, Grešková A (2007) Fluvial geomorphological approach to river as-sessment—methodology and procedure. Geografický časopis 59, 2, 22 tabs., 44 refs
Magurran AE (1988) Ecological diversity and its measurements. Princeton University Press, New Jersey, NJ, p 179
Singh VP (1994) Elementary hydrology. New Delhi, Prentice Hall of India
Soil Survey Staff (2009) Soil survey field and laboratory methods manual. In: Burt R (Ed) Soil survey investigations report No. 51, Version 1.0. U.S. Department of Agriculture, Natural Resources Conservation Service
Tabios GQ, Salas JD (1985) A comparative analysis of techniques for spatial interpolation of precipitation. Water Resour Bull 21(3):365–380

Waugh D (2006) Geography: an integrated approach. 3rd Edition and Supplement Set

Wickramaarachchi WWUI, Peiris TUS, Samita S (2020) Rainfall trends in the North-Western and Eastern coastal lines of Sri Lanka using non-parametric analysis. Tropical Agric Res 31(2):41–54

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