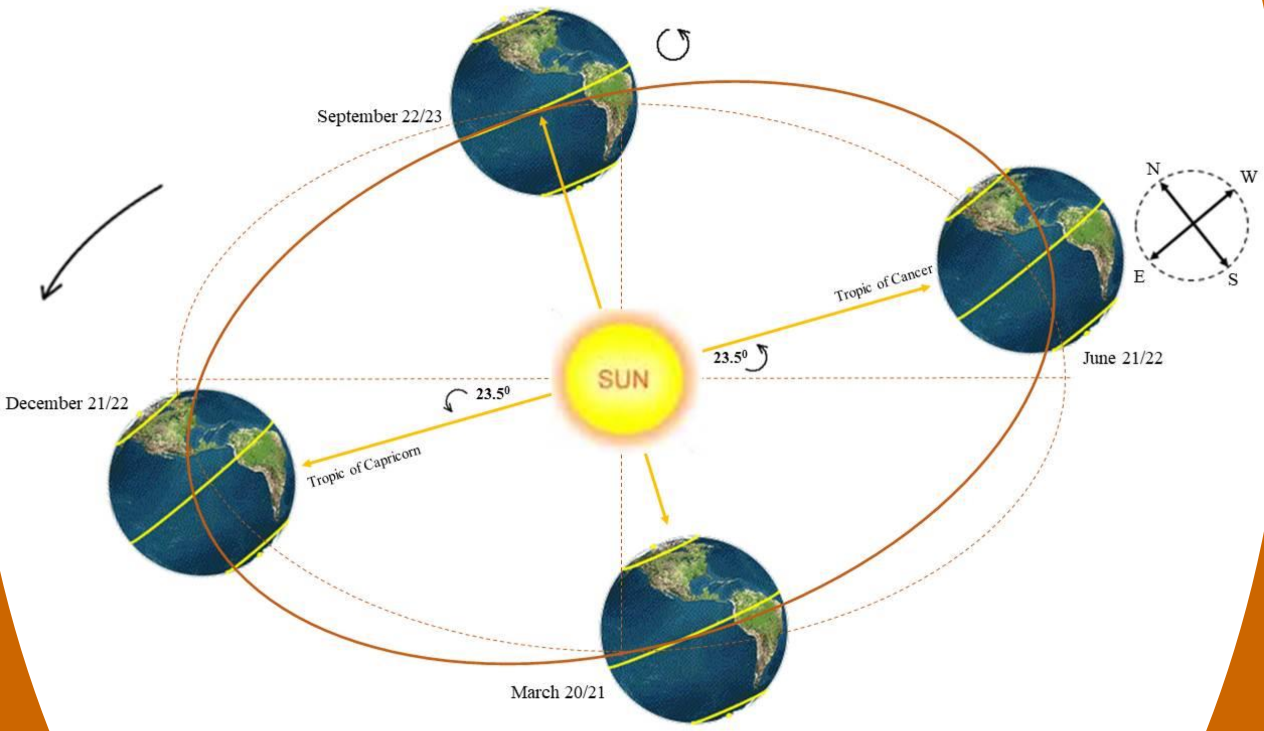
Effects of the Atmospheric Conditions and Ecoclimate to the Agriculture in Sri Lanka



Agriculture and Environment Statistics Division
Department of Census and Statistics
Democratic Socialist Republic of Sri Lanka

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Foreword

The basic objective and concept of this study is to amelioration of the territorial agricultural industry and fixation of the greenery agriculture by constructive utilization of natural resources and studying the pattern of the climate changes as well as weather conditions in regional level.

Locally collected and published information as well as the information which is extracted and ingest the knowledge gained by pursuit the international articles and magazines are also used to prepare this valuable report.

Amplification process of the environment statistics is very essential to overcome all the challenges against the greenery agriculture and promote the local agricultural productions. It should be improved the environmental statistics by data collecting and producing indicators in the country and therefore excessive weight is given to the environmental related clarifications.

This report will be a very valuable guide line to the novice researchers to contribute the green revolution in Sri Lanka.

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Chapter 1 : Classical Approach to the Behaviour of the Sun

Earth revolves around the Sun. Thousands of years ago these things were not widely known. The heavens above were anyone's guess, and the ancient people believed that the gods had made all the things. It was felt there was no need to truly understand them or put them in any kind of order.

This began to change in the early days of civilization. People in the land of Babylonia (Iraq and Syria in modern times) created a large city on the banks of the Euphrates River. From roughly 2300 to 1879 BC, Babylonia grew from a small town to a large city and at last became the capital of an empire. As it became a seat of power, Babylonia’s people started to ask questions about their gods and the world around them. How could they understand the will of the gods to predict what would occur in their future?.

Astronomy began by serving the Babylonians not as a science but as a part of their religion. The Babylonians believed that the Universe was divided into six levels with three heavens, the topmost being a “heaven of stars” which the gods used to communicate with them. The planets of our solar system, which were believed to be the brightest “stars” in the night sky, were most important to them. Particular devotion was given to the movements of Jupiter, which they identified with their chief god Marduk (Babylonian god), and Venus, associated with Ishtar (Mesopotamian goddess), their goddess of war and love. The movements of Jupiter, Venus, and the other planets were believed to be messages from the gods rather than the gods themselves and were very important in Babylonian religion. These movements were used to predict many important things, such as crop failures and war.

1.1 Traditional methods of crop cultivations in Sri Lanka

The crop cultivations according to the seasonal cultivation pattern have been practiced by the ancestors from very ancient period. It has two seasons as Maha and Yala according to the northeast monsoon winds and southwest monsoon winds. March to April is first transitional period from Maha to Yala and September to October is the second transitional period. Thundering and lightning are the primary signals for the seasonal changes and heavy rains can be expected after these transitional periods. All the calculations which were relevant to the cultivations were done by studying the lightning and thundering patterns.

1.12 Paddy cultivation in Sri Lanka

Rice is the staple food of the community in Sri Lanka and main item of the food dish is rice for at least two meals out of three main meal times namely breakfast, lunch and dinner of them. Livelihood of the ancient people was agriculture and main cultivated crop was the paddy. The country was self-sufficient with paddy and exported it.

The rice paddy was a sacred crop (Bhuddha Boogaya) according to the ancestors and it has been cultivated twice a year as first season (Maha) and second season (Yala). The pattern of the climate changes and weather conditions throughout the year has been studied before cultivations by the farmers. In addition, the seeding time was decided by concerning the rising pattern of the moon, raining pattern and auspicious times. Paddy cultivation of the first season was done in the month of October seven days passed after full moon day and the same period of moon's month of the month of April for the second season as a tradition. The Sinhala and Hindu new year festival on April was ceremonially commemorate after compete the harvesting of the second season cultivation.

The darken period is started seven days after full moon day and farmers had understood that the activity of the insects were minimum around this period and it was increased with the improvements of the moon. Seeds paddy which were filled in to the sack should be submerge in the pure water for soak around thirty six hours (it was ninety hours according to the ancient local measurement of time). Then the bag with seed paddy which was tied up the opening of the sack hardly deposited in dark place and loaded some weight over the sack with seed paddy for germination around twenty four hours. The first date of this seedling process was concerned as the initial date of the life circle of paddy plant. Further, the paddy plant is blooming after sixty days of sowing if the lifetime of the paddy plant is around ninety days. Then the blooming period was also very darken as seeding time and therefore, activity of the insects were minimum and not necessary to use insecticides. The seed varieties with higher lifetimes (wedumal Vee) than the seed varieties which have been used for second season (baala Vee) were used in the first season to overcome the problems arisen from climate changes on that season.

The first portion of the harvest was dedicated to the consecrations and other religious rites and it was identified as harvest feast. It was a collective action of the farmers of the area and they will consume the newly produce harvest after completing the harvest feast and it was the tradition of the ancient community and still is continuing.

1.13 Cultivations of other crops

Potato, cassava, sweet potato, coco yam and other yams were cultivated in the period from March to April and August to September. They never cultivated any sort of yam on February because they believed that the yield will be minimal if it is cultivated in this month. Greens, pot herbs and other plants with root nodules were cultivated in the month of February. Rains can be expected very rarely in this month.

1.2 Usage of the technology

There were very rich ancient hydraulics system under this civilization for the water management and rain water has stored in water tanks for the usage of cultivations and other necessities according to the climate changes.

Organic fertilizers have been used for the cultivations and it has been produced by applying worm eaten plants and carcasses of animals in addition to the wastes of the living beings. Cow dung and poultry manures were very famous among them. Animal husbandry was also carried on parallel to the cultivation and its by-products were used as manure on free of charge. The rotation of crops system was practiced to minimize the insects' attacks and other infectious diseases.

The ancient people had not known anything about the scientific background of the photosynthesis process. But they have known that the nutritional level is comparatively higher in daylight period than the night. Therefore, the harvesting of the crops was done in the afternoon. Specially, they believed that the nutritional level is maximized in greens and pot herbs when the sundown is occurred and those plants disburse deposited nutrients for their own growth in the night. As a result of that, these crops were harvested at the sundown.

Further, they had not known about the self pollination as well as cross pollinations of the plants. However, they have known that some plants can beer fruits as single tree but it should be at least two plants for the bearings of fruits for some other species like butter fruit (Avocado).

1.3 Existing evidence base decision making

Blooming of the flower of the paddy plant is precisely occurred when the sun is perpendicular to the earth. It has been found by very ancient community by their steely observations and that time was identified as twelve noon. The same phenomenon was done to the millet plant at the midnight twelve. They have arranged their time schedule base on this phenomenon for day to day activities.

In addition, they have decided the raining pattern and the lengthen period of the drought by studying the demeanour of living beings. The humidity level of the atmosphere was measured by perspiration pattern of the body and if it is stewed overly in their body then they decided that it will be rain today.

Chapter 2 : Scientific Approach to the Behaviour of the Sun

The Sun is the largest object in our solar system. It is the center of our Solar System and contains most of the mass in the Solar System. All of the planets in our Solar System, including Earth, orbit around the Sun.

2. Daily motion of the earth around the sun

The Earth revolves around the Sun once each year and spins on its axis of rotation once each day. This axis of rotation is tilted 23.5 degrees relative to its plane of orbit around the Sun. The axis of rotation is pointed toward Polaris, the North Star. As the Earth orbits the Sun, the tilt of Earth's axis stays lined up with the North Star.

2.1 Solar radiation on the earth

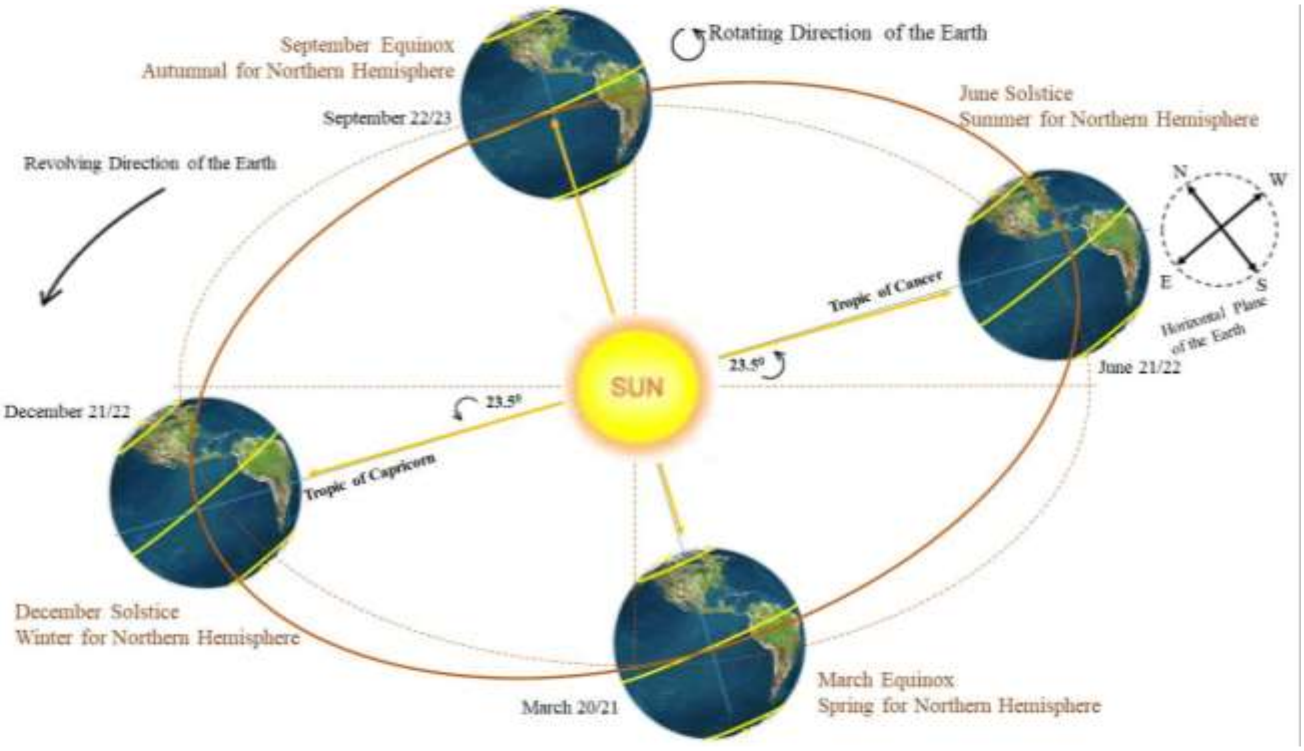


Figure 2.1 : Revolution pattern of the earth around the sun

The sun appears to move along with the celestial sphere on any given day, but follow different circles at different times of the year. The sun is most northerly at the June solstice and most southerly at the December solstice. The sun's path follows the celestial equator at the equinoxes.

In late March and late September (at the "equinoxes"), the sun's path follows the celestial equator. Then it rises directly east and sets directly west. The exact dates of the equinoxes vary from year to year, but are always near March 20 and September 22.

The latitude, 23.5° below the North Pole, is called the Arctic Circle (66.5^0 N). The sunset in the north of the Arctic Circle will never be occurred at the days when the sun is around the June solstice. Similarly, it never rises to the Arctic Circle on the December solstice.

The power of the solar radiation gets higher and higher of the noon sun when it is traveling southward in the northern hemisphere. The first qualitative change occurs at 23.5° latitude, where the noon sun on the June solstice passes directly overhead. This latitude is called the Tropic of Cancer (23.5^0 N). Farther south, in the so-called tropics, the noon sun will still appear in the northern sky for a period of time around the June solstice.

At the equator, the noon sun is straight overhead on the equinoxes and this phenomenon can be seen twice a year as March and September. The south latitude which is far 23.5° from the equator is called Tropic of Capricorn (23.5^0 S) and the latitude, 23.5° above the South Pole, is called the Antarctic Circle (66.5^0 S).

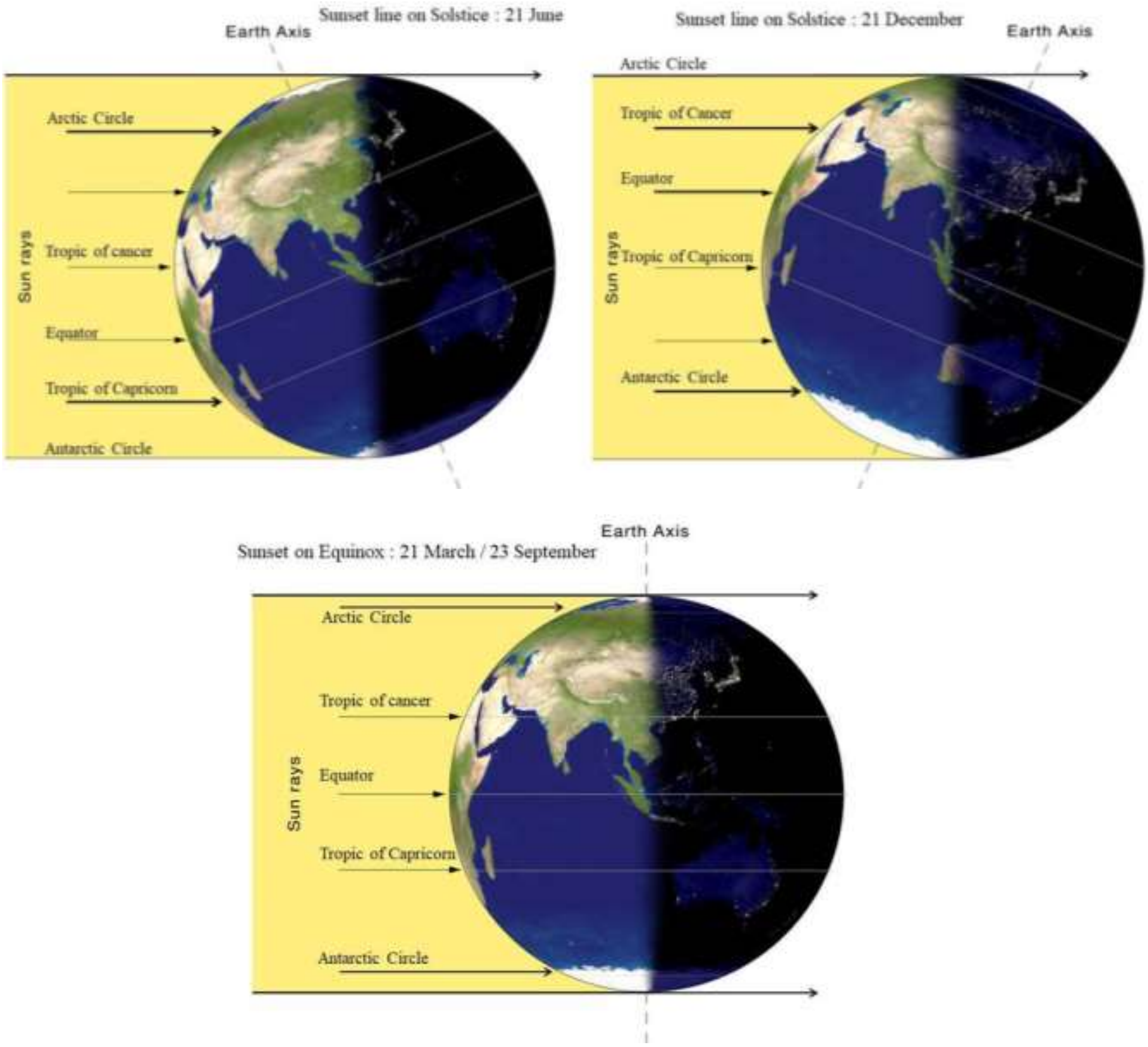


Figure 2.2 : Sun rising pattern to the various latitudes of the earth

These are actual images which were obtained on or near the first days of the Northern Hemisphere's fall, winter and summer seasons. Next, examine the small drawing to the right of each Earth image.

The drawing shows the relative positions of Earth, the satellite, and rays of sunlight at the time each image was recorded.

2.2 Climatic zones in the world and seasonal variations

Different parts of the Earth receive different amounts of solar radiation. Some part of the planet receives the most insolation. The Sun's rays strike the surface most directly at the equator. Different areas also receive different amounts of sunlight in different seasons. The seasons are caused by the direction Earth's axis is pointing relative to the Sun.

2.21 Summer in to the Northern Hemisphere

The North Pole is tilted towards the Sun and the Sun's rays strike the Northern Hemisphere more directly in summer. At the summer solstice, June 21 or 22, the Sun's rays hit the Earth most directly along the Tropic of Cancer (23.5 degrees N) as perpendicular lines. That is what the angle of incidence of the sun's rays there is zero. When it is summer solstice in the Northern Hemisphere, it is winter solstice in the Southern Hemisphere because the angle of incidence of the sun's rays is comparatively larger value to the southern hemisphere. See Figure 2.2 above.

2.22 Winter in to the Northern Hemisphere

Winter solstice for the Northern Hemisphere happens on December 21 or 22. The tilt of Earth's axis points away from the Sun. Light from the Sun is spread out over a larger area, so that area isn't heated as much. With fewer daylight hours in winter, there is also less time for the Sun to warm the area. When it is winter in the Northern Hemisphere, it is summer in the Southern Hemisphere.

2.23 Spring and autumn in to the Northern Hemisphere

Halfway between the two solstices, the Sun's rays shine most directly at the equator, called an "equinox". The daylight and nighttime hours are exactly equal on an equinox. The autumnal equinox happens on September 22 or 23 and the vernal or spring equinox happens March 21 or 22 in the Northern Hemisphere. A reciprocal curve can be seen in the Southern Hemisphere with mutual change of above two seasons.

The seasonal changes are very significant when is gone far from the equator and the seasonal pattern is shown in the following Figure 2.3 with location of the Earth in the constellation within the year.

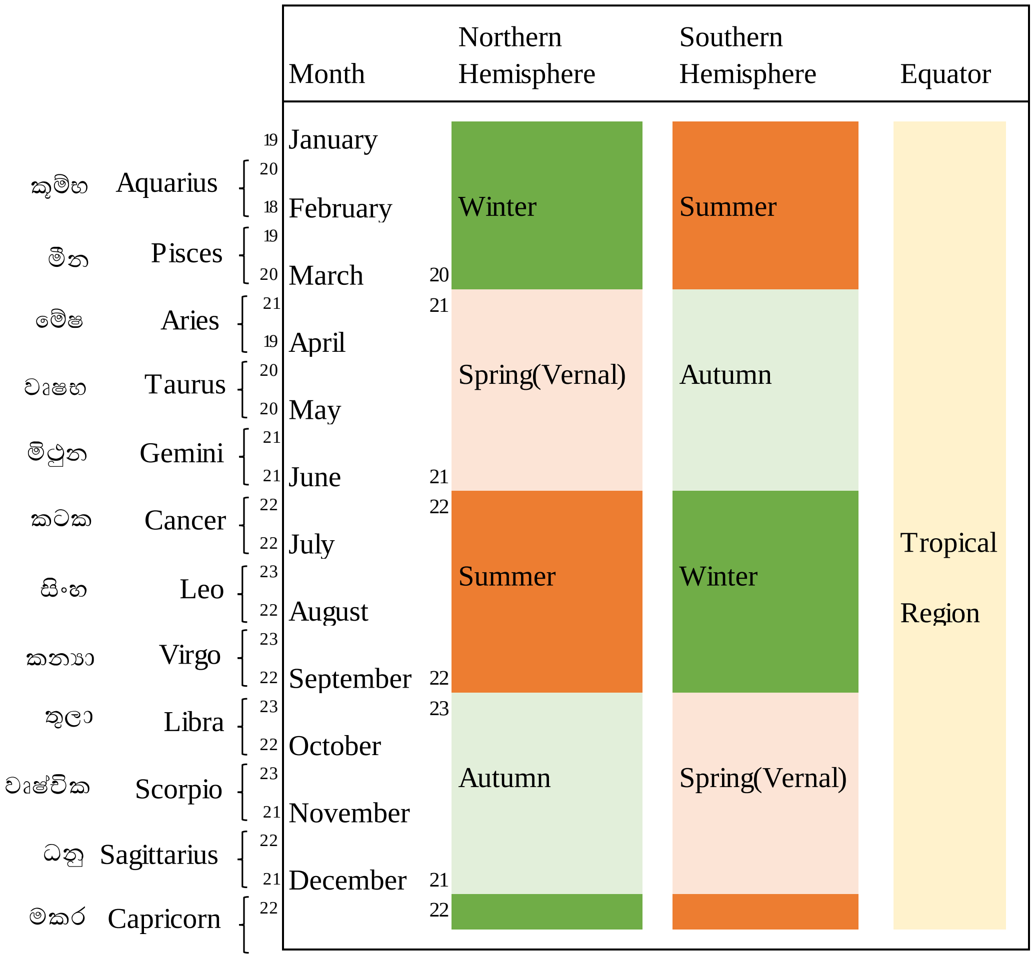


Figure 2.3 : Seasonal changes of the earth

There will be more and more days of darkness in winter and continuous sunlight in summer for farther north of the Arctic Circle. At the North Pole, the sun is above the horizon for six straight months (March through September), spinning around in horizontal circles, reaching a maximum height of 23.5° above the horizon at the June solstice.

Much farther south is the Antarctic Circle, where the sun never quite rises on the June solstice because the noon sun is always in the north on that period and the sun never quite sets on the December solstice. The South Pole has continuous daylight from September through March and continuous night (including twilight) from March through September.

The Arctic and Antarctic regions are almost always cold even in the summer when they get 24 hours of sunlight a day because the sun's angle above the horizon is never very high.

The intermediate latitudes, which generally have hot summers and cool or cold winters, are called the temperate zones. The north temperate zone lies between the Tropic of Cancer and the Arctic Circle, while the south temperate zone (where the seasons are reversed) lies between the Tropic of Capricorn and the Antarctic Circle.

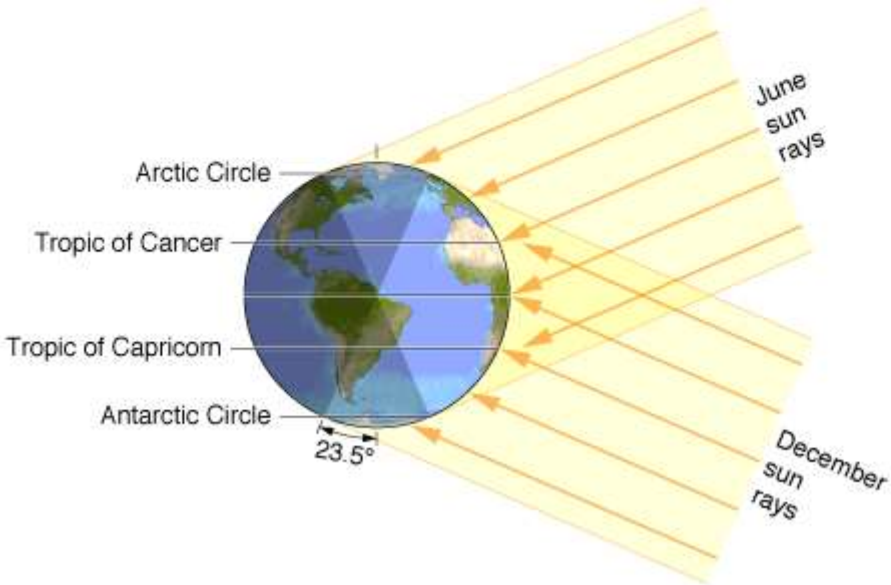


Figure 2.4 : Cast shadow of the sun rays to the latitudes at the equinoxes

2.3 Global pattern of the seasonal diversifications and monsoon winds

A monsoon is a seasonal change in the direction of the prevailing or strongest winds of a region. Monsoons cause wet and dry seasons throughout much of the tropics and most often associated with the Indian Ocean. Monsoons always blow from cold to warm regions. They always blow from cold, high-pressure regions. Monsoons are part of a yearlong cycle of uneven heating and cooling of tropical and mid-latitude coastal regions.

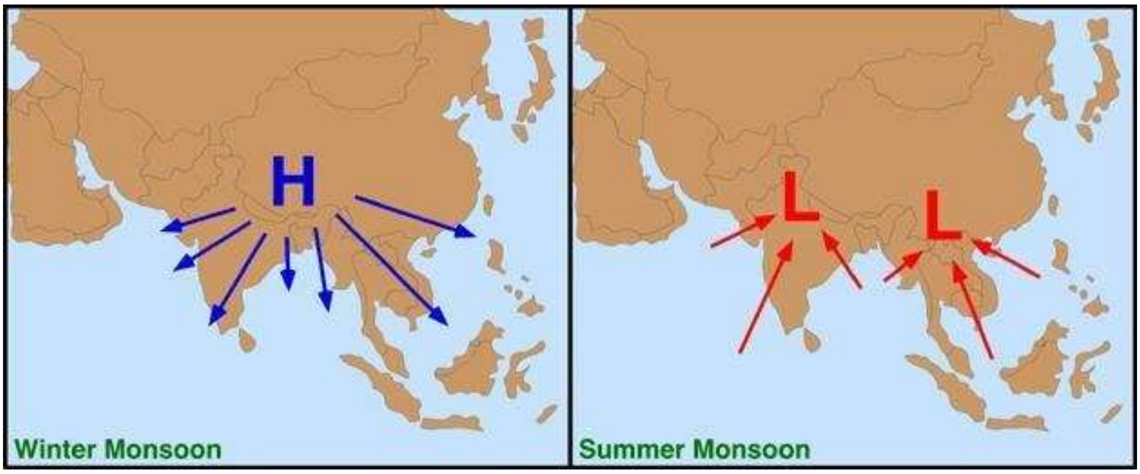


Figure 2.5 : Monsoon wind pattern in Southeast Asia
Source : A Text Book on Agricultural Meteorology ; CCS Haryana Agricultural University

Northeast Winter Monsoon : (Asia). In Asia, the northeastern winter monsoons take place from December to early March. The lower temperature over central Asia, creates a zone of high pressure there. The jet stream in this region splits into the southern subtropical jet and the polar jet. The subtropical flow directs northeasterly winds to blow across south Asia, creating dry air streams which produce clear skies over India from the months of November to May. Meanwhile, a low pressure system develops over northern Australia and winds are directed toward Australia. During the Northeast Winter Monsoon, Australia and Southeast Asia receive large amounts of rainfall.

Southwest Summer Monsoon : The Southwestern Summer Monsoons occur from June to August, and are drawn towards the Himalayas, creating winds blowing rain clouds towards India, some areas of which receive up to 1000 cm of rain.

Jet streams are geostrophic winds that form near the boundaries of air masses with different temperatures and humidity. The rotation of the Earth and its uneven heating by the sun also contribute to the formation of high-altitude jet streams.

The air over land is heated and cooled more quickly than the air over the ocean. Therefore warm land-air rises during the summer and creating a space for the cool and moist air from the ocean. As the land heats the moist air, it rises, cools, condenses, and falls back to Earth as rain. During the winter, land cools more quickly than the ocean. The warm air over the ocean rises, allowing cool land-air to flow in.

Most winter monsoons are cool and dry, while summer monsoons are warm and moist. Asia's winter monsoons bring cool, dry air from the Himalaya mountains. The famous summer monsoon, on the other hand, develops over the Indian Ocean, absorbing tremendous amounts of moisture. Summer monsoons bring warmth and precipitation to India, Sri Lanka, Bangladesh, and Myanmar.

The summer monsoon is essential for the health and economies of the Indian subcontinent. Aquifers are filled, allowing water for drinking, hygiene, industry, and irrigation

2.31 Affect of the Moon to the seasonal changes of the Earth

If someone stands on a beach for several hours, he will see the tide coming in and out. The tide is the rise and fall of ocean water over a period of time. Tides rise and fall every day or sometimes even twice a day.

If it is looks up into the night sky the Moon can be seen in some period of the month and it will be recurring throughout the year. Because the Moon moves around the Earth in a path shaped like a circle and that is called orbit. The Moon and Earth pull on each other due to gravity. When the Moon pulls on Earth, the solid parts of Earth stay in place. They cannot move very much. But the water in the oceans can move more easily. The Moon's gravitation force pulls the ocean water toward it. This causes a bulge in the ocean in the direction of the Moon. This bulge is what causes a high tide. Ocean water comes up higher on a shoreline as it is pulled toward the Moon. As the ocean is pulled toward the Moon, it causes a low tide in another part of Earth.

We are able to see the Moon because it reflects light from the Sun. It can be noticed that the Moon's shape changes during the month. The Moon seems to get bigger, and then it seems to get smaller. Sometimes, it seems to disappear completely.

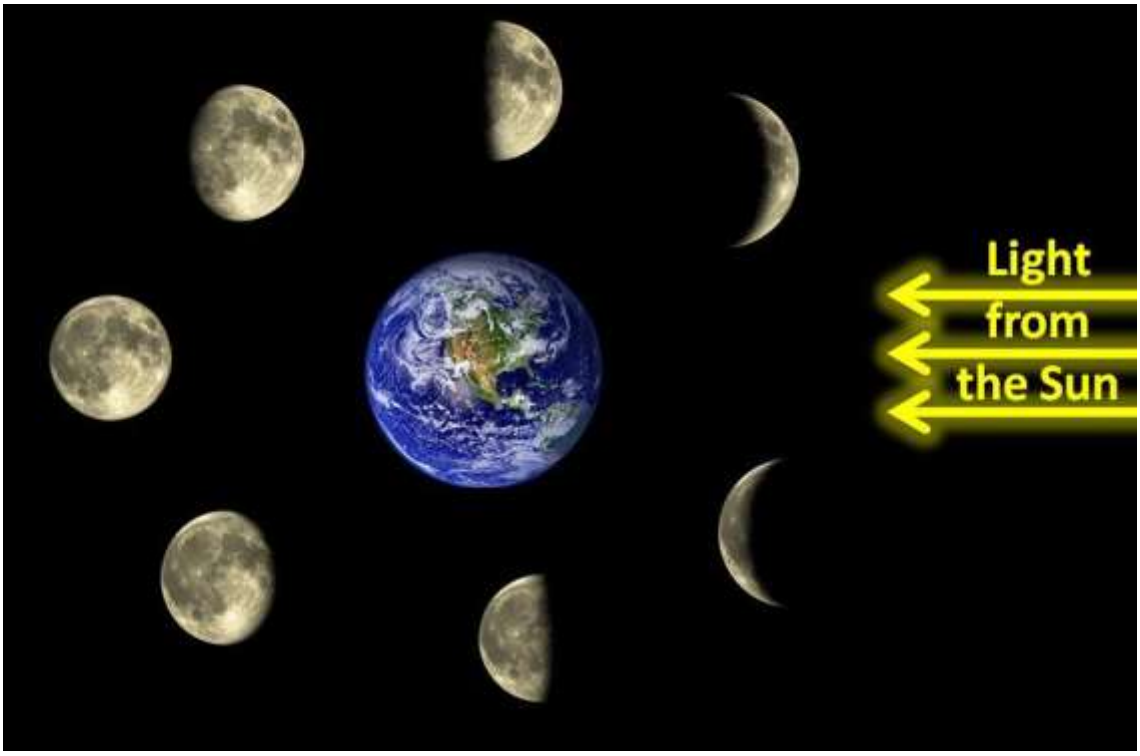


Figure 2.6 : Appearance of the moon within the month to the earth
Source : Rice University

These changes happen in the same pattern each month. In fact, the Sun always shines on half of the Moon. But on Earth, we cannot always see the sunlit half. This is because the Moon moves around Earth in an orbit. At the beginning of each month (Moon month), we cannot see the Moon at all. The sunlit half of the Moon faces away from Earth. Each night we see more of the Moon. After about two weeks, we can see the entire sunlit half of the Moon. Then, the Moon seems to get smaller again. Each night we see less and less. At the end of the month, we cannot see the Moon at all again. The pattern then repeats itself.

Ancient people (Specially Asians) used the Moon's changing appearance to make a calendar. Each month has 28 days according to the calendar. The amount of time it takes the Moon to orbit Earth. The beginning of a month was marked by a new moon.

2.32 Seasonal pattern of the ocean currents

The Moon has a gravitation power though it is not strengthen as the gravity of the Earth. However, it can be pulled the ocean water very easily than the solid parts of the Earth. This attractive force of the moon is highest in the full moon day because it is the nearest day of the Moon to the Earth. Therefore, high tides can be expected on the full moon day and low tides experience on new moon day (Amawaka pohoya) after fourteen days as shown in following Figure 2.7.

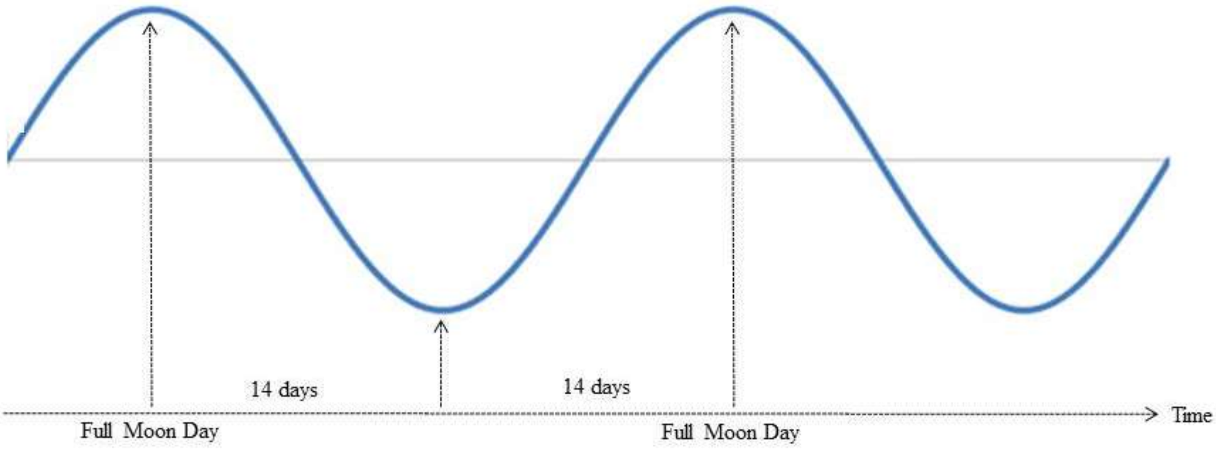


Figure 2.7 : High tide and low tide pattern within the moon month (around 28 days)

The atmospheric pressure in addition to the gravity of the Earth influence to pull ocean water to the earth. However, it is been created a lower atmospheric pressure in summer season on southern hemisphere at December solstice and the vast majority of the area is the ocean. Therefore the ocean water can be spring up due to the low atmospheric pressure in this time perios as shown in Fugeru 2.8 below.

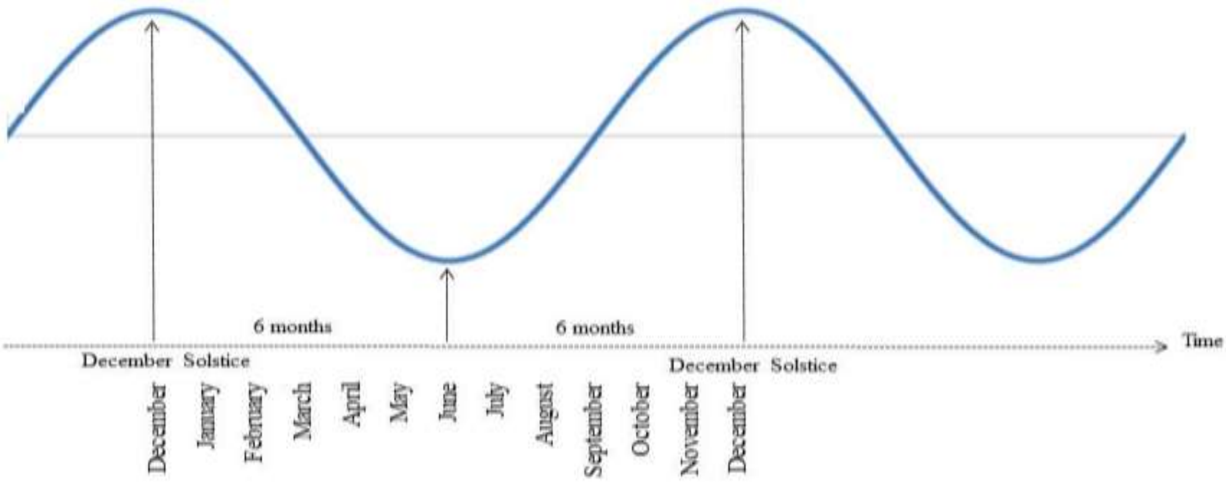


Figure 2.8 : High tide and low tide pattern within the twelve months period

The first zone, extending north from latitude 10° S, has a monsoon climate (characterized by semiannual reversing winds). During the Northern Hemisphere "summer" (May–October), low atmospheric pressure over Asia and high pressure over Australia result in the southwest monsoon, with wind speeds up to 28 miles (45 km) per hour and a wet season in South Asia. During the northern "winter" (November–April), high pressure over Asia and low pressure from 10° S to northern Australia bring the northeast monsoon winds to the opposite direction and a wet season for southern Indonesia and northern Australia. Different behavioural patterns of the ocean current can be expected in above both periods.

2.4 Receiving pattern of the solar power

The summer is highly warmer than winter and one reason is added hours of daylight. But the most important reason is that the angle of the mid-day sun. The noon sun is much higher for the northern hemisphere in June than in December. Therefore, the sun's rays strike the ground more directly in June. In December, on the other hand, the same amount of energy is diluted over a larger area of ground as illustration below.

The intensity of the sunlight striking the ground depends on the sun’s angle in the sky. When the sun is at a lower angle, the amount of energy is spread over a larger area of ground, so the ground is heated less. The angles shown here are for the noon sun at latitude 41^0 north.

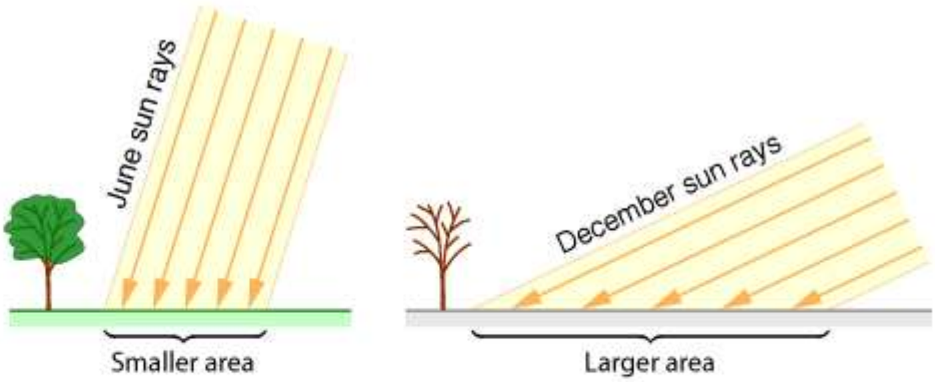


Figure 2. 9 : Falling pattern of the sunlights to the nortyhern hemisphere at the equinoxes

There is a common misconception that summer is warmer than winter because the sun is closer to us in the summer. Actually the sun's distance hardly changes at all and in fact, the sun happens to be closest to earth in January. Therefore, the distance of the sun is not directly effect to the climatic changes as warmer in summer than winter or cooler in winter than summer or any other changes in spring and autumn. The seasonal changes in climate are caused by the varying angle of the sun's rays, together with the varying amount of time that the sun is above our horizon.

During the northern hemisphere summer solstice, earth is tilted such that the sun's rays strike perpendicular to the surface at the Tropic of Cancer. At noon, the sun is directly overhead in this location (and at a decreasing height above the horizon north and south of the Tropic of Cancer). At locations north, the Sun will be at its highest position above the horizon and will take the greatest amount of time to cross the sky. All northern locations have more than 12 hours of daylight. All locations in the south experience less than 12 hours of daylight. Locations above the Arctic Circle (north of 66.5 degrees latitude; 90 degrees minus the tilt of Earth's axis) receive 24 hours of sunlight. Locations below the Antarctic Circle (66.5 degrees south latitude) experience 24 hours of darkness.

The pattern is completely changed when the sun's rays strike perpendicular to the surface at the Tropic of Capricorn and it is called southern hemisphere summer solstice.

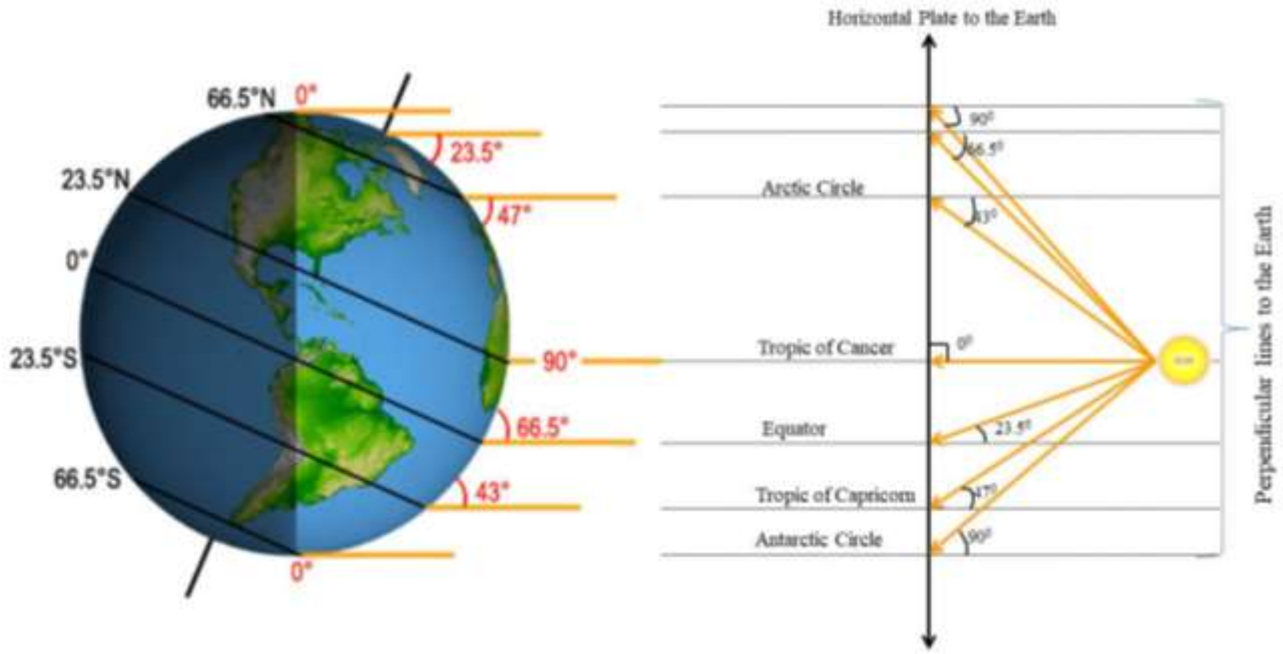


Figure 2.10 : Angles of the sun’s rays when sun is directly overhead to the Tropic of Cancer

2.41 Atmospheric Environments

Climate, weather, and the current state of the atmosphere, generally varies from day to day, more over the seasons. Climate is the long-term summary of weather conditions and it follows patterns that remain nearly constant from year to year. Astronomical factors which govern the amount of sunlight received play a major role in predicting these weather and climate patterns.

Our solar system consists of the Sun and a series of planets orbiting at varying distances from the Sun. It can be seen other stars and have detected other planets. However, Earth is the only world on which we are sure life exists. The Sun’s energy makes all life possible. The variations in the amounts of solar energy received at different locations on Earth are also fundamental to the seasonal changes of weather and climate.

Essentially, all the energy received by Earth originates from thermonuclear reactions within the Sun. Energy from the Sun travels outward through the near-vacuum of space. The concentration of the Sun’s emissions decreases rapidly as they spread in all directions. By the time they reach Earth, some 150 million kilometers (93 million miles) from the Sun, only about 1/2,000,000,000 of the Sun’s electromagnetic and particle emissions are intercepted by Earth. This tiny fraction of solar energy is still a significant amount, with almost 2 calories falling each minute on each square centimeter (1370 Watts per square meter ; 0.24 Calories per second ≈ 1 Watt) of a surface oriented perpendicular to the Sun's rays above Earth's atmosphere. This important amount of energy to the earth system is called the "*solar constant*", even though it does vary slightly with solar activity and the position of Earth in its elliptical orbit. For most purposes, the delivery of the Sun's energy can be considered essentially constant at the average distance of Earth from the Sun.

The incoming energy at any one instant strikes only one point on Earth's surface at a 90-degree angle because of the nearly spherical form of the earth (called the sub-solar point). All other locations on the sunlit half of Earth receive the Sun's rays at lower angles, causing the same energy to be spread over larger areas of horizontal surface. The lower the Sun in the sky, the less intense the sunlight received.

Earth has two planetary motions that affect the receipt of solar energy at the surface. Once per day rotation in its own axis and the other per year revolution about the Sun are these two motions. These combined motions cause daily changes in the receipt of sunlight at individual locations.

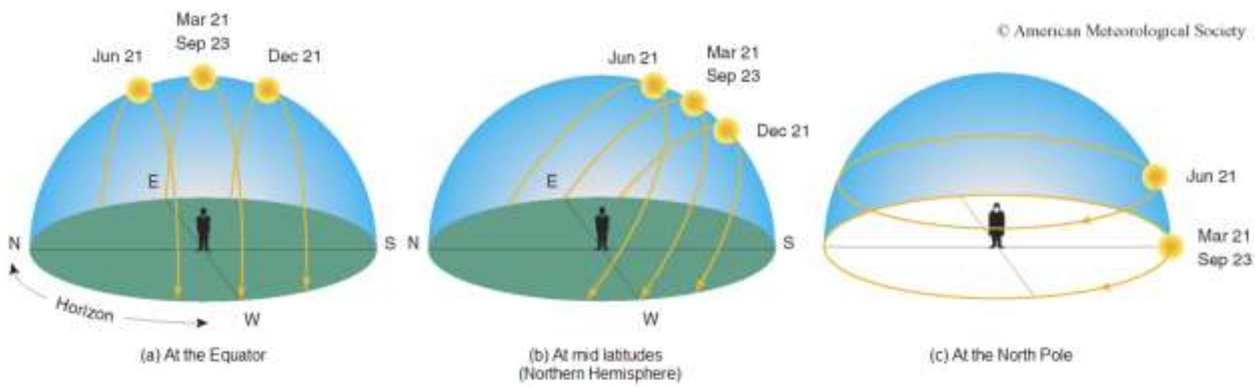


Figure 2.11 : Path of Sun through the sky at equatorial, mid-latitude, and polar locations
Source : American Meteorological Society

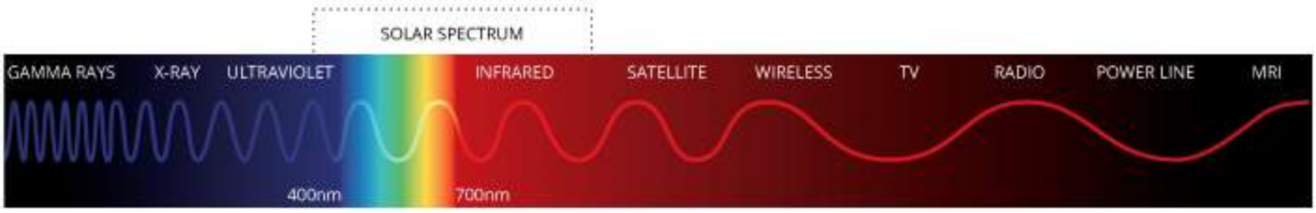
Twice a year, equator (Earth's axis) is positioned perpendicular to the Sun's rays. In the absence of atmospheric effects, all places on Earth except the poles experience equal period of daylight and darkness (see figure (a) in above illustration). These times are the equinoxes. The first days of spring and autumn (fall) and they occur on or about March 21 and September 23, respectively.

Earth's rotational axis is positioned at the greatest angle from its perpendicular equinox orientation to the Sun's rays on the solstices. On or about June 21, our Northern Hemisphere is most tipped toward the Sun on its first day of summer. On or about December 21, the Northern Hemisphere is most tipped away from the Sun on its first day of winter.

2.42 Heat transfer by solar radiation

All of the energy from the Sun that reaches the Earth arrives as solar radiation, part of a large collection of energy called the electromagnetic radiation spectrum. Solar radiation includes visible light, ultraviolet light, infrared, radio waves, X-rays, and gamma rays.

The electromagnetic spectrum encompasses all types of radiation. The part of the spectrum that reaches Earth from the sun is between 100 nm (nanometer) and 1 mm wavelengths. This band is broken into three ranges: ultraviolet, visible, and infrared radiation. Ultraviolet contains wavelengths between 100-400 nm. Visible light falls within the range of 380-700 nm, and infrared light contains wavelengths from 700 nm to over 1 mm. In the visible light spectrum, the colors are determined by the length. Longer wavelengths appear red while shorter wavelengths are blue/violet as they range closer to the ultraviolet spectrum. (1 cm = 10,000,000 nanometers)



0.0005	0.5	250	400	700	10000				5,000,000,000	Nanometers - Wavelenght
2,480,000	2480	4.96	← 2.48	→	0.124				0.000000248	Electron vots - Energy
Gama Rays	X-Rays	Ultraviolet	Visible	Light	Infrared	Satellite	Wireless	TV	Radio	

Figure 2.12 : Electromagnetic spectrum of the solar radiation
Source : Fondriest Environmental Learning Center

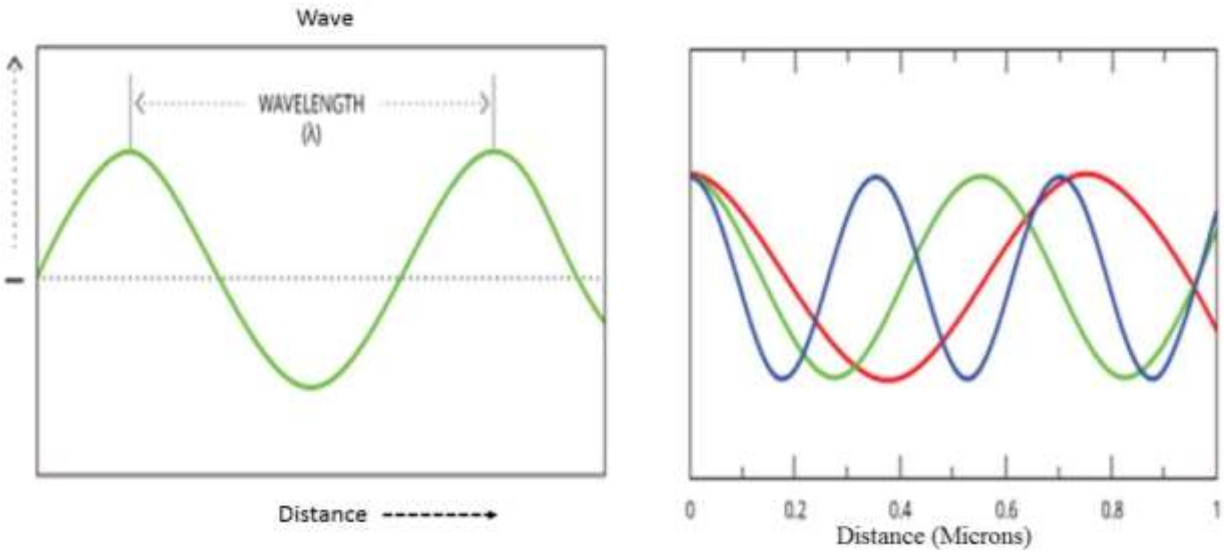


Figure 2.13 : Idea of the wavelength and the frequency of the electromagnetic wave

2.43 Refraction pattern of the visible sun rays

The phenomenon of splitting of white light into its constituent seven colors on passing through a glass prism is called dispersion of light.

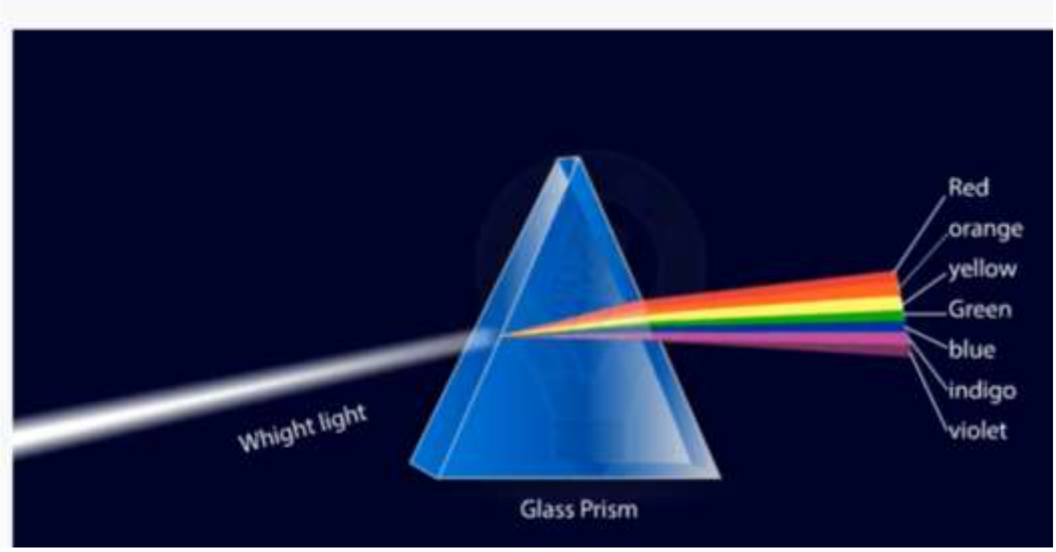


Figure 2.14 : Spectrum of the visible sunlight through a glass prism

When it is fallen visible sunlight on the various surfaces of the Earth such as leaves of the plants, water and other penetrating surfaces then the incidence white rays split in to the several rays with different refraction angles according to the colour. Finally, it can be seen seven different emergent rays with seven colours as shown in the above figure.

The incidence angle of the sun rays to the surface of the Earth are been changing throughout the year according to the pattern as already explain at the beginning of this section 2.4. Therefore, the intensities of the emergent rays with different seven colours will be changed within the twelve months.

Table 2.1 : Wavelength, frequency and energy of the visible light according to the colour

Colour	Wavelength (nm)	Frequency (THz)	Photon energy (eV)
Violet	380 - 450	670 - 790	2.75 - 3.26
Blue	450 - 485	620 - 670	2.56 - 2.75
Cyan	485 - 500	600 - 620	2.48 - 2.56
Green	500 - 565	530 - 600	2.19 - 2.48
Yellow	565 - 590	510 - 530	2.10 - 2.19
Orange	590 - 625	480 - 510	1.98 - 2.10
Red	625 - 700	400 - 480	1.65 - 1.98

2.44 Top of atmosphere insolation variation with the latitudinal shifting

All weather and climate circumstances begin with the Sun. That is because solar radiation is the only significant source of energy that determines conditions above the Earth's surface.

The average rate at which solar radiation is received outside Earth's atmosphere on a surface oriented perpendicular to the Sun's rays is about 1370 Watts per square meter (2 calories per square centimeter per second) per minute. The amount of solar radiations that actually reaches Earth's surface at any particular location is quite different and changes continuously during daylight hours.

The nearly-spherical Earth, rotating once a day on an axis inclined to the plane of its orbit, presents a constantly changing face to the Sun. Wherever there is daylight, the daily path of the Sun through the local sky changes through the course of a year. Everywhere on Earth, except at the equator, there is variation in the daily number of hours of daylight throughout the year. In addition, the atmosphere absorbs and scatters solar radiation passing through it. Clouds, especially, can block much of the incoming radiation.

Variation of solar energy receiving pattern is illustrated in following Figure 2.15 when it is gone away from the equator.

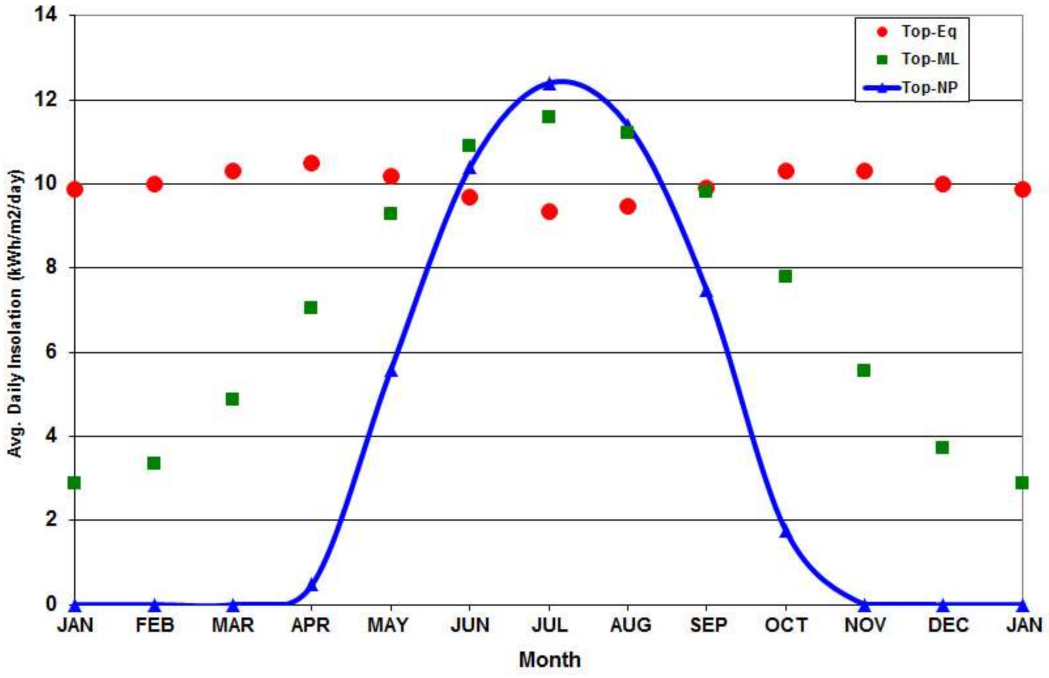


Figure 2.15 : Variation of solar radiation received on horizontal surfaces at the top of the atmosphere at equator (●), midlatitude (■), North Pole (▲).
Source : National Aeronautics and Space Administration (NASA)

The countries near to the equator are receiving approximately steady amount of energy with little fluctuations, but a significant change of the pattern can be seen when it is gone away from the equator.

2.45 Absorption and reflection of sunlight

Sunlight travels through space at nearly 300,000 kilometers per second (186,000 miles per second). When sunlight strikes the Earth, it is mostly reflected or absorbed. Reflected light bounces back into space while absorbed light is the source of energy that drives processes in the atmosphere, hydrosphere, and biosphere.

Changes in the proportion of incoming solar radiation that is reflected instead of absorbed depends on the composition of Earth’s surface and atmosphere, and can alter global climate and ecosystems.

The Sun provides the Earth with most of its energy. Today, about 71% of the sunlight that reaches the Earth is absorbed by its surface and atmosphere. Absorption of sunlight causes the molecules of the object or surface it strikes to vibrate faster, increasing its temperature. This energy is then re-radiated by the Earth as longwave, infrared radiation, also known as heat. The more sunlight a surface absorbs, the warmer it gets, and the more energy it re-radiates as heat. This re-radiated heat is then absorbed and re-radiated by greenhouse gases and clouds, and warm the atmosphere through the greenhouse effect.

The following diagram shows the percentage of sunlight that is reflected by different earth surfaces or clouds.

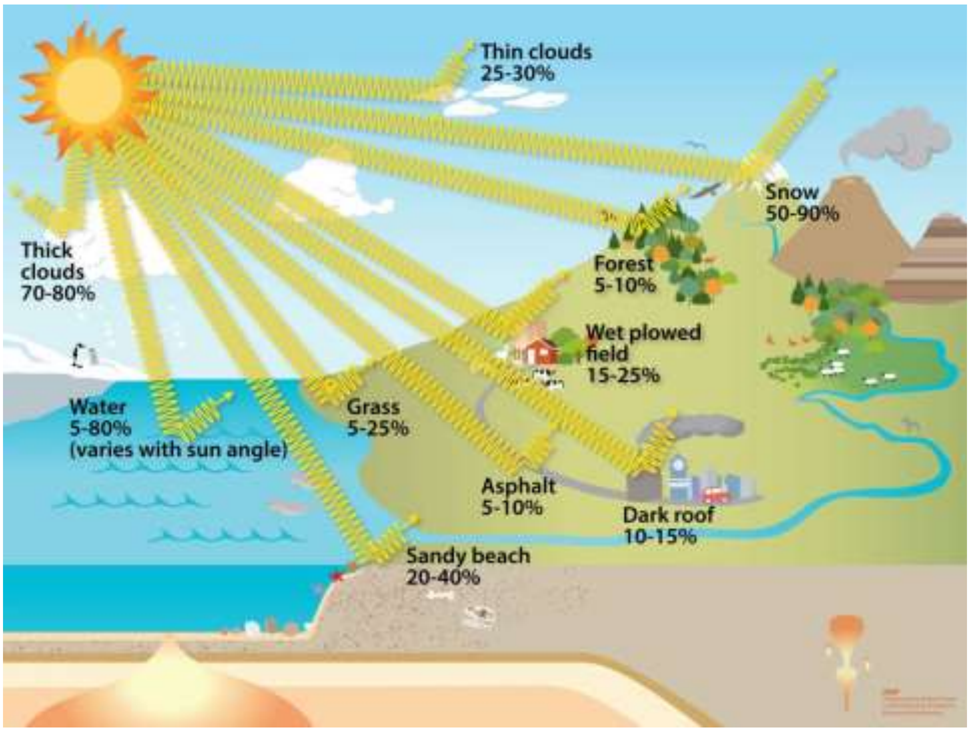


Figure 2.16 : Reflection of the sunlight by different Earth surfaces or clouds
Source ; Understanding Global Change ; University of California ; Museum of Paleontology

This model shows some of the changes to Earth’s surface and atmosphere that can affect the amount of sunlight that is absorbed or reflected. These changes influence the amount of heat that is re-radiated, and can also greatly influence the biosphere by altering the amount of sunlight available for photosynthesis.

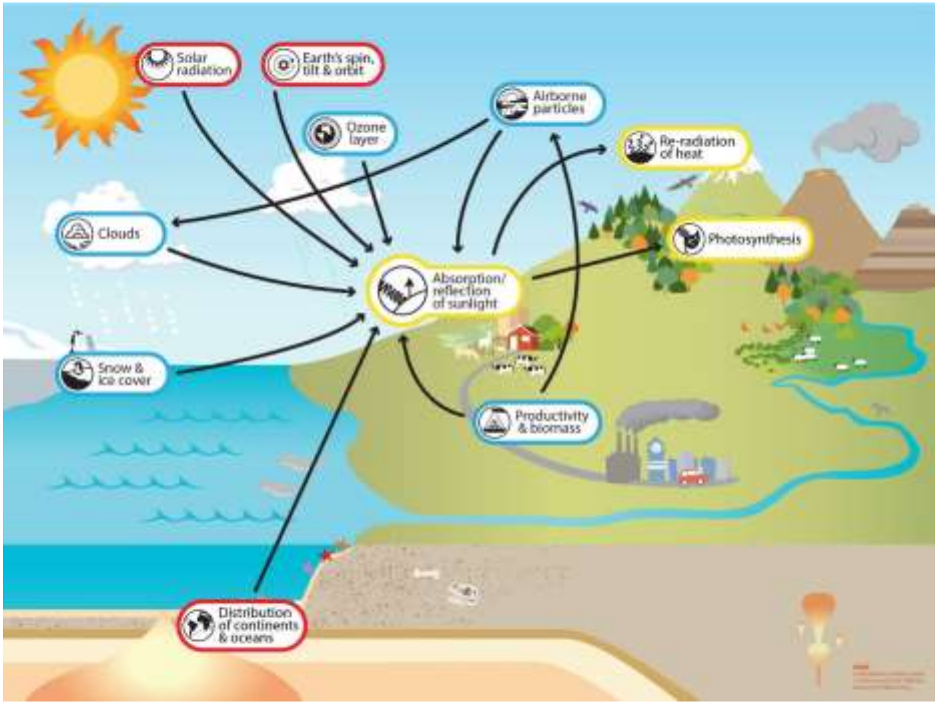


Figure 2.17 : Absorption and reflection pattern of sunlight
Source ; Understanding Global Change ; University of California ; Museum of Paleontology

2.46 Influence of the human activities to the absorption and reflection of sunlight

The human activities directly affect the amount of sunlight that is absorbed and reflected by Earth's surface. The development and spread of urban areas, especially using asphalt and other dark colored materials, can dramatically increase the absorptivity of the surface. This creates urban heat islands, where cities experience higher temperatures than surrounding areas.

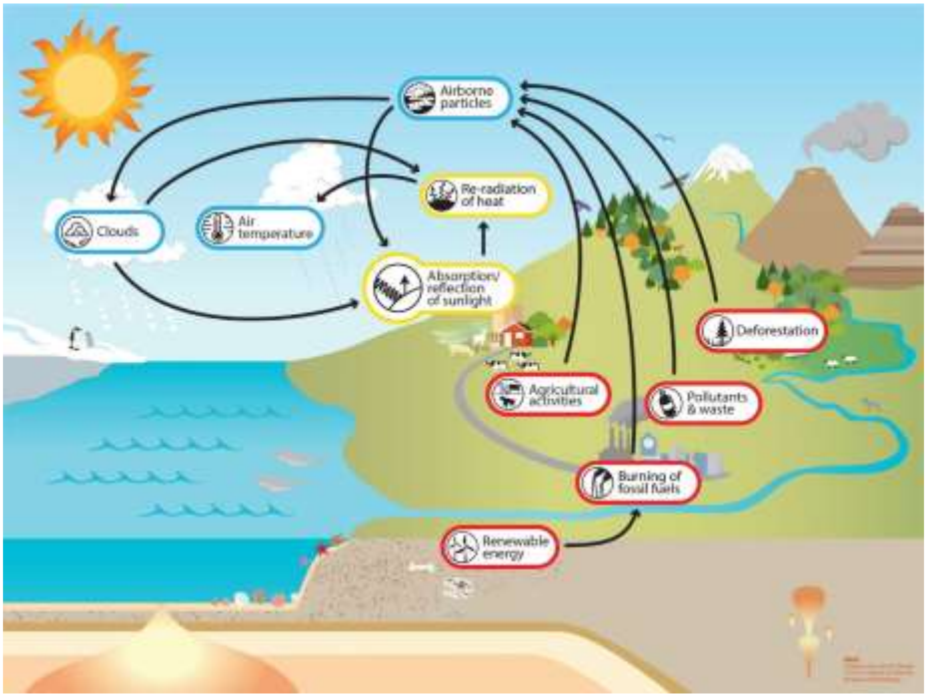


Figure 2.18 : Influence of the human activities to the intensity of sunlight
Source ; Understanding Global Change ; University of California ; Museum of Paleontology

2.5 Environmental impact of the air pollution and global warming

The interactions between humans and their physical surroundings have been extensively studied, as multiple human activities influence the environment. The environment is a coupling of the biotic (living organisms and microorganisms) and the abiotic (hydrosphere, lithosphere, and atmosphere). Pollution is defined as the introduction into the environment of substances harmful to humans and other living organisms. Pollutants are harmful solids, liquids, or gases produced in higher than usual concentrations that reduce the quality of our environment.

2.51 Effects of Greenhouse Gas to the air Pollution

Gases that trap heat in the atmosphere are called greenhouse gases. The main gases responsible for the greenhouse effect include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and water vapor (which all occur naturally) (H_2O), and fluorinated gases (which are synthetic).

Carbon dioxide enters the atmosphere through burning fossil fuels (coal, natural gas, and oil), solid waste, trees and other biological materials, and also as a result of certain chemical reactions (e.g., manufacture of cement). Carbon dioxide is removed from the atmosphere (or "sequestered") when it is absorbed by plants as part of the biological carbon cycle. Methane is emitted during the production and transport of coal, natural gas, and oil. Methane emissions also result from livestock and other agricultural practices, land use and by the decay of organic waste in municipal solid waste landfills. Nitrous oxide is emitted during agricultural (application of nitrogen fertilizers), land use, industrial activities, combustion of fossil fuels and solid waste, as well as during treatment of wastewater.

Fluorinated gases: Hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride, and nitrogen trifluoride are synthetic, powerful greenhouse gases that are emitted from a variety of industrial processes. Fluorinated gases are sometimes used as substitutes for stratospheric ozone-depleting substances (e.g., chlorofluorocarbons (CFC), hydrochlorofluorocarbons (HCFC), and halons). These gases are typically emitted in smaller quantities, but because they are potent greenhouse gases, they are sometimes referred to as High Global Warming Potential gases

2.52 Health and Environmental Effects of Ozone Layer Depletion

Reduced ozone levels as a result of ozone depletion mean less protection from the sun’s rays and more exposure to UVB (a band of ultraviolet radiation with wavelength from 280-320 nanometers produced by the Sun) radiation at the Earth’s surface. Studies have shown that in the Antarctic, the amount of UVB measured at the surface can double during the annual ozone hole. Ozone layer depletion increases the amount of UVB that reaches the Earth’s surface. UVB causes non-melanoma skin cancer and plays a major role in malignant melanoma development. In addition, UVB has been linked to the development of cataracts, a clouding of the eye’s lens.

2.53 Global warming

Global warming usually refers to human-induced warming of the Earth system, whereas climate change can refer to natural as well as anthropogenic change.

Global warming is the long-term heating of Earth’s climate system observed since the pre-industrial period (between 1850 and 1900) due to human activities, primarily fossil fuel burning, which increases heat-trapping greenhouse gas levels in earth’s atmosphere. The term is frequently used interchangeably with the term climate change, though the latter refers to both human- and naturally produced warming and the effects it has on our planet. It is most commonly measured as the average increase in Earth’s global surface temperature. Global warming is badly effect to the photosynthesis activities in addition to the living conditions of the human beings.

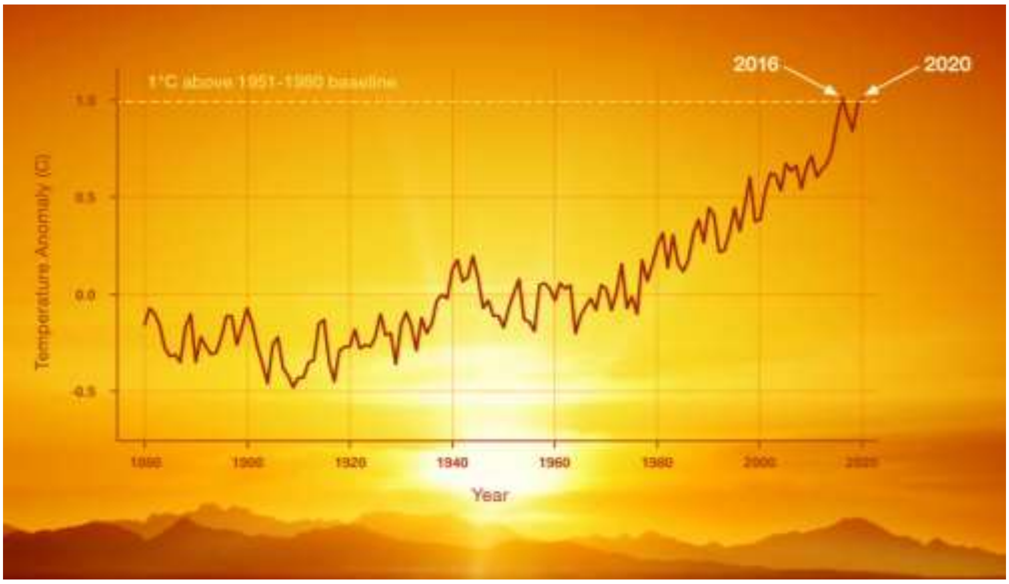


Figure 2.19 : Pattern of the global warming
Source : NASA's Goddard Institute for Space Studies

This graph illustrates the change in global surface temperature relative to 1951-1980 average temperatures, with the year 2020 tying with 2016 for warmest on record.

Chapter 3 : The Phenomenon of Soil Fertilization Naturally

Soil fertility can be further improved by adding organic matters to the soil, which leads to improved soil structure and promotes a healthy, fertile soil.

3.1 Air ionization, Lightning and Thundering

Clouds contain crystals of snow and tiny droplets of water. Wind blows fast from the bottom to the top of insides the clouds. Crystals and water droplets rub each other due to the fast blowing of these winds. Electrostatic charges are formed in the crystals and water droplets because of this rubbing. There are two types of electrostatic charges as positive and negative. It has been discovered that in a cumulonimbus cloud (dark cloud) positive charges accumulate in the upper region whereas negative charges get collected in the lower region of the cloud.

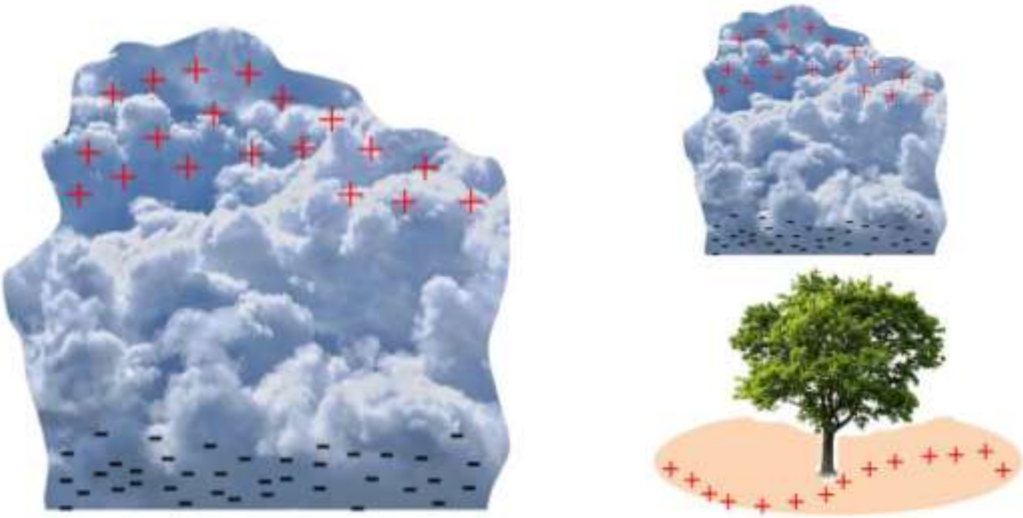


Figure 3.1 : How charges are distributed in a cumulonimbus cloud

The air in a cloud is an insulator. Hence electrical charges do not flow easily through air. Therefore, a large amount of electrical charges accumulate in the upper and lower regions of a cloud. When, very large amounts of charges are developed like this, a moment will arise where electricity can flow even through the air. Then a jump of electrical charges or an electric discharge occurs. This phenomenon is known as lightning. Lightnings can be classified into three types depending on the sites between which the charges jump as cloud to cloud lightning, cloud to air lightning and cloud to ground lightning.

Figure 3.2 : Pattern of the cloud to cloud lightning, cloud to air lightning and cloud to ground lightning

A jump of charges either between two regions of a charged cloud or between two clouds with different charges is referred to as a cloud to cloud lightning. Sometimes a discharge of charges accumulated in a cloud occurs to surrounding air. It is a cloud to air lightning. The most dangerous type is the cloud to ground lightning.

When a charged cloud positions itself above a certain point on the Earth, positive charges are induced on the ground due to the influence of the negative charged accumulated in the lower part of the cloud. At a certain moment negative charges from the cloud jump to Earth when the amounts of charges in the cloud and on Earth increase. This is called a cloud to ground lightning and identified as very destructive thunderbolt. The voltage of a cloud to ground lightning is about 10 million volts. Current of nearly 25 000 amperes flows in such a lightning.

When the lightning is within sight, however, we see it first because the speed of sound in air is considerably slower than that of the electron flow.

3.2 Advantages of air ionization phenomenon to the agriculture

An ion is an atom that has a positive or negative charge. When an atom or molecule has an equal number of protons and electrons, it is balanced or neutral. If an electron is lost the atom becomes positively charged. If an electron is gained, it becomes negatively charged.

Atmosphere is a mixture of gases including nitrogen (78%), oxygen (21%), carbon dioxide, water vapor, and other trace gases, any one or more of which can be ionized. When any one or more of these gas molecules gains or loses an electron, it becomes charged and thus called air ions. As a result of the solar energy pass through the above air mixture, the air is being subject to ionization and positively charged ions will be deposited above region of the cloud and negatively charged ions is in the below region of the same cloud layer. However, the water vapor is most easily become ionized under electrostatic process as explain above. The recurring equation of the ionization of water vapor is given below.

Electrostatic Process

$$H_2O + H_2O \rightleftharpoons H_3O^+ + HO^-$$

Hydronium Ion   Hydroxide Ion

However, current of nearly 25 000 amperes flows in a lightning. The enormous energy of lightning breaks atmospheric nitrogen molecules (N_2) which is relatively inter gas, and enables their atoms to combine with oxygen in the air forming nitrogen oxides. These dissolve in rain, forming nitrate (NO_3^-) that are carried to the Earth and it is a salience plant nutrient.

Air Lightning

$$N_2 + 3O_2 \longrightarrow 2NO + O_2 \longrightarrow 2NO_2 + \text{O2} \longrightarrow 2NO_3^-$$

Nitrogen   oxygen   Nitric Oxide   Nitrogen Dioxide   Nitrate

In addition, under great pressure, at a temperature of 600°C, and with the use of a catalyst, atmospheric nitrogen and hydrogen can be combined to form ammonia (NH_3).

$$N_2 + 3H_2 \longrightarrow 2\,NH_3$$

The nitrogen cycle is given in the following Figure 3.3 with all the conversion stages and it is activated under the lightening process.

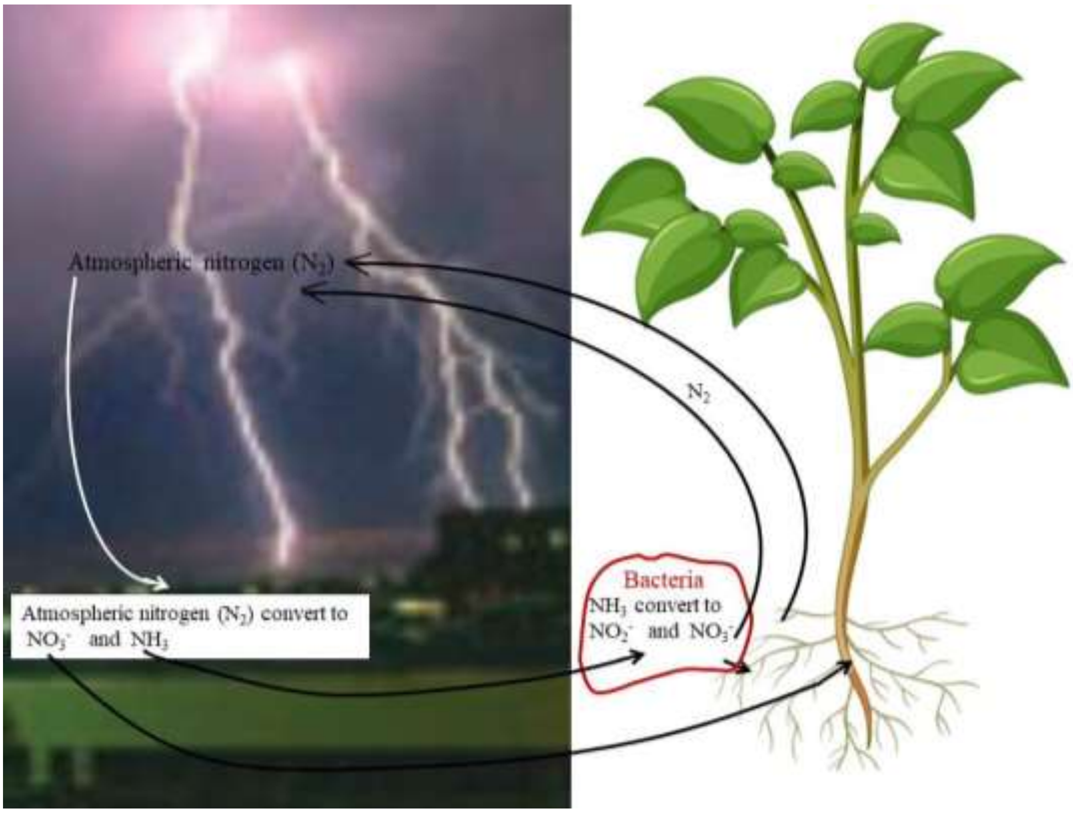


Figure 3.3 : The nitrogen cycle

After fixation of ammonia, that is formed will be transferred further, during the nitrification process at the soil. Aerobic bacteria use oxygen to convert these compounds. Nitrosomonas bacteria first convert nitrogen gas to nitrite (NO_2^-) and subsequently nitrobacter convert nitrite to nitrate (NO_3^-), a plant nutrient.

$$2NH_3 + 3O_2 \xrightarrow{\text{Aerobic bacteria}} 2NO_2^- + 2H^+ + 2H_2O$$

$$2NO_2^- + O_2 \xrightarrow{\text{Nitrosomonas bacteria}} 2NO_3^-$$

Ammonia can be used directly as fertilizer. Most of its further processed to urea [$(NH_2)_2CO$] and ammonium nitrate (NH_4NO_3).

Ammonium nitrate (NH_4NO_3) is produced by neutralizing nitric acid (HNO_3) with ammonia (NH_3). All ammonium nitrate plants produce an aqueous ammonium nitrate solution through the reaction of ammonia and nitric acid in a neutralizer according to the following equation.

$$NH_3 + HNO_3 \longrightarrow NH_4NO_3$$

3.3 Lightning and thundering pattern throughout the year and optimization period

Lightning flash most frequently occurs over the land than over the oceans and lightning seems to happen more often closer to the equator according to satellite observations. The higher frequency of lighting over land makes sense because solid Earth absorbs sunlight and heats up faster than water. The stronger convection and greater atmospheric instability lead to the formation of thunder and lightning producing storms.

A large number of flashes have observed during the month of May in the Brahmaputra Valley of far eastern India according to the scientists from NASA. The heating and weather patterns are unstable and changeable at that time just before the onset of the monsoon, which brings plenty of rain but much less lightning. In contrast, locations in Central Africa and Northwestern South America have large amounts of lightning throughout the entire year.

The winds from the southern hemisphere and northern hemisphere converge and appear as a band of clouds that circle the globe near the equator. Over the Indian Ocean, during the northern hemisphere winter, the cloud band is much broader than it is over either the Atlantic or Eastern Pacific oceans. This area of the Indian Ocean is identified as Inter Tropical Convergent Zone and Sri Lanka is also belonged to this zone. Induce semi-persistent low-pressure conditions in this zone causing heavy rains and lightning throughout the island and at many other places at the same latitude.

Chapter 4 : Natural Foods Production by Photosynthesis

Plants are called autotrophs because they can use energy from light to synthesize, or make, their own food source. Many people believe that they are "feeding" a plant when they put it in soil, water it, or place it outside in the Sun, but none of these things are considered food. Rather, plants use sunlight, water, and the gases in the air to make glucose, which is a form of sugar that plants need to survive. This process is called photosynthesis and is performed by all plants, algae, and even some microorganisms. Plants need three things as carbon dioxide, water, and sunlight to perform photosynthesis. It is a metabolic process of producing complicated organic foods by using inorganic compounds like carbon dioxides and water amid of the photosynthetic pigmentation and solar power.

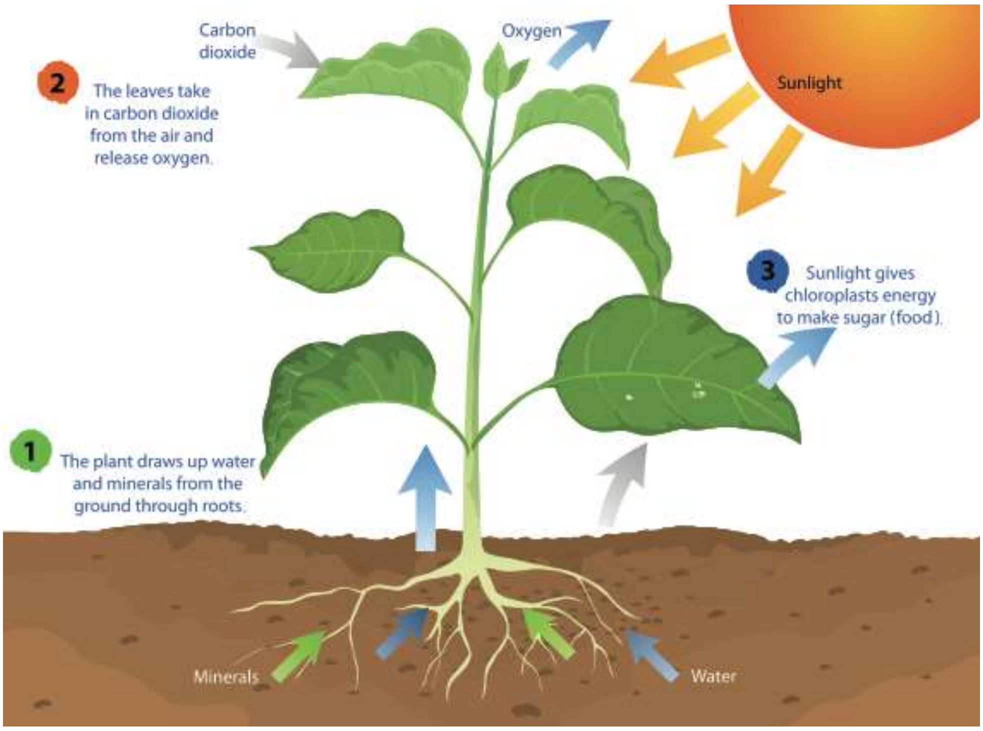


Figure 4.1 : Photosynthesis process of the plant
Source : Smithsonian Science Education Center

By taking in water (H_2O) through the roots, carbon dioxide (CO_2) from the air, and light energy from the Sun, plants can perform photosynthesis to make glucose (sugars) and oxygen (O_2).

Plants also need to take in gases in order to live as other living beings. Animals take in gases through a process called respiration. During the respiration process, animals inhale all of the gases in the atmosphere, but the only gas that is retained and not immediately exhaled is oxygen. Plants, however, take in and use carbon dioxide gas for photosynthesis. Carbon dioxide enters through tiny holes in a plant's leaves, flowers, branches, stems, and roots. Plants also require water to make their food. Depending on the environment, a plant's access to water will vary. But every photosynthetic organism has some sort of adaptation, or special structure, designed to collect water. For most plants, roots are responsible for absorbing water.

4.1 The process of food production by photosynthesis

The last requirement for photosynthesis is an important one because it provides the energy to make sugar. The making process of food molecules by using carbon dioxide and water molecules is very interesting natural phenomena of the plans. The energy from light which is given by the Sun causes a chemical reaction that breaks down the molecules of carbon dioxide and water and reorganizes them to make the sugar (glucose) and oxygen gas. After the sugar is produced, it is then broken down by the mitochondria into energy that can be used for growth and repair. The oxygen that is produced is released from the same tiny holes through which the carbon dioxide entered. Even the oxygen that is released serves another purpose. Other organisms, such as animals, use oxygen to aid in their survival.

The formula for photosynthesis would looks like this:

Carbon dioxide + Water —SUNLIGHT→ Glucose (Sugar) + Oxygen

Under the photosynthetic pigments

$$6CO_2 + 6H_2O + \text{Light energy} \rightarrow C_6H_{12}O_6 \text{ (sugar)} + 6O_2$$

The whole process of photosynthesis is a transfer of energy from the Sun to a plant. Humans, other animals, fungi, and some microorganisms cannot make food in their own bodies like autotrophs, but they still rely on photosynthesis. Plants produce sugar through the transfer of energy from the sun to plants and humans consume to drive their daily activities. Further, herbivores then obtain this energy by eating plants, and carnivores obtain it by eating herbivores.

The process

During photosynthesis, plants take in carbon dioxide (CO_2) and water (H_2O) from the air and soil. Within the plant cell, the water is oxidized, meaning it loses electrons, while the carbon dioxide is reduced, meaning it gains electrons. This transforms the water into oxygen and the carbon dioxide into glucose. The plant then releases the oxygen back into the air, and stores energy within the glucose molecules.

Chlorophyll

Inside the plant cell are small organelles called chloroplasts, which store the energy of sunlight. Within the thylakoid membranes of the chloroplast is a light-absorbing pigment called chlorophyll, which is responsible for giving the plant its green color. During photosynthesis, chlorophyll absorbs energy from blue-light waves (450 nm – 550 nm) and red-light waves (650 nm – 700 nm), and reflects green-light waves, making the plant appear green.

4.2 Mechanism of the photosynthesis

There are different types of photosynthesis, including C_3 plants photosynthesis, C_4 plants photosynthesis and CAM (Crassulacean Acid Metabolism) plants. C3 photosynthesis is used by the majority of plants. It involves producing a three-carbon compound called 3-phosphoglyceric acid during the Calvin Cycle, which goes on to become glucose. C_4 photosynthesis, on the other hand, produces a four-carbon intermediate compound, which splits into carbon dioxide and a three-carbon compound during the Calvin Cycle. A benefit of C_4 photosynthesis is that by producing higher levels of carbon, it allows plants to thrive in environments without much light or water. Crassulacean Aid Metabolism (**CAM**) plants minimize photorespiration and save water by separating these steps in time, between night and day.

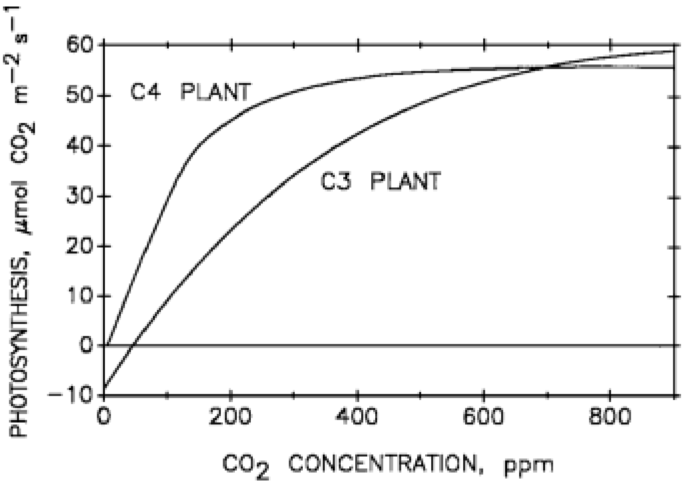


Figure 4.2 : Photosynthesis intensity for C3 crops and C4 crops

The following examples can be given for the C_3, C_4 and CAM photosynthesis plants.

C_3 Plants	C_4 Plants	CAM Plants
Rice, paddy	Maize	Pineapple
Wheat	Sugar cane	Cacti
Soybeans	Sorghum	
Potatoes	Switchgrass	
Cotton, lint	Crabgrass	
Tomatoes		
Grapes		
Apple		
Peanuts		
Cassava		
Barley		
Oats		
Sunflower		
Tobacco		
Alfalfa (lucerne)		

The vast majority of the plants (about 85% of the plant species on the planet including all trees) are C_3 plants which have no special features to combat photorespiration.

Plant type	Separation of initial CO_2 Fixation and calvin cycle	Stomata open	Best adapted to
C_3	No separation	Day	Cool, wet environments
C_4	Between mesophyll and bundle-sheath cells (in space)	Day	Hot, sunny environments
CAM	Between night and day (in time)	Night	Very hot, dry environment

4.3 Pattern of the chemical reactions

Chlorophylls and carotenoids are the two major classes of photosynthetic pigments found in plants and algae. Each class has multiple types of pigment molecules. There are two types of chlorophyll pigments namely chlorophyll a (the main photosynthetic pigment) and chlorophyll b. β-carotene as well as above both types of chlorophyll pigments can absorb visible solar radiations. The colour of the chlorophyll a is yellowish green and bluish green for chlorophyll b. The absorbing power of red-light waves is higher in Chlorophyll a than chlorophyll b and converse of it for blue-light waves. However, the absorbing power is comparatively higher in blue-light waves than red-light waves for both types of chlorophyll pigments. See following figure.

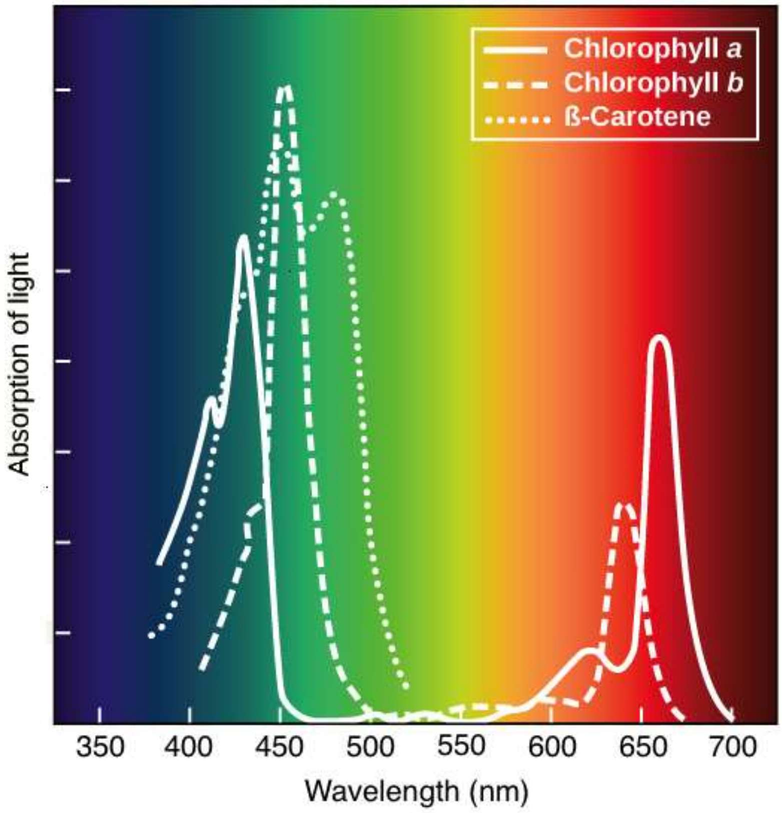


Figure 4.3 : Absorption spectra of pigments
Source : Module 6 : Metabolic Pathways, Biology for Majors I ; Lumen

Further, Carotene (carotenoids) and Xanthophyllin are another key group of pigments that can absorb blue light waves and violet light waves of the visible light spectrum for the photosynthesis. The brightly colored carotenoids found in fruits such as the red of tomato (lycopene), the yellow of corn seeds (zeaxanthin), or the orange of an orange peel (β-carotene). The majority of plants and crops which bear with red, yellow or orange colored fruits or yields are belong to this group.

Carrots, cantaloupe, sweet potatoes, papaya, pumpkin, tangerines, tomatoes, winter squash can be given as examples for the carotene included plants.

4.4 Activation of the visible lights with variations of the incident angle of the solar rays

The intensity of the refraction on the plant leaf for visible light (absorption of the visible light) is very high when the sun is perpendicular to the earth. Therefore, it is comparatively higher for the countries which are near to the equator and refraction angle is not significantly change throughout the year for these countries. However, the variation of the absorption rate of visible light is considerably changed to the countries which are far from the equator and near to the June solstice and December solstice within the year. Therefore, the photosynthesis process will be optimized in the period near to the summer solstice and it will be minimal at the winter solstice.

Solar radiation levels are dependent on the time of day and on the sun's angle toward Earth. This angle will vary by latitude and season. The sunlight must pass through more distance in ozone layer to reach the surface when the angle of the sun is higher. In addition to the sun's angle, atmospheric conditions can affect radiation levels. Cloud cover, air pollution and the hole in the ozone layer all alter the amount of solar radiation that can reach the surface. These all factors cause typical radiation levels to differ.

The enzymes are functioning as catalyzers to improve the intensity of the chemical reactions and it can be changed within the temperature range from 0^0C to 37^0 C. However, the optimal temperature for photosynthesis is 25^0 C and intensity of the photosynthesis process will be declined due to inaction of the enzymes at the higher temperature levels.

4.5 Compilation of foods to the living beings

Although, the plants produced glucose by the photosynthesis activities, they cannot store the production as its basic form and therefore it has to be converted into carbohydrate and there are four groups of it according to the concatenated number of glucose molecules.

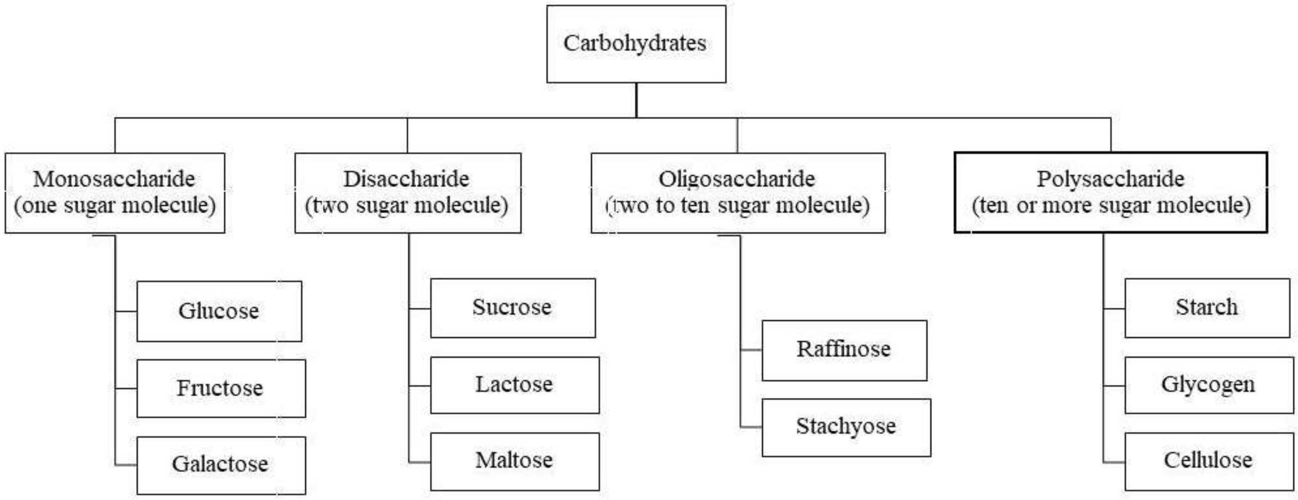


Figure 4.4 : Parting compounds of the carbohydrate

When it is combined a typically made up of foods with many different nutrients and other elements, that can make up a healthy meal. Most of the food and drink we eat can be broken down into three major parts as proteins, fats and carbohydrates. The other ingredients are vitamins, minerals and water.

Monosaccharide (eg. glucose, galactose, fructose)

- Foods that contain glucose like grapes, dried apricots, honey and soft drinks.
- Foods that contain galactose like celery, beetroot, basil, spinach, kiwi fruit and plums.
- Foods that contain fructose like most fruit, soft drinks, sports drinks, cakes, confectionery and chocolate.

Disaccharides (eg. lactose, maltose, sucrose)

- Foods that contain lactose like dairy products (milk, cheese, yoghurt, etc), chocolate and soft-serve ice cream.
- Foods that contain maltose like grains and wheat (wheat, cornmeal, some ancient grains and sweet potatoes etc).
- Foods that contain sucrose like soft drinks, cookies, cakes, some fruits (tangerines for example) and sugary cereals.

Polysaccharides (eg. starch, glycogen, fibre or cellulose)

- Foods that contain starch or ‘starchy carbohydrates’ like potatoes, corn and rice.
- Foods that contain fibre like split peas, chickpeas, beans and lentils.
- Foods that contain cellulose like fruits and vegetables (including the skin of apples and pears), wheat bran and spinach.

Storage of the produced glucose is done as carbohydrates in the plants as explain above and these nutrients are used for the growing of the plants by various ways. Different behavioural patterns of growing are performing by different plants and trees. However, the food crops can be classified in to two groups as perennial crops and seasonal crops. The carbohydrates which they have produced under the photosynthesis process are continuously used for their growing by the perennial crops and after become matured fertility stages, they produce fruits and other edible fesult with nutrients continuously. At the same time, the seasonal crops also use their own produced carbohydrates for their growing and then they produce their yields as fruits or yams or pods or any other ways after matured and then completed their life cycle. Both types of outcomes are consumed by human beings and other living beings as nutritional foods.

4.6 Environmental obstructions to the photosynthesis

The leaves of the plants are damaged due to air pollutions and then the photosynthesis process is weaken. Specially, gases like sulfur dioxide (SO_2) damage leaves of the plants and debilitate the growth of the leaves. In addition, stomata of the plant leaves are blocked with dust and other small particles and then absorption of the carbon dioxide (CO_2) is also weaken. Further, the photosynthesis process is exhausted amidst the very higher atmospheric temperature with global warming and damaging of ozone layer due to the effects of the greenhouse gases.

Chapter 5 : Solar Energy Pattern in Sri Lanka

Sri Lanka is the island in tropical region and it is situated very near to the equator in between 5^0 and 10^0 northern latitudes and 79^0-82^0 eastern longitudes.

5.1 Direction of the sun throughout the year in Sri Lanka

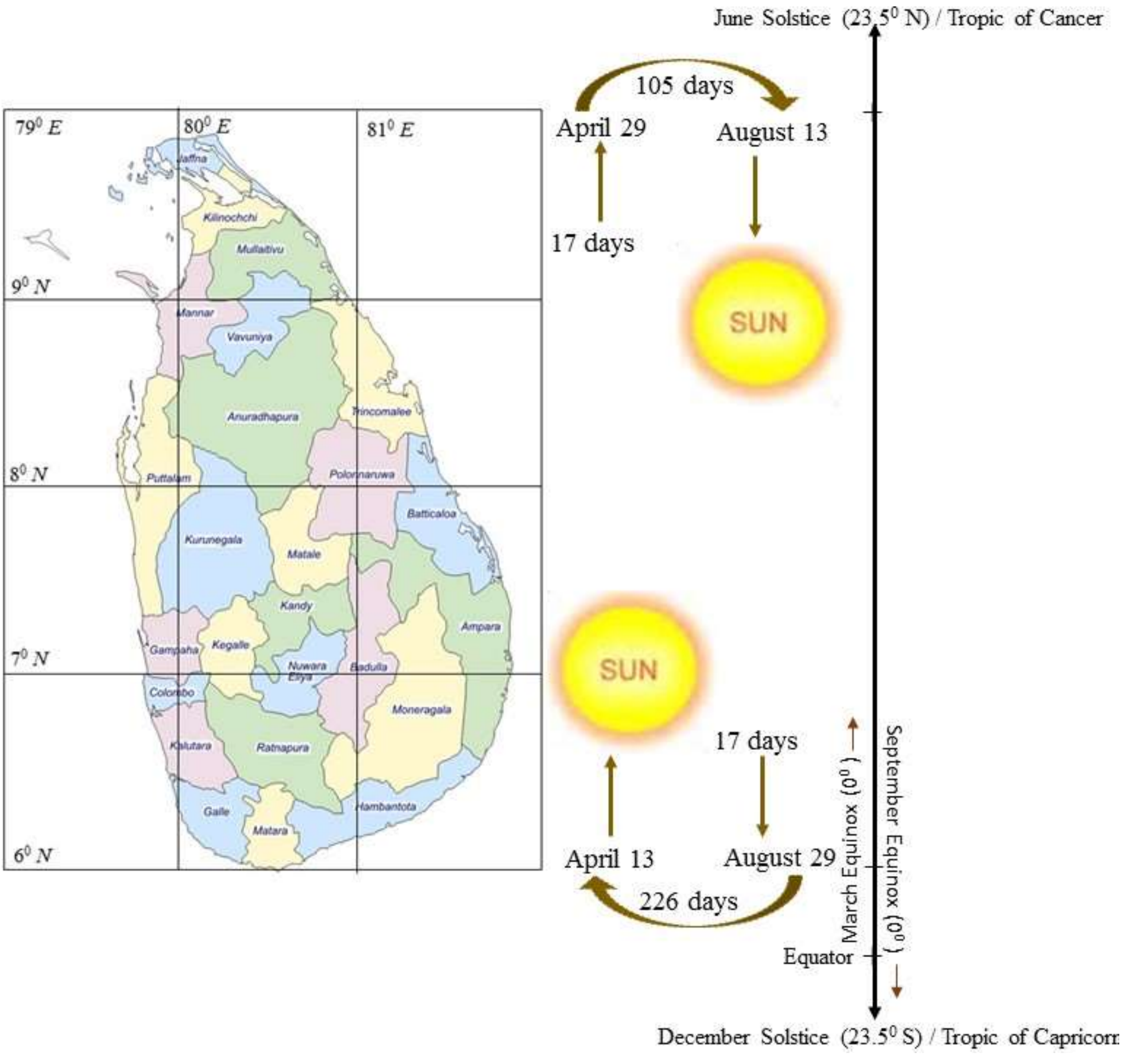


Figure 5.1 : Path of Sun through the sky With time period when is gone over Sri Lanka

The Sun reaches directly over the country approximately on 13 April from the southern direction after passing the March 21 equinox and pass through the country on 29 April to the northern direction each year. The sun will reach again over the country approximately on 13 August from northern direction after June solstice and pass through the country again on 29 August to the southern direction by completing the second approach. The sun rays fall as perpendicular lines to the country within these two periods of 17 days in each year as shown in above figure 5.1.

5.2 Receiving pattern of solar energy with seasonal variations

Persistence of the solar system in this universe including the Earth depends on the solar energy and the amount of energy which is received by the Earth can be varied with the latitude position as shown experimental figures below Table 5.1 and Figure 5.2.

Table 5.1 : Variation of solar energy received on horizontal surfaces at different latitudes (Cal/Sq.cm per day)

Month	Experimental figures			Calculated values
	Singapore (1.5^0 N)	Brockport (43.5^0 N)	Antarctica (90^0 S)	Sri Lanka (8^0 N)
January	394	132	376	344
February	403	190	205	362
March	410	274	40	384
April	386	365	0	382
May	354	446	0	372
June	342	500	0	372
July	365	495	0	390
August	361	418	0	372
September	368	310	18	357
October	359	210	129	331
November	323	117	333	284
December	337	92	433	290

Source : American Meteorological Society

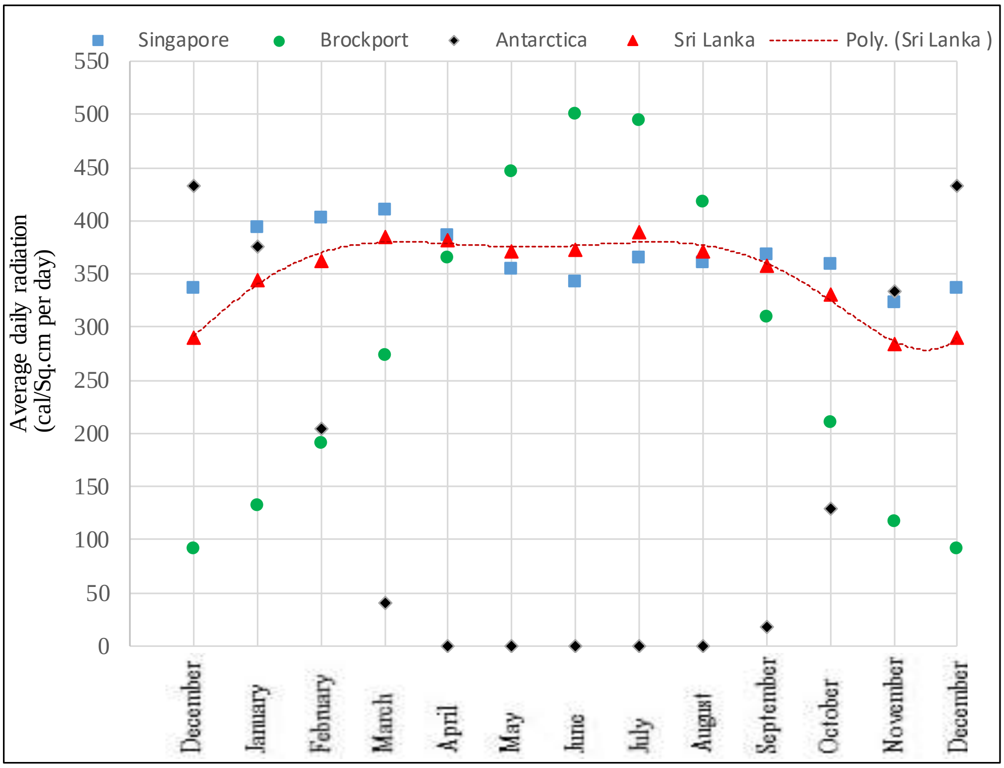


Figure 5.2 : Solar energy receiving pattern to the different areas of the earth

Variation of solar radiation received on horizontal surfaces at different latitudes is given in the above Table 5.1 and it is given by calories per square centimeter per day.

The energy receiving pattern is significantly varying when the country is comparatively far from the equator. However, the countries near to the equator have been received optimum amount of energy throughout the year with few fluctuations. The countries which are situated in Tropic of Cancer are received maximum amount of energy at the June solstice and it is minimal for December solstice. The pattern is completely reverse to the Tropic of Capricorn.

A maximum amount of solar energy can be received on July in Sri Lanka, but the variation is not significant in the period from March to August. The minimum amount of solar energy is receiving in November and December to the country.

5.3 Direction of the solar radiations throughout the year

The insident angle of the sun rays is around 8^0 on the horizontal plane of the ground in the mid point of the country when the sun is at the March equinox on the way to the northern hemisphere (see Figure 5.3). the same phenomenon is been repeated at the September equinox that is on the way to the southern hemisphere of the sun's travel relatively to the Earth. The sunrays are perpendicular to the earth on latter part of the April and August as illustrated on the figure.

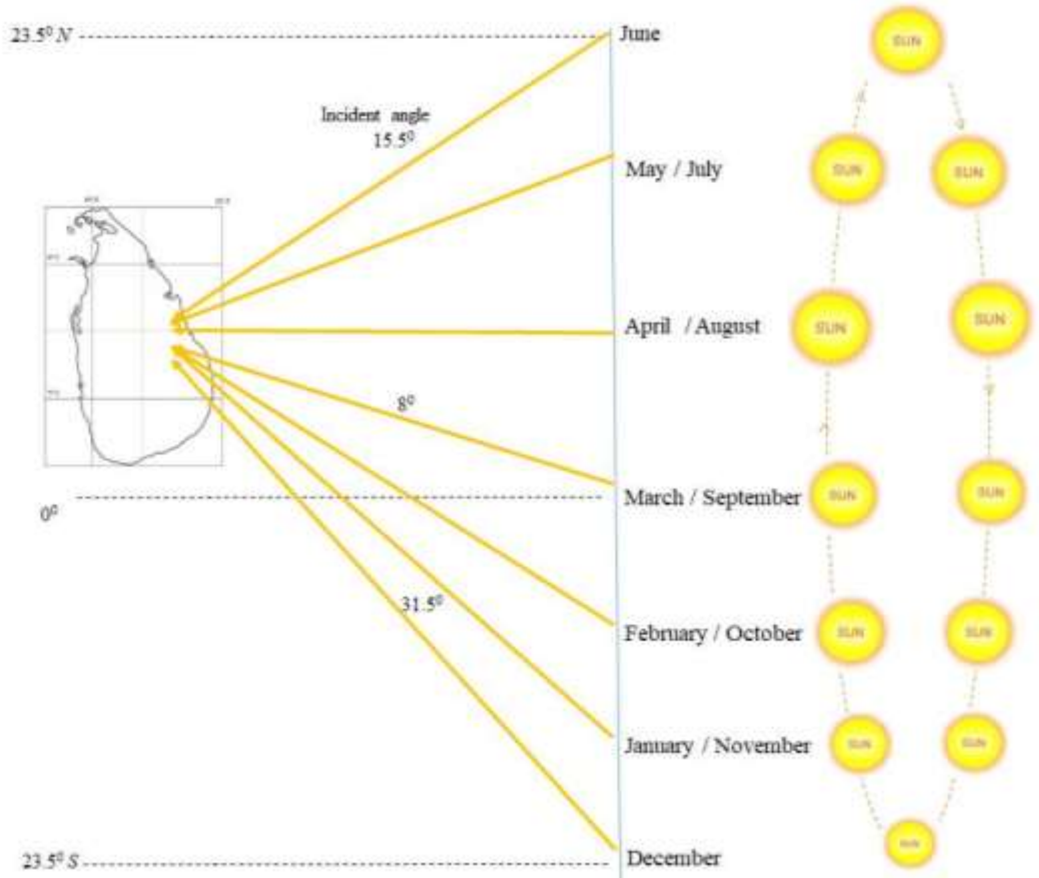


Figure 5.3 : Direction of the solar radiations by month in Sri lanka through out the year

Anyway, the sun rays are directly fallen on the Earth with the range less than 8^0 dimension of the insident angle in the period from March to May and July to September. The insident angle of sun rays is significantly larger value in the period from November to January (three months period) and minimal level of solar energy has also been received in that period.

Radiations of the sun pass through a long distance in the ozone layer when the insident angle is large and air filtering is automatically done by the ozone layer. Therefore, it can be expected comparatively lower air heating as well as lower level of solar energy in the period from November to January. In addition, the reflection rate of the solar radiations are also comparatively higher in this period due to the inclination of the solar radiations. The ground heating is in lower level in this period due to this phenomenon and therefore it will be cooled very quickly in the night. Very cooling weather condition in the morning and night can be expected as a result of this low night temperature. Day and night temperature difference is also comparatively higher in this period.

Further, the period from November to January is most famous for the flushes growing and synchronous flowering of the fruits farming (Plants). In the sub-tropics, low night temperatures (5-10°C) result in synchronous flowering. However, night temperatures of 10-18 °C produce asynchronous flowering similar to that in the tropical zone as this country.

Florescence of the vast majority of the fruit trees are occurred in this season as a result of the temperature difference (low night temperature) that is scientifically explained above. Some of them are blooming as hermaphrodite flowers and then self pollination can be practiced to produce fruits. The fruit bearing plant like avocado cannot perform self pollination because those are not hermaphrodite flowers blooming plants and therefore, it is very necessary to grow two or more plants in the same area to do the cross pollination. Fruit bearings of all the perennial crops except jack tree and other few varieties can be expected in this season largely but some of them perform second season around the month of August but very rarely.

The majority of these fruits are become matured and ripe in the month of April though it is varying from March to May or June. Completing the harvesting of first season paddy cultivation, fruits harvesting season and traditional new year celebration of the Sri Lankans all are occurred simultaneously in the month of April and it is called festival season in the country.

5.4 Distribution pattern of air temperature by geographical locations in Sri Lanka

The minimum temperature was reported from Nuwara Eliya district and it was fluctuating around 16 degrees of centigrade (16 ^{0}C) in the year 2019. The peak of the curve can be seen in the period from April to June as 17.4, 17.7 and 17.5 respectively. See the first group of the following set of figures.

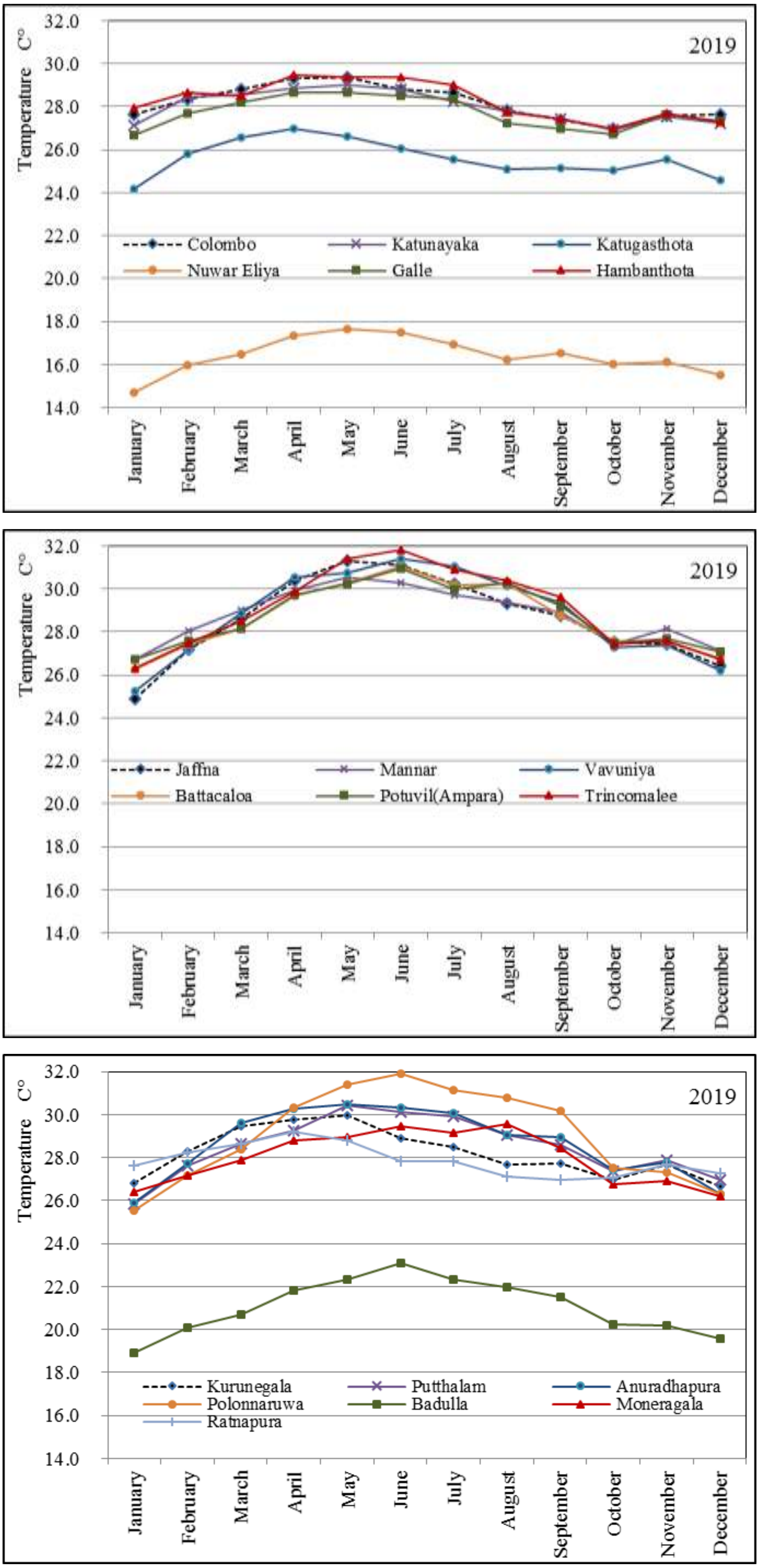


Figure 5.4 : Distribution pattern of air temperature by observation stations in Sri Lanka

Source : Department of Meteorology in Sri Lanka

Other districts has also performed same pattern as Nuwara Eliya in the first set of the figure but the temperature was increased. The peak value of the majority of the locations has moved to June as shown in the second and third sets of the figures. North Central province, Northern province and the Eastern province can be identified as most vulnerable areas to the ferocious solar radiations and it should be adverse effects of the June solstice of the northern hemisphere. A highest value of temperature has reported on June and it was around 32 ^{0}C to the area.

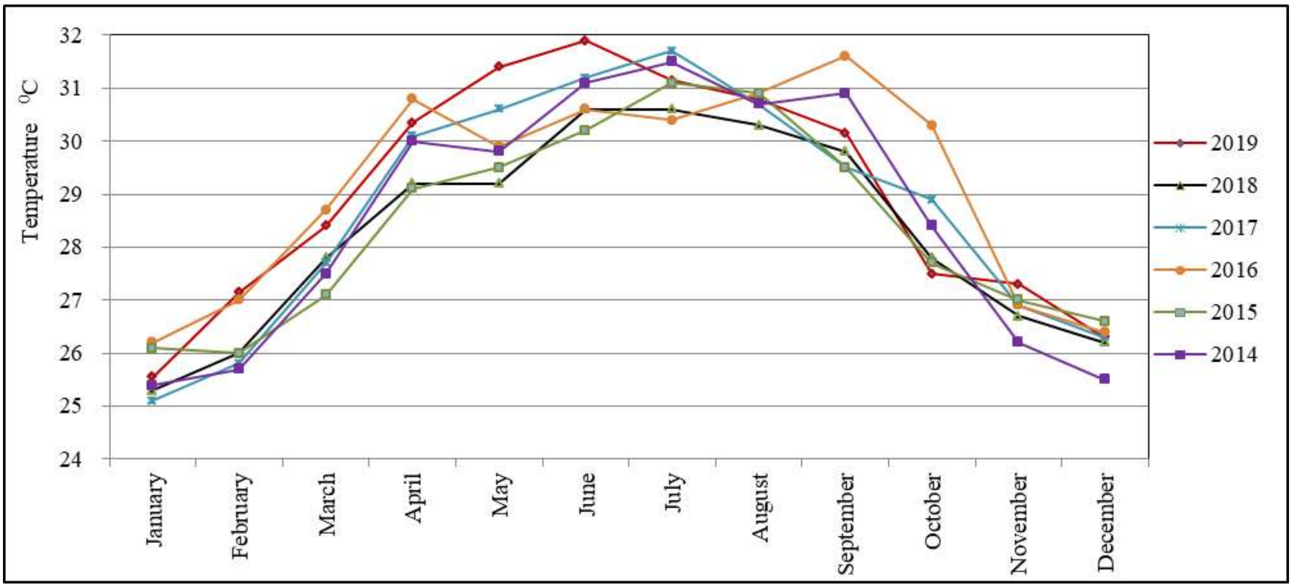


Figure 5.5 : Distribution pattern of air temperature in Polonnaruwa district from 2014 to 2019
Source : Department of Meteorology in Sri Lanka

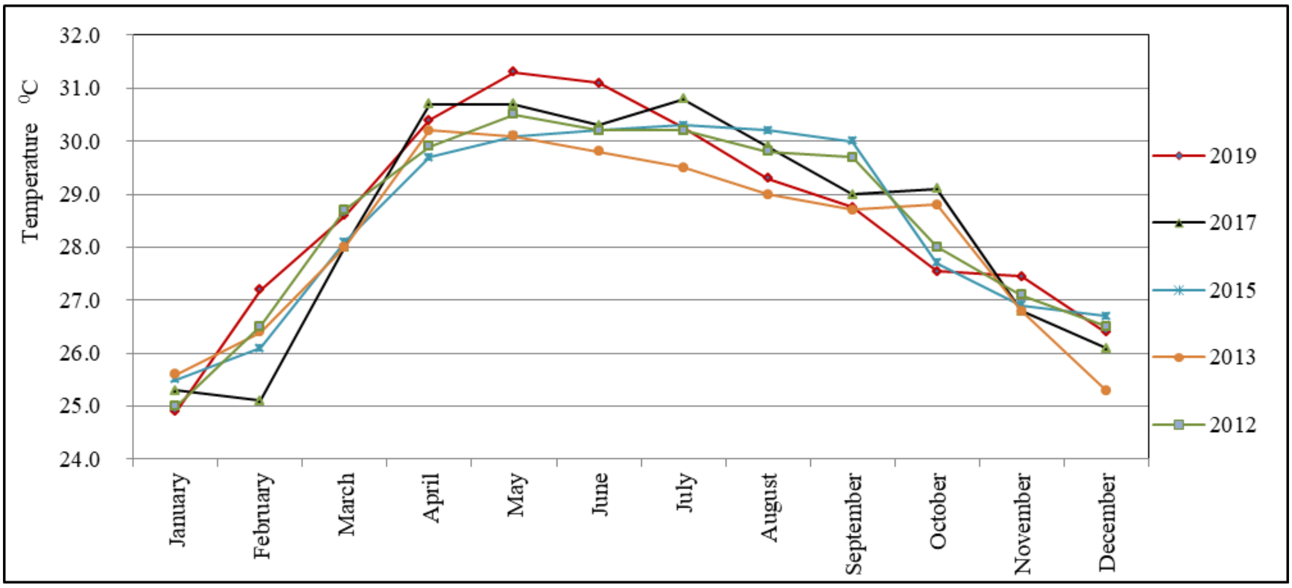


Figure 5.6 : Distribution pattern of air temperature in Jaffna district from 2014 to 2019
Source : Department of Meteorology in Sri Lanka

Both Polonnaruwa and Jaffna districts are belonged to different areas of the different provinces but temperature pattern is approximately same. An increment of the temperature can be seen in these districts in this period of time according to the above figure 5.5 and 5.6. Further, comparatively low temperature level around 26 ^{0}C was reported in four months period from November to February in these areas and therefore, special crops can be grown in this time period by concerning the rainfall pattern.

Anyhow, Nuwar Eliya, Badulla and Kandy districts were the areas with temperate climate. Therefore these areas are most suitable for the improvements of milk production industry by imported milk cows.

5.5 Lightning and thundering pattern in Sri Lanka

It is not practicable to count the number of Lightning flashes and thunder strikes manually, but it can only be measured by using satellites very accurately. However, it can be assume that the number of lightning flashes and thundering strikes are directly proportionate to the number of human deaths, injuries and property damages by the lightning and thundering accidents in the area. The information which is based on the assumption is illustrated in the following Figure 5.7.

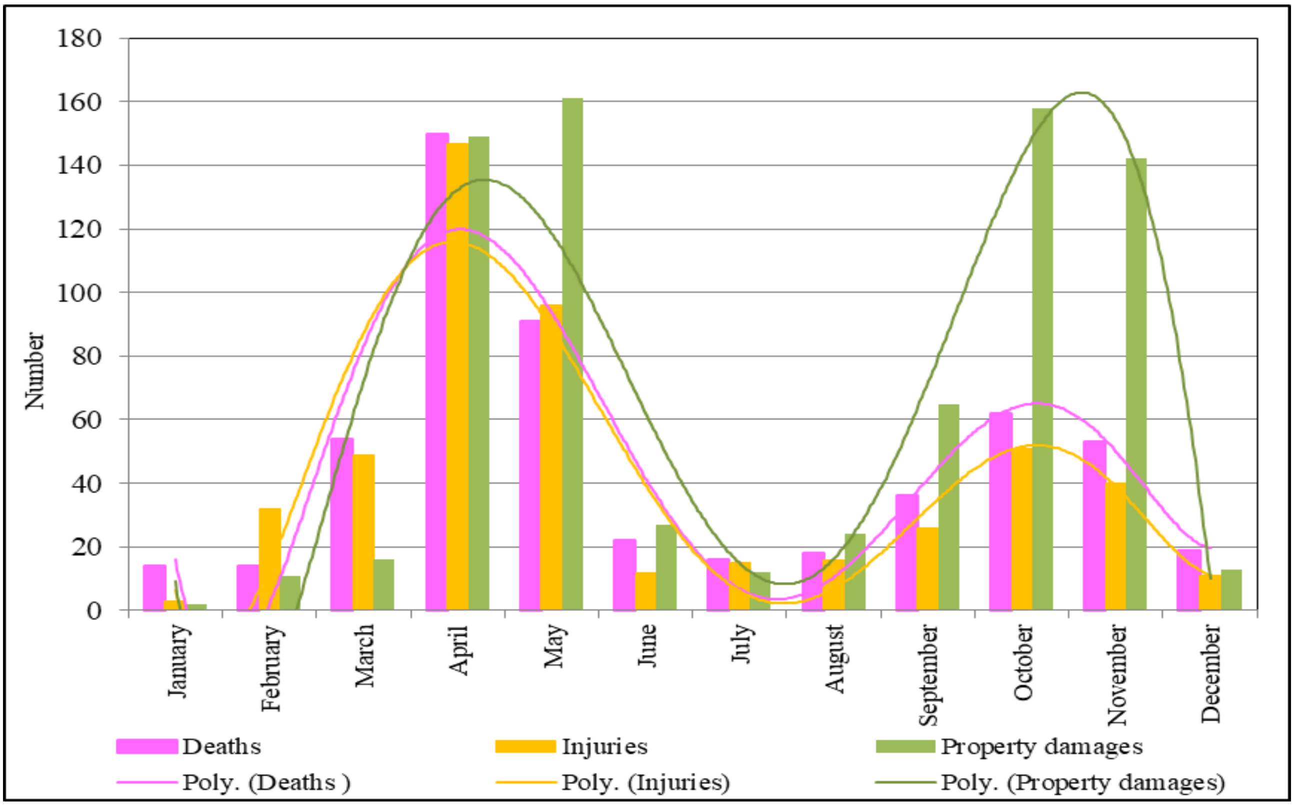


Figure 5.7 : Monthly variations of lightning accidents (reported number) in Sri Lanka from 1974 to 2019
Data Source : ISPRS International Journal of Geo-Information

The maximum lightning accidents can be seen over the first inter-monsoon period around the March 21 equinox (April) in the country. The second peak has occurred during the second inter-monsoon period around the September equinox (October), but it was not acute so far as first inter monsoon period. Therefore, it can be suggested that the most vulnerable periods are April/May and October/November for lightning flashes and thundering strikes in Sri Lanka.

Kegalle administrative district was the most vulnerable area to the human deaths and injuries as well as property damages by lightning flashes and thundering strikes in Sri Lanka according to the following Figure 5.8. However, the reported number of property damages in the area has incredibly increased and it should be done a special study to ascertain it. The northern and eastern areas of the country were the most protected regions to this calamity and lightning flashes and thundering strikes were minimal in these areas.

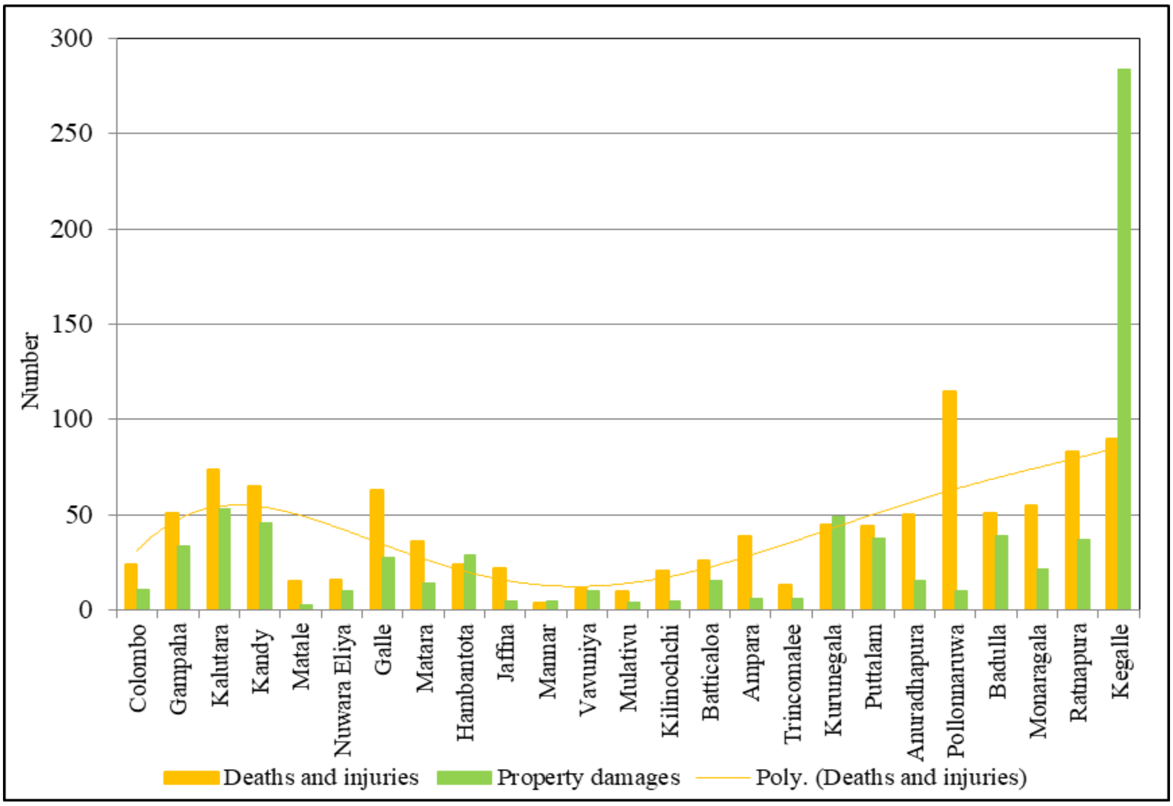


Figure 5.8 : Lightning accidents by administration districts in Sri Lanka from 1974 to 2019
Data Source : ISPRS International Journal of Geo-Information

5.6 Seasonal variations of the weather and climatic conditions throughout the year

The Seasonal variations of the weather conditions and the climatic changes in Sri Lanka are depended on the revolving pattern of the Earth around the Sun throughout the year.

The transitional periods around March 21 equinox and September 23 equinox are concerned as the inter monsoon seasons. It is approximately one month period and inter monsoonal rain is been receiving in these both period of times and it is called convectional rains. South West monsoonal rain and North East monsoonal rain are activated immediately after ending with above two inter monsoon seasons respectively.

5.61 The process of rain cycle

Without rain and water, no living beings can survive. How we get rain depends on the water cycle. The entire process of the rain cycle starts with the sea.

The entire process starts with the sea. First, seawater gets heated by the sun and evaporates. The seawater turns into water vapor and steam. As the hot air tends to be light, it rises upward. When the water vapor rises, it is cooled. The air cannot hold moisture as much as it could when it was warmer. The cold air reaches a point where it is 100% saturated, it becomes heavier, and it cannot hold any more water. This is called the dew point. Above this dew point condensation occurs. Condensation is a process in which the water vapor (a gas) held in the air is turned back into water droplets (a liquid). This cooling turns the water vapor to condense, and as the vapor condenses, the cloud is formed. The cloud receives vapor until the point it can hardly store anymore. The cloud, therefore, being saturated begins to precipitate and fall as rain.

5.62 Pattern of the seasonal rain in Sri Lanka

Direction of the winds flow and rainfall pattern are changing seasonally as illustration in the following Figure 5.9.

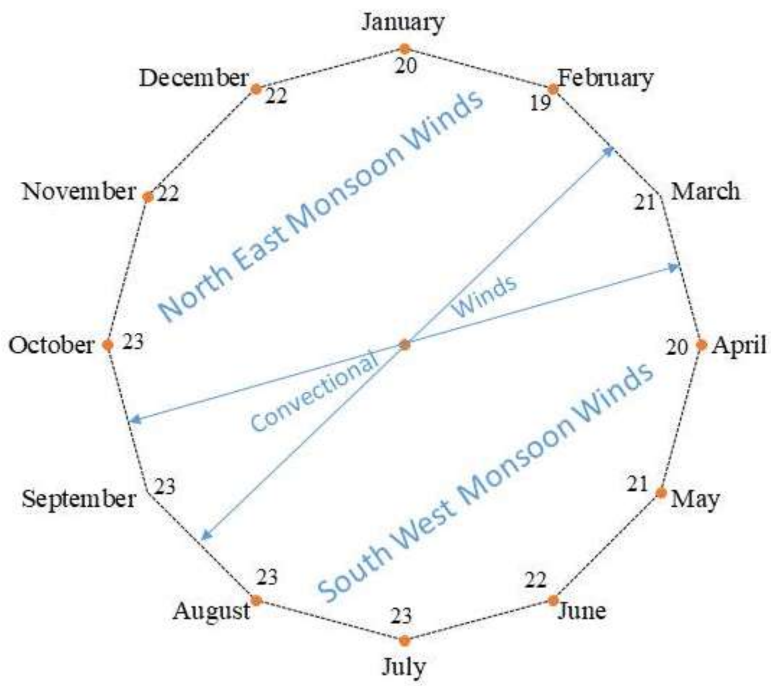


Figure 5.9 : Seasonal variation pattern throughout the year

Monsoon Rains, Convectional Rains and cyclonic Rains are the three main sources of rains during the year in Sri Lanka. It has a typical time period for monsoon rain and conventional rain but cyclonic rains can be expected any time thruogh out the year. Normally, convectional rains are activated in transitional periods of two diferent monsoon winds as north eastern monsoon winds to south western monsoon winds and vice versa. This rains can be expected on March/April and September/October as illustration in above figure.

Convectional rainfall is very common in summer in tropical or equatorial regions where it is very hot, and the ground is heated by the Sun. The preconditions for this kind of rainfall are intense heating of the ground surface by incoming shortwave electromagnetic solar radiation and ample supply of moisture caused by evaporation to the air to result in high relative humidity. Convectional rain frequently occurs in the afternoon on hot days with thundery showers from cumulus or cumulonimbus cloud. This rainfall variant is heavy but of short duration. It is highly localized, and a minimum amount of cloudiness occurs.

5.7 Seasonal pattern of the monsoon rains

The south-western monsoon brings rain to the south-west of Sri Lanka (Wet zone) between May and September prominently, while the dry season in this region runs from October to March. In the North and East coastal regions (Dry zone), the monsoon brings wind and rain between October and March under influence of north eastern monsoon winds. In the mean time, the intermediate zone of the country depends on above two types of monsoon winds and rains with different climatic pattern.

The pattern of the monsoon seasons in Sri Lanka is depend on the winter, spring summer and autumn seasonal patterns of the northern and southern hemispheres. The south-western monsoon winds are activated at the summer season to the northern hemisphere and when it is bear with winter, then north eastern monsoon winds are successfully activated here.

Figure 5.10 : Direction of the monsoon wings

Sri Lanka has a heterogeneous agro-ecological environment and therefore the country has traditionally been classified into three climatic zones as Wet Zone, Dry Zone and Intermediate Zone on rainfall distribution as shown in above Figure 5.10. The Wet Zone covers the south-western region including the central hill country and receives relatively higher annual average rainfall over 2,500 mm without pronounced dry periods. The Dry Zone covers predominantly the northern and eastern part of the country, being separated from the Wet Zone by the Intermediate Zone. The annual average rainfall of the Dry zone is less than 1,750 mm and the dry season is influenced from May to September in to the zone. The Intermediate zone receives a mean annual rainfall between 1,750 to 2,500 mm with a short and less prominent dry season. See the Figure 5.10 above and Table A in Appendix to study the zonal demarcations of the country.

5.8 Annual rainfalls pattern in Sri Lanka

Annual rainfall pattern of the previous five year period is shown in the following figure. Ratnapura district has received maximam rainfall and it was considerable amount for Western provence and Galle district too. A minimum amount of rainfall has been reported from the areas with higher temperature levels like Northern province, Eastern province and North Central province.

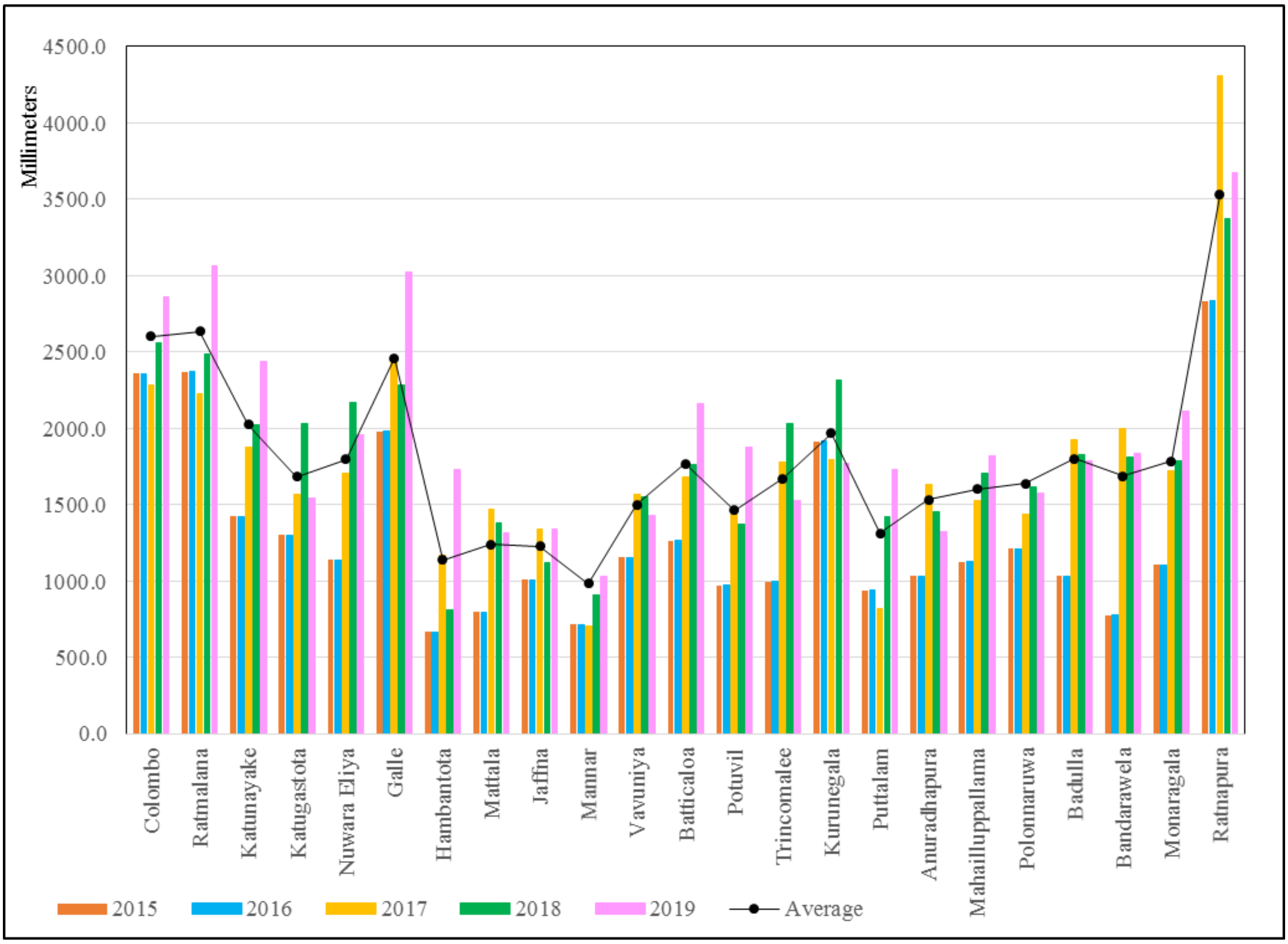


Figure 5.11 : Annual rainfalls by observation stations in Sri Lanka

Source : Department of Meteorology in Sri Lanka

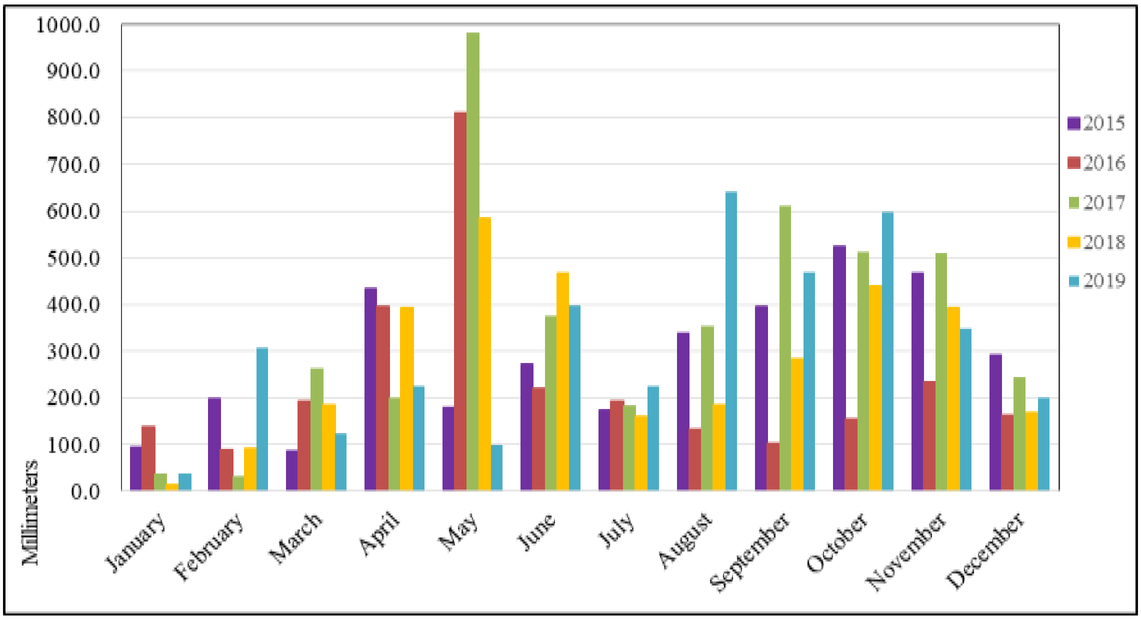


Figure 5.12 : Monthly rainfalls pattern in Ratnapura district from 2015 to 2019
Source : Department of Meteorology in Sri Lanka

The Ratnapura district was receiving significant amount of rainfall throughout the year but a few decline can be seen in January and February. See figure 5.12 above.

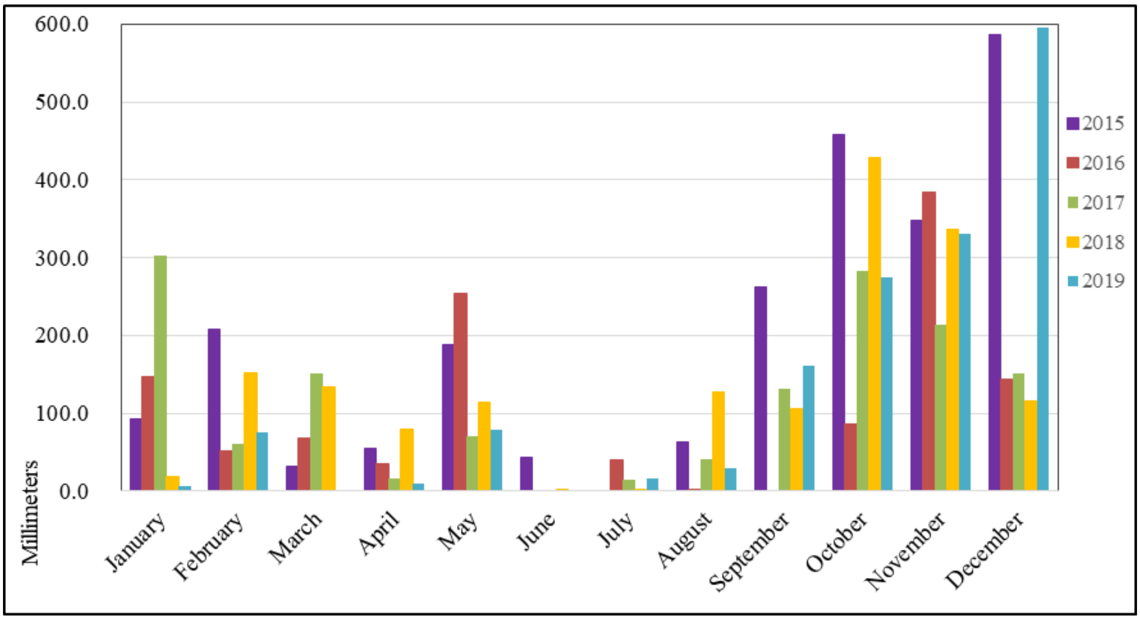


Figure 5.13 : Monthly rainfalls pattern in Polonnaruwa district from 2015 to 2019
Source : Department of Meteorology in Sri Lanka

A maximum amount of rainfall can be expected from October to January in Polonnaruwa district (see Figure 5.13) and congenial air temperature has also received in this period. The paddy cultivation can be successfully done with substantial amount of harvesting due to this environment. Experiments have to be carried on to improve other suitable vegetables and fruits in addition to the paddy cultivation in this area.

Monthly rainfall pattern and air temperature distributions by observation locations are given under the appendix section at the end of the report. The crop variety and the cultivation periods of various locations can be decided by studying these figures.

5.9 Adverse weather conditions and natural disasters

Although the normal climatic behaviors and weather conditions are as above interpretations, Sri Lanka has situated in the tropical region and therefore it is faced to the tropical cyclones frequently. Very heavy rainfalls can be expected due to these sudden climatic changes. A major contributive factor for the formation of tropical cyclone is sea surface temperature. The sea surface temperature is required to maintain at over 26 – 27 ^{0}C. But sea surface temperature rise and it is induced by the global warming. The global warming has been recognized as one of a major cause to increase the intensity of the tropical cyclones. The occurrence of cyclone activities in Bay of Bengal is comparatively higher than the other areas and it is directly effect to the sudden climatic changes in the country.

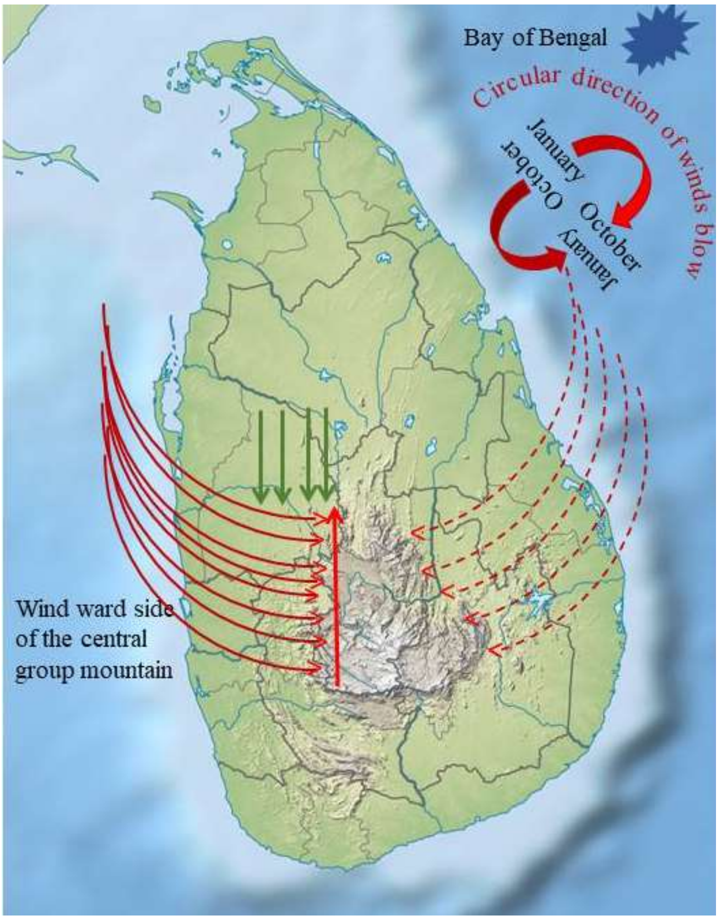


Figure 5.14 : Effects of the Bay of Bengal to adverse weather in Sri Lanka

From January to October, the air current is northward flowing with the clockwise circulation pattern. The remainder of the year, the counterclockwise air current is southwestward flowing with the circulation pattern as shown in above figure 5.14. The windward side of the central group of mountains in Sri Lanka is the west direction of the drop of the group mountain to the period from

October to January. After collide this air current on the drop of the mountain, it is rising and condense the water vapor due to cooling at the upper regions of the sky. This water vapor is falling as rain when it becomes saturated point. The most vulnerable areas for these heavy rains are northern and eastern part of the Kegalle administrative district because it is situated in the west side cliff of the group of mountain. Further, the most vulnerable period is October to January in each year and this can be affirm by studying the lightning and thundering damages reported from the district as explain in Figure 5.8. Eastern drop of the central mountain group is the leeward side zone in this period but that area (some parts of the Budulla district and Moneragala district) is dominated to the calamity in the period from January to October. However, the intensity is not as western side. The low pressure conditions are suddenly arisen in the area of Bay of Bengal irregularly without any seasonal pattern.

Furthermore, much of the water from heavy rainfall events in Sri Lanka would be lost as run-off to the sea. The country faces the challenge of inundation due to the pernicious trend of human activities and coastal inundation as a result of rise in sea level.

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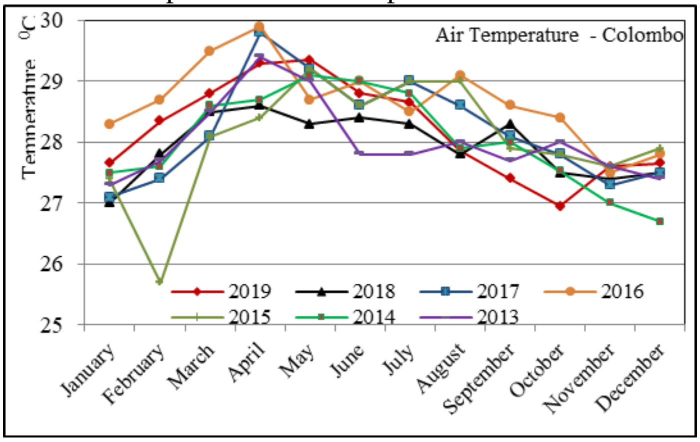
Appendix

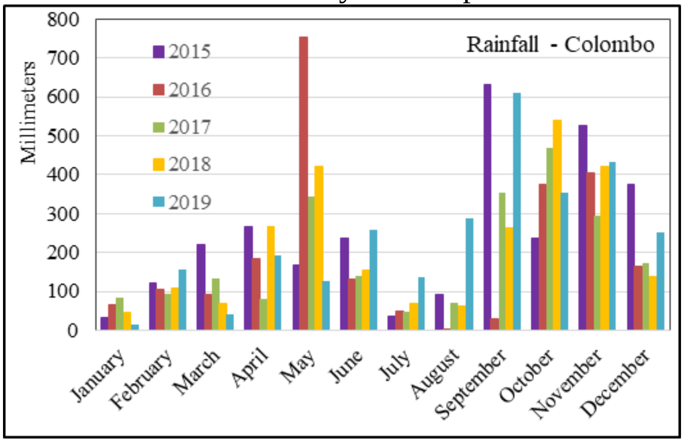
Table A : Distribution pattern of administrative districts by climatic zones in Sri Lanka

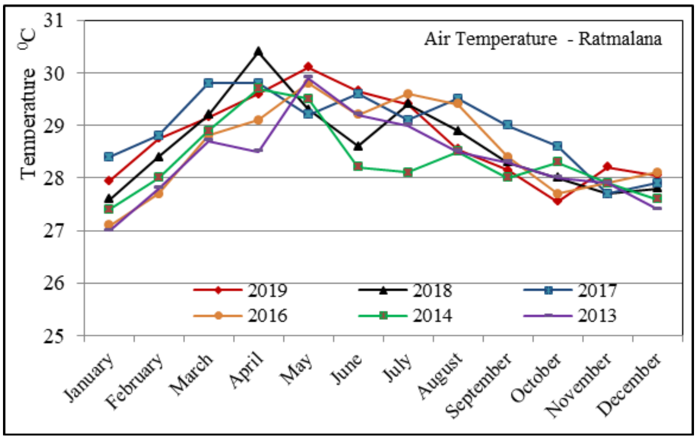
Wet zone	Intermediate	Dry zone
Colombo		Jaffna
Gampaha		Mannar
Kalutara		Vavuniya
Galle		Mullaitivu
Matara		Kilinochchi
Kegalle		Batticaloa
Kandy (Except Minipe) →	Minipe	Ampara
NuweraEliya (Except Walapane) →	Walapane	Trincomalee
	Nildandaheenna	Anuradhapura
		Polonnaruwa
	Kurunegala (Except Giribawa) →	Giribawa
	Badulla (Except Mahiyanganaya) →	Mahiyanganaya
Ukuwela ←	Matale (Except Ukuwela Dambulla and Wilgamuwa)	Dambulla
		Wilgamuwa
	Hambantota	Hambantota
	Weeraketiya	Sooriyawewa
	Katuwana	Lunugamvehera
	Walasmulla	Thissamaharama
	Okewela	Hambantota
	Beliatta	Ambalantota
	Tangalle	Angunakolapelessa
	Puttalam	Puttalam
	Madampe	Kalpitiya
	Mahawewa	Vanathawilluwa
	Nattandiya	Karuwalagaswewa
	Wennappuwa	Nawagattegama
	Dankotuwa	Puttalam
		Mundel
		Mahakumbukkadawala
		Anamaduwa
		Pallama
		Arachchikattuwa
		Chilaw
	Moneragala	Moneragala
	Bibila	Siyambalanduwa
	Madulla	Wellawaya
	Medagama	Buttala
	Moneragala	Katharagama
	Badalkumbura	Thanamalvila
		Sevanagala
	Ratnapura	Ratnapura
Ratnapura (Except -------------->	Balangoda	Embilipitiya
	Kalthota	
	Weligepola	
	Kolonna	

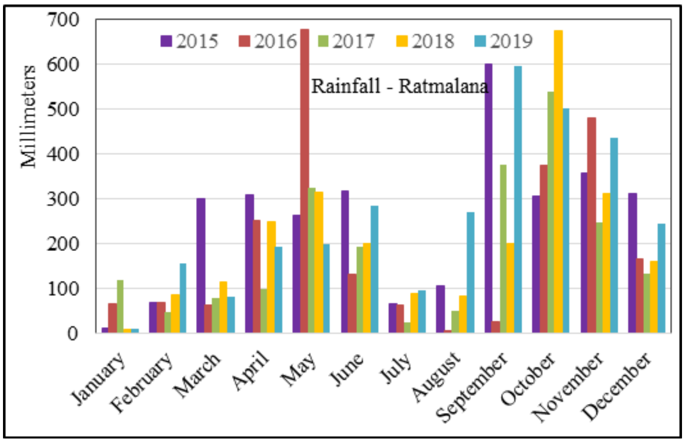
Distribution pattern of air temperature

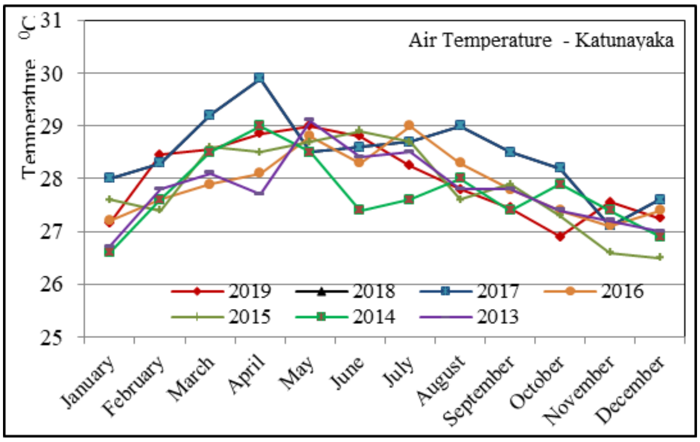
Distribution of the monthly rainfall pattern

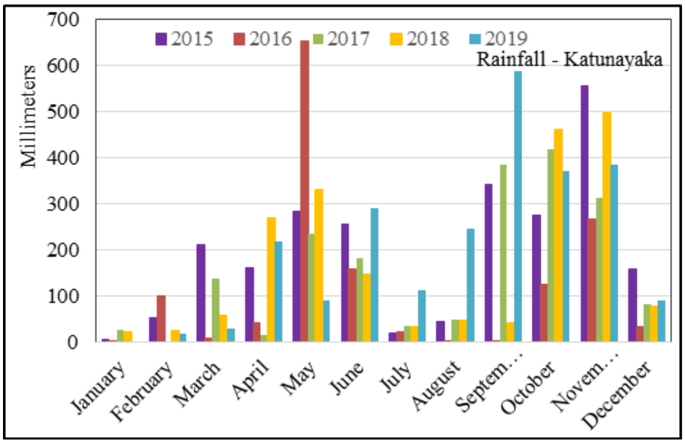


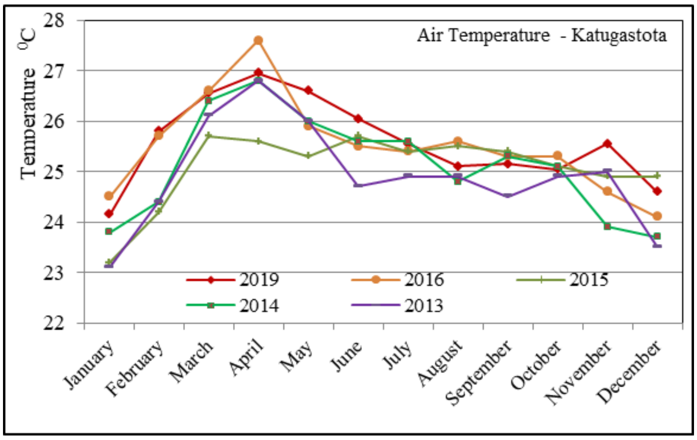


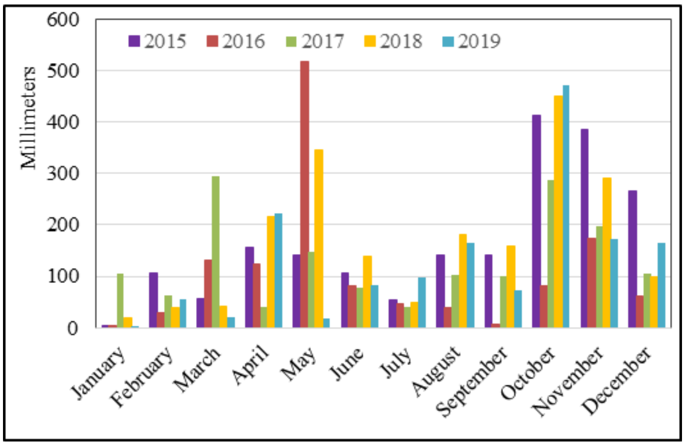






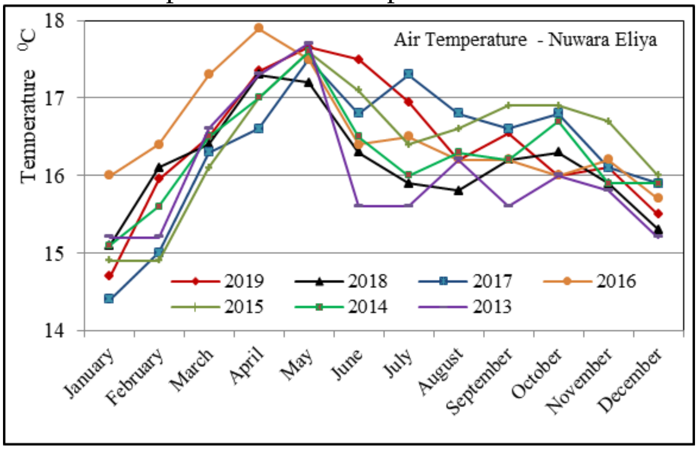


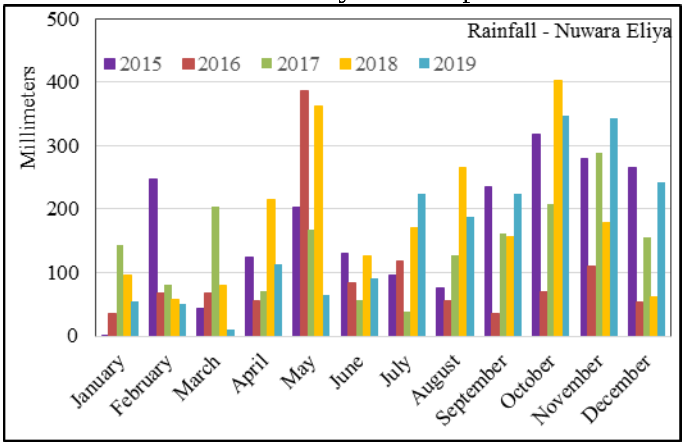


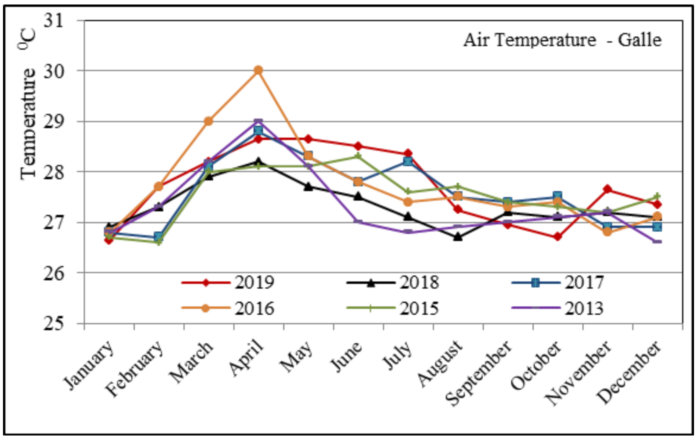


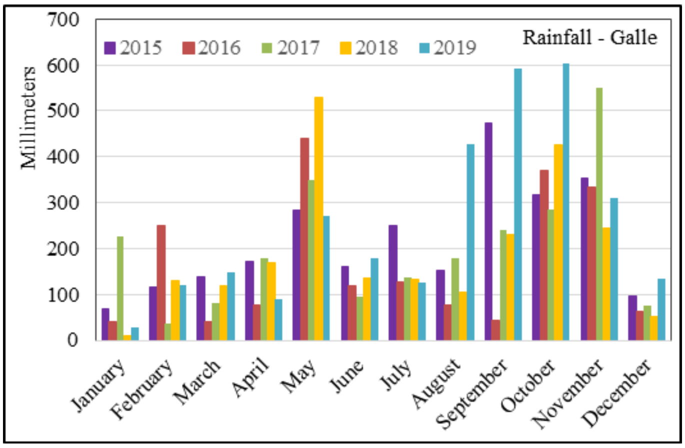
Distribution pattern of air temperature

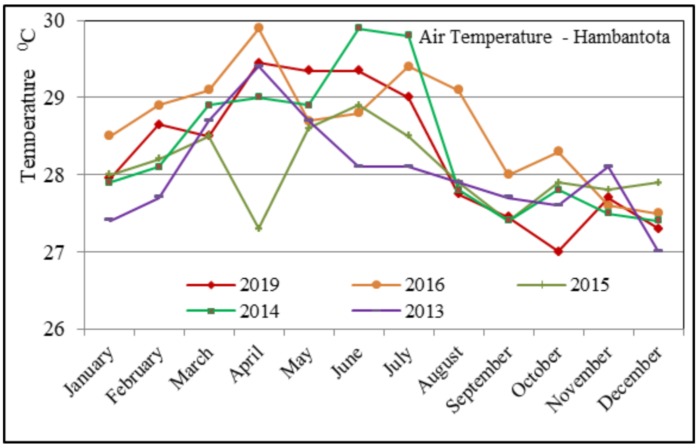
Distribution of the monthly rainfall pattern

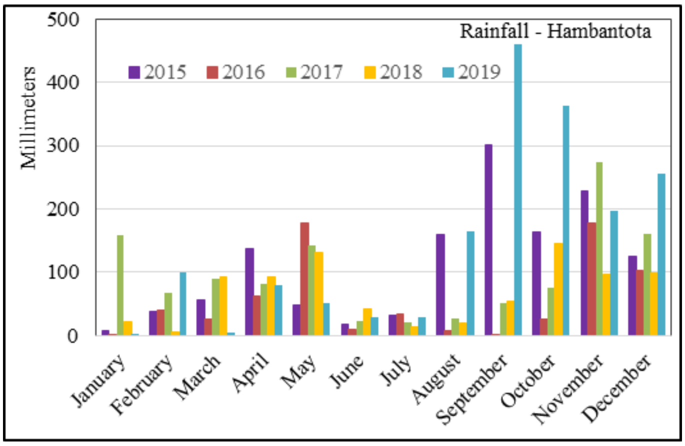


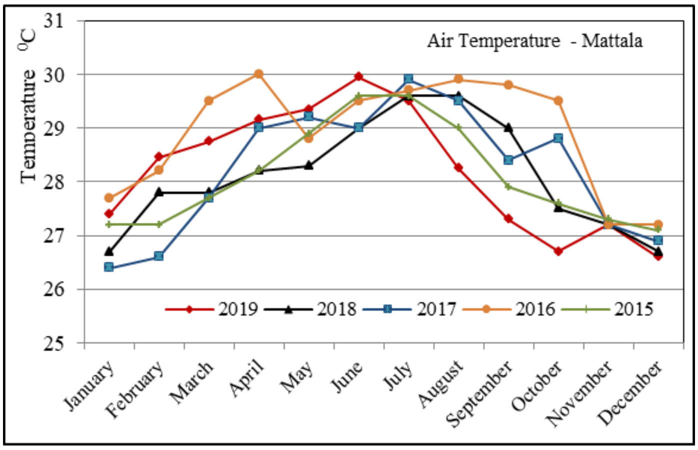


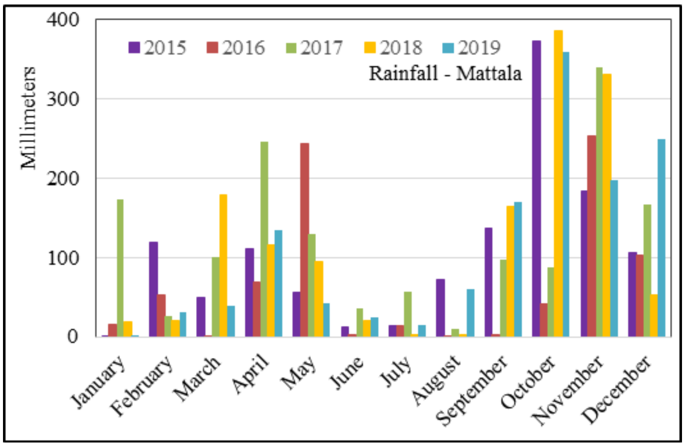






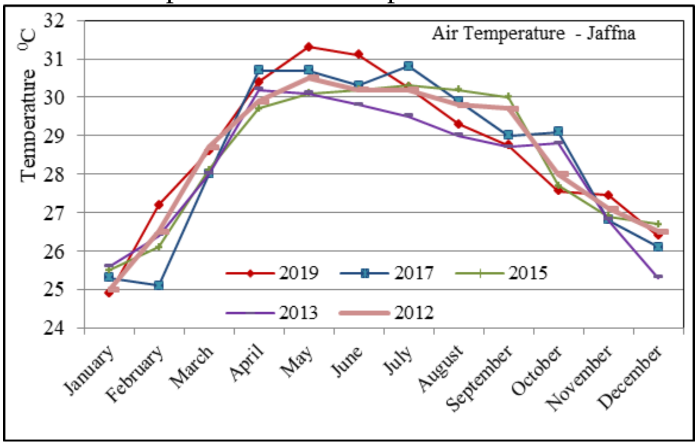


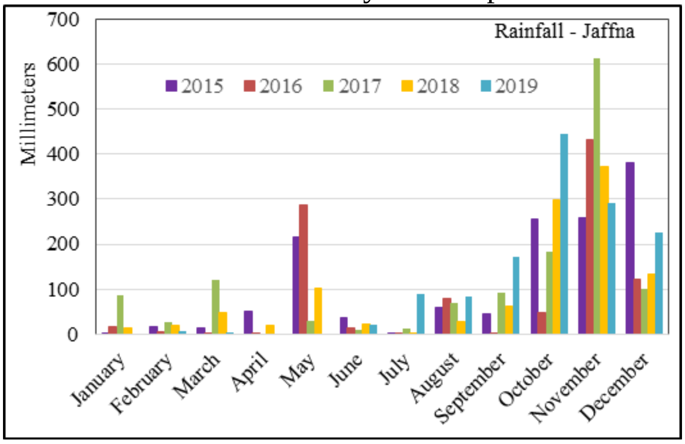


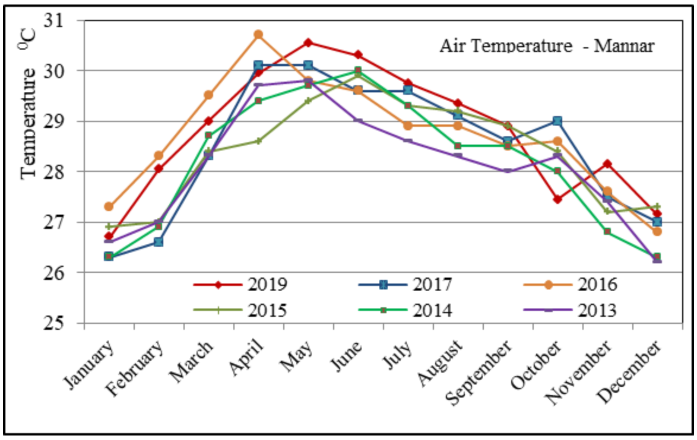


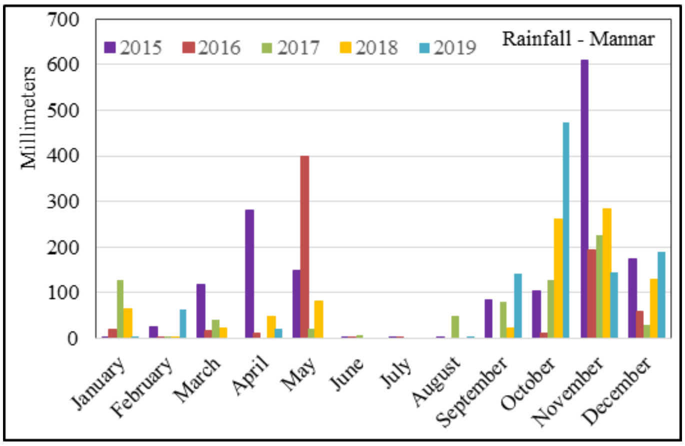
Distribution pattern of air temperature

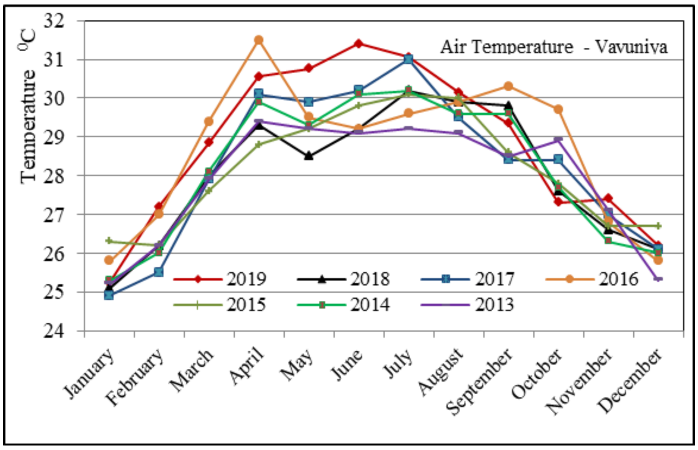
Distribution of the monthly rainfall pattern

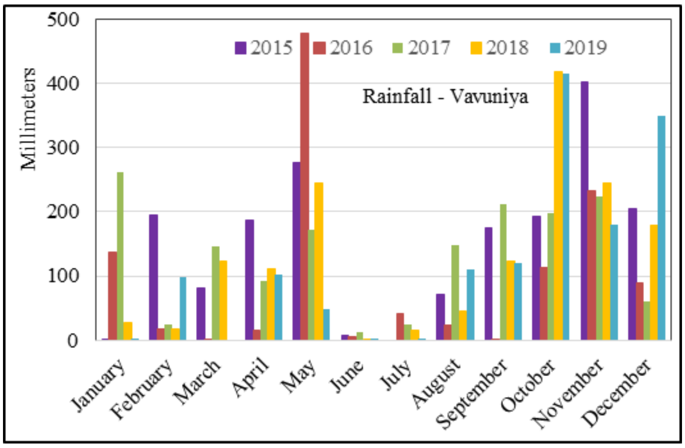


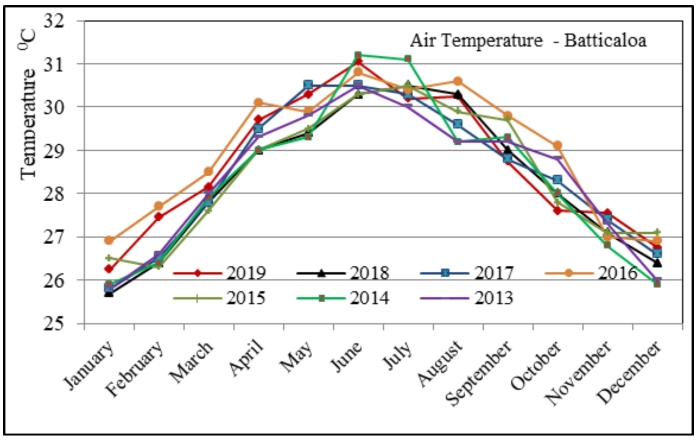


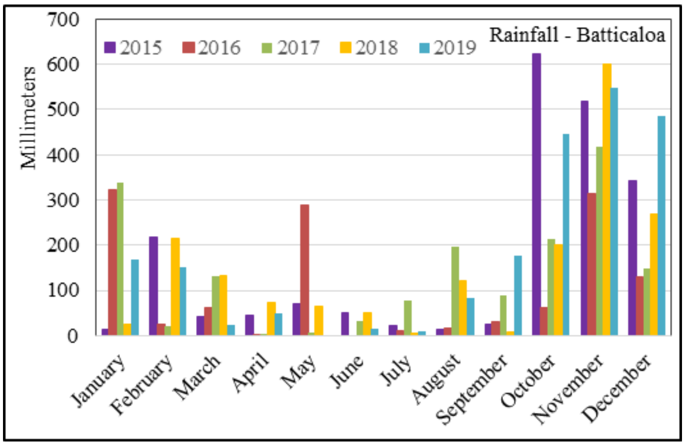






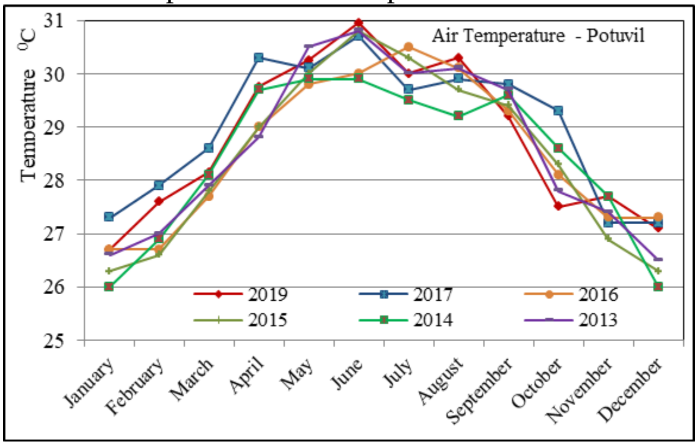


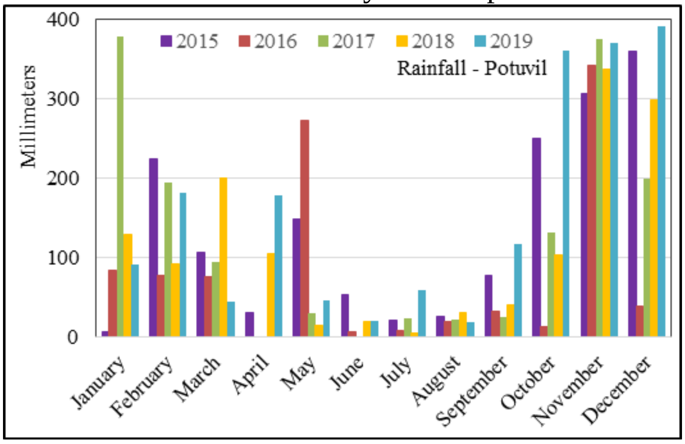


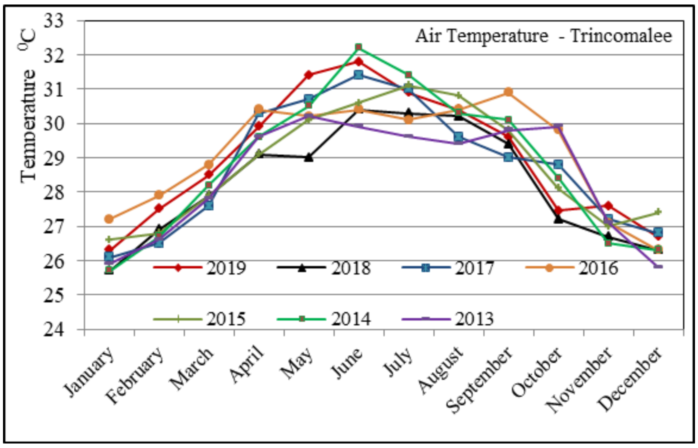


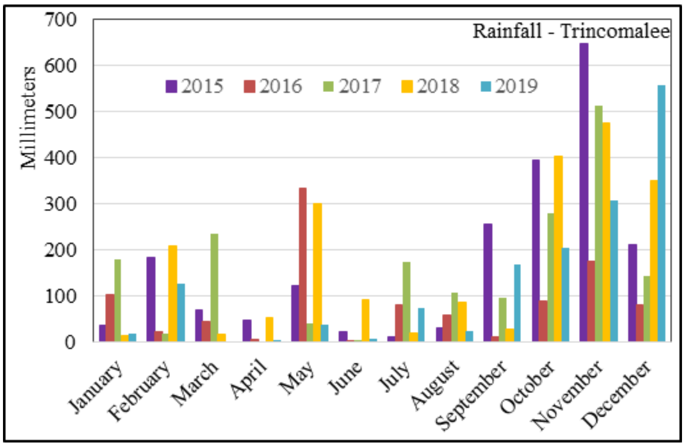
Distribution pattern of air temperature

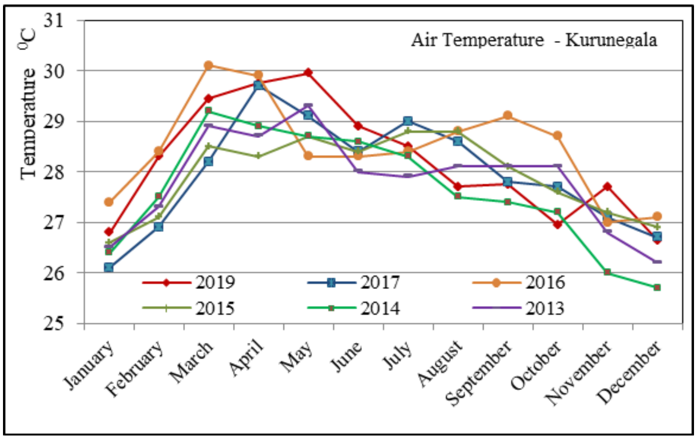
Distribution of the monthly rainfall pattern

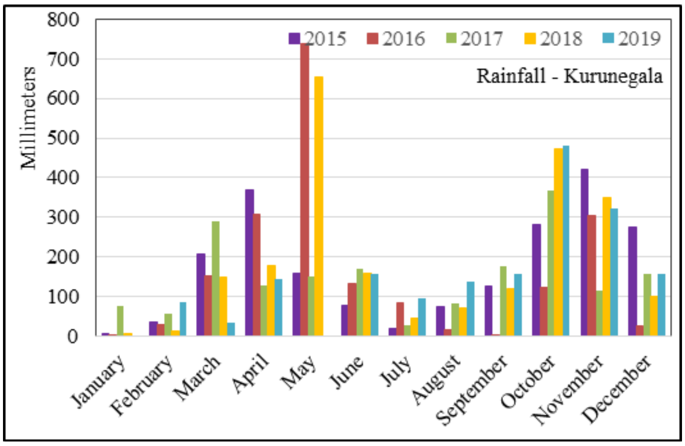


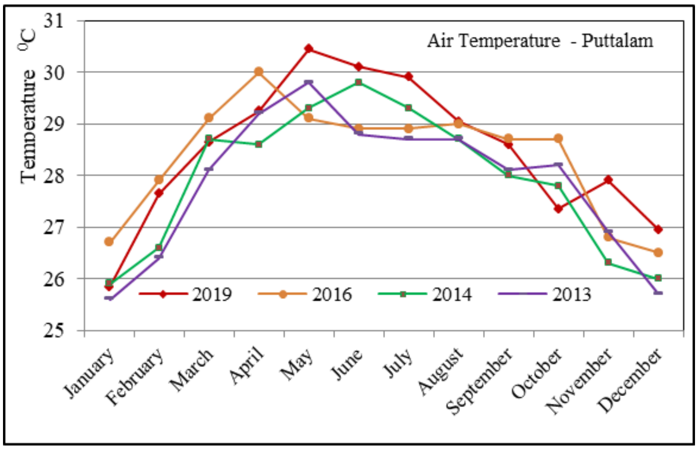


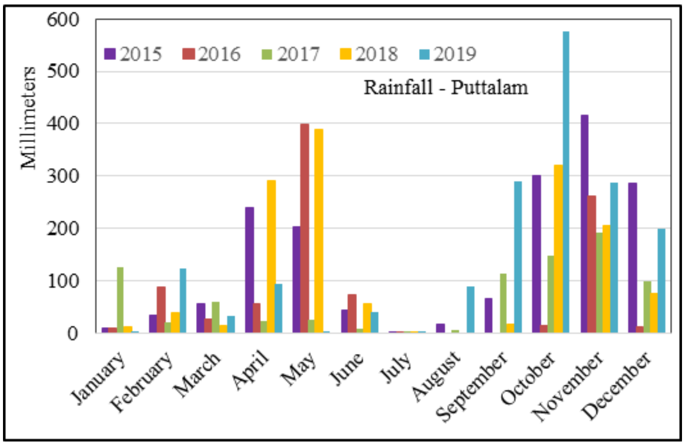




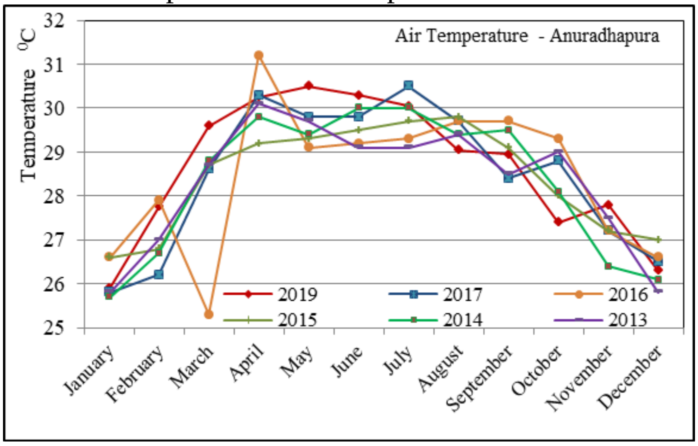


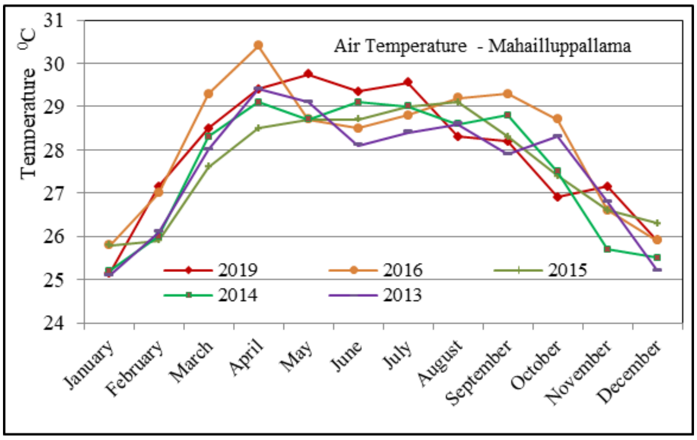


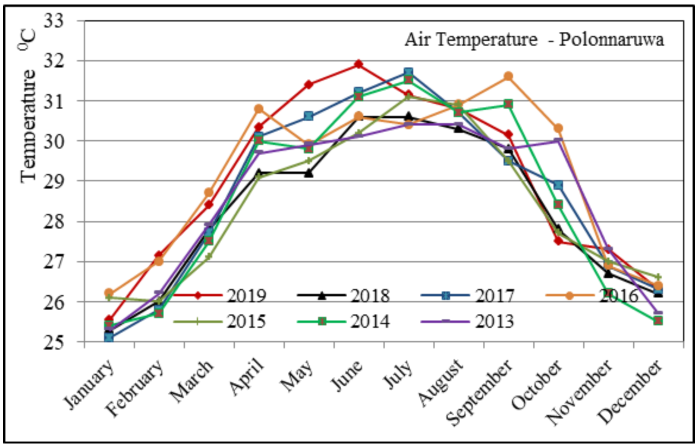


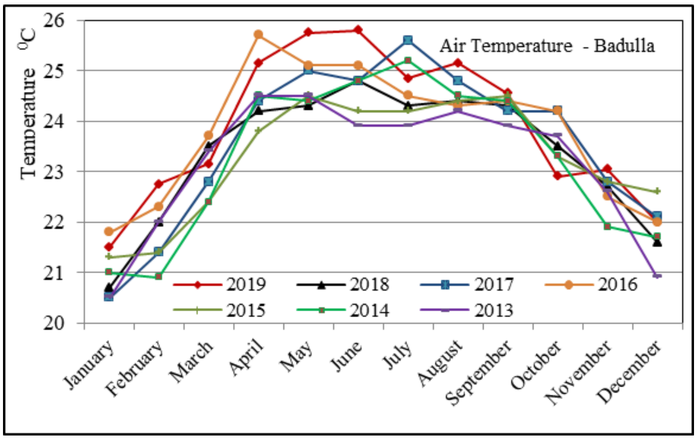


Distribution pattern of air temperature

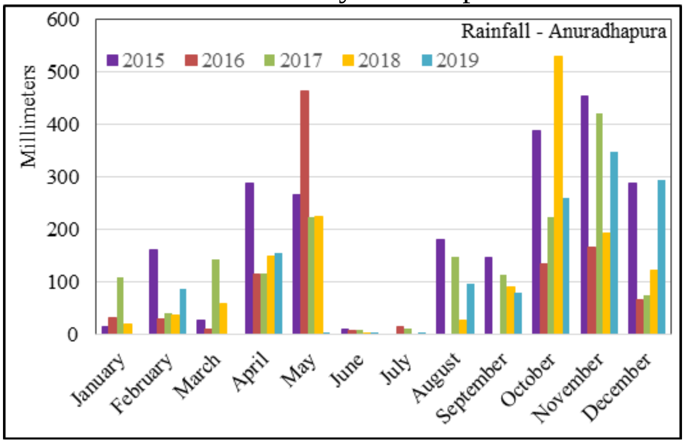


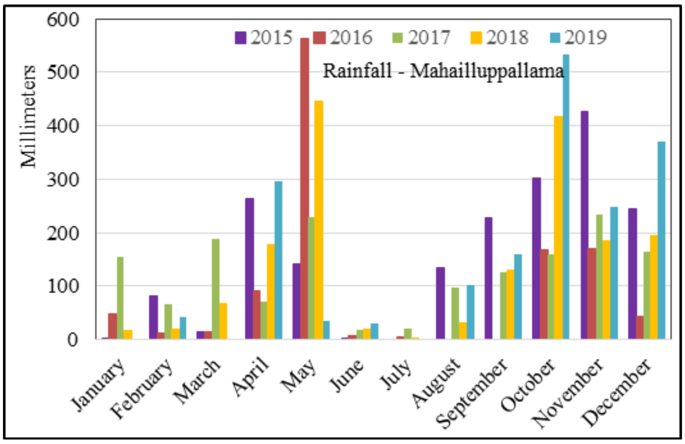


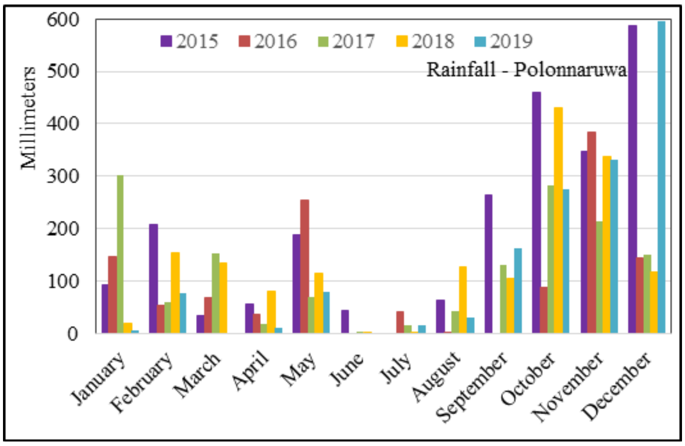


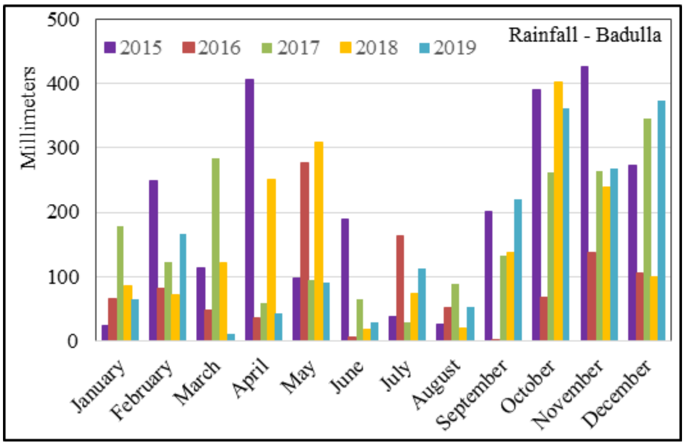


Distribution of the monthly rainfall pattern









Distribution pattern of air temperature

Distribution of the monthly rainfall pattern