

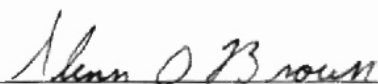
**RAINFALL TRENDS AND STREAMFLOW
SENSITIVITY IN THE
PHILIPPINES**

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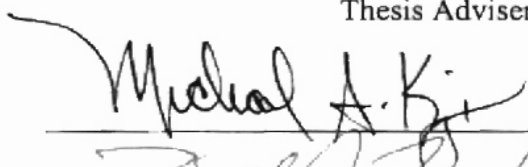
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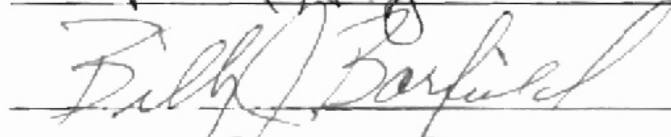
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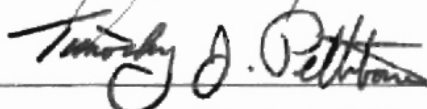
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CHAPTER 1

INTRODUCTION

Climate is an essential element in man's survival and prosperity. Obviously, climate variation plays an important role in the success and failure of agricultural production systems. Moreover, climate variation affects other elements of weather that impact sectors of the society that are dependent on the hydrologic system and water resources. Among these sectors are agriculture, terrestrial and freshwater ecosystems, coastal and marine ecosystems, human health, human settlements, energy and industry (McCarthy, et al., 2001).

Climate variation refers to any short-term variability and long-term trend or shift of weather, whether caused by natural mechanism or because of human activity (Claussen et al., 2001). This aspect of the earth's climate varies significantly over spatial and temporal scales as the atmosphere interacts with the geophysical components of the climatic system. Climate variability or change may be manifested through various climatic measures and the most commonly used are temperature, precipitation and wind. Of the three, precipitation is much more variable in both time and space than temperature (Claussen et al., 2001). A study (IPCC, 1990) has shown that by late 1980s, there was an increase in precipitation outside of the tropics and a trend to decline in the subtropics.

In tropical countries, climatic variability and change is directly associated with the general atmospheric circulation. The Philippines in particular, which lie between 4°N and 22°N latitude, have a tropical maritime climate. "The country is exposed to the Southwest monsoon, Northeast monsoon, North Pacific Trades, Intertropical Convergence Zone, tail end of the cold front, easterly waves, the passage of tropical cyclones, and the El Niño Southern Oscillation (ENSO) phenomenon" (Acebes, 1997). These climatic elements are some of the phenomena that cause climatic variability, particularly in rainfall. Moreover, the numerous mountain ranges, valleys, and the surrounding sea, augmented this variability.

In 1972, the Philippines Atmospheric, Geophysical, and Astronomical Administration (PAG-ASA) compiled rainfall data. PAGASA's recent studies shows that "in western Luzon, rainfall trends are mainly increasing, while in the eastern section of Luzon, in the most parts of Visayas and the whole of Mindanao, a decreasing trend in rainfall are indicated" (Jose, et. al, 1998). Hulme and Sheard (1999) used the MAGICC climate model and stated that the Philippines annual rainfall has declined by about 6 per cent during the course of the century. However, it was also stated that the change was based from the average of 1961 - 1990 rainfall data. (The findings were most probably based on just 1961 to 1990 data.)

Changes in rainfall consequently affect streamflow. Streamflow, is defined as the movements of overland flow, interflow, and base flow down the stream channels and has tremendous impacts on the hydrologic system. Unmanaged overland flow, for example, can tremendously impact agricultural land, water supply, transportation, and hydroelectric generation (Garbrecht, et al. 2002). Garbrecht has also shown that

precipitation changes for the central U.S. tend to occur in specific seasons. Thus, a prolonged dry season may result from a reduction in precipitation during just one season. Moreover, Brown, et al. (2002) stated that “long-term variations in annual precipitation can have significant impact on groundwater recharge and subsequent stream base flows”.

Arnell, N.W. (1999), uses climate change scenarios developed from the Hadley Centre climate simulations (HadCM2 and HadCM3), and simulated global river flows. The results suggest that average annual runoff will increase at high latitudes, in equatorial Africa and Asia, and Southeast Asia. The study of the Energy and Resources Institute (2000) revealed that the Philippines’s rainfall variability is high and the frequency of severe weather distortions like typhoons and flooding were projected to increase. Extreme drought during the El Niño Southern Oscillation and intense rainfall could greatly increase management costs on agricultural lands, hydroelectric water reservoirs, and irrigation systems. The Cagayan, Agno, and Pampanga river basins are now highly vulnerable to flooding.

Objectives

This study is aimed at:

1. Determining the climatic variation as manifested by annual rainfall amounts based on records from 1865 to 1937 (Selga, 1935 and 1938) and data gathered from the Philippine Atmospheric, Geophysical, and Astronomical Administration (PAG-ASA) from 1961 to 2000;
2. Determining seasonal precipitation variations over the same years of record;
3. Determining the correlation of rainfall to streamflow at a single stream; and
4. Determining the sensitivity of streamflow to rainfall fluctuations.

CHAPTER 2

HYDROLOGIC DATA USED

Geography

The Philippines is situated in Southeast Asia and lies between $4^{\circ} 23' \text{ N}$ and $21^{\circ} 25' \text{ N}$ latitude and 116° E and 127° E longitude. An archipelagic nation composed of 7,107 islands and islets, the Philippines is divided into three main island groups; Luzon, Visayas, and Mindanao. The Luzon island group is located in the northern part and Luzon, itself, is the largest island of the country. The Visayas group is in the center and has only nine large islands. Mindanao is the second largest island in the country and its group is situated in the south. The country is flanked on the east by the Pacific Ocean, on the northwest by the South China Sea, and on the south by the Celebes Sea (Department of Agriculture, Philippines, 1999).

The country's total land area is around 74.13 million acres of which 34.84, 14.09, and 25.2 million acres are in Luzon, Visayas, and Mindanao respectively. Thirty two million acres are classified as agricultural land. In regard to irrigation, Sundquist (2003) reported that 2.96 million of the 22.24 million acres of cultivated land is irrigated.

Climate Types

Valmayor (1983), enumerated the four existing climatic conditions or types in the Philippines. Type 1 has two pronounced seasons with a rainy season from June to November and a dry season from December to May. This climate type is found in the

western portion of the country, which is protected by topography from the northeast monsoon and trade winds. However, it is open to the southeast monsoon and cyclonic storms. Type 2 rainfall pattern has no dry season with a pronounced maximum rainy period from December to February. This climate type is experienced in areas situated along or near the eastern coast of the country that are open to the northeast monsoon, trade winds, and cyclonic storm. Type 3 has no pronounced maximum rain period with a short dry season lasting only one to three months. This type is found in the middle of the country where areas are partly sheltered from the northeast monsoon and trade winds but are open to the southwest monsoon and cyclonic storms. Type 4 has a more or less evenly distributed rainfall throughout the year. This type is observed in regions located such that they receive moderate effects of the northeast monsoon, trade winds, southeast monsoon, and cyclonic storms.

Precipitation Stations

Rainfall data from 1961 to 2000 and the streamflow data used in this study were procured directly from the Philippines Atmospheric, Geophysical, and Astronomical Administration (PAG-ASA). The rainfall data was obtained from forty-six synoptic stations spread throughout the Philippines. For the purpose of this study and for simplicity, stations were numbered from 1 to 46 from the north to the south (Figure 1). Data was obtained where available, in monthly totals. The highest monthly-recorded rainfall of 4,773.9 millimeters was observed at station 6 (Baguio). Station 41 (Hinatuan, Surigao del Sur) received the highest 40-year mean while the lowest was received in General Santos City (Table 1).

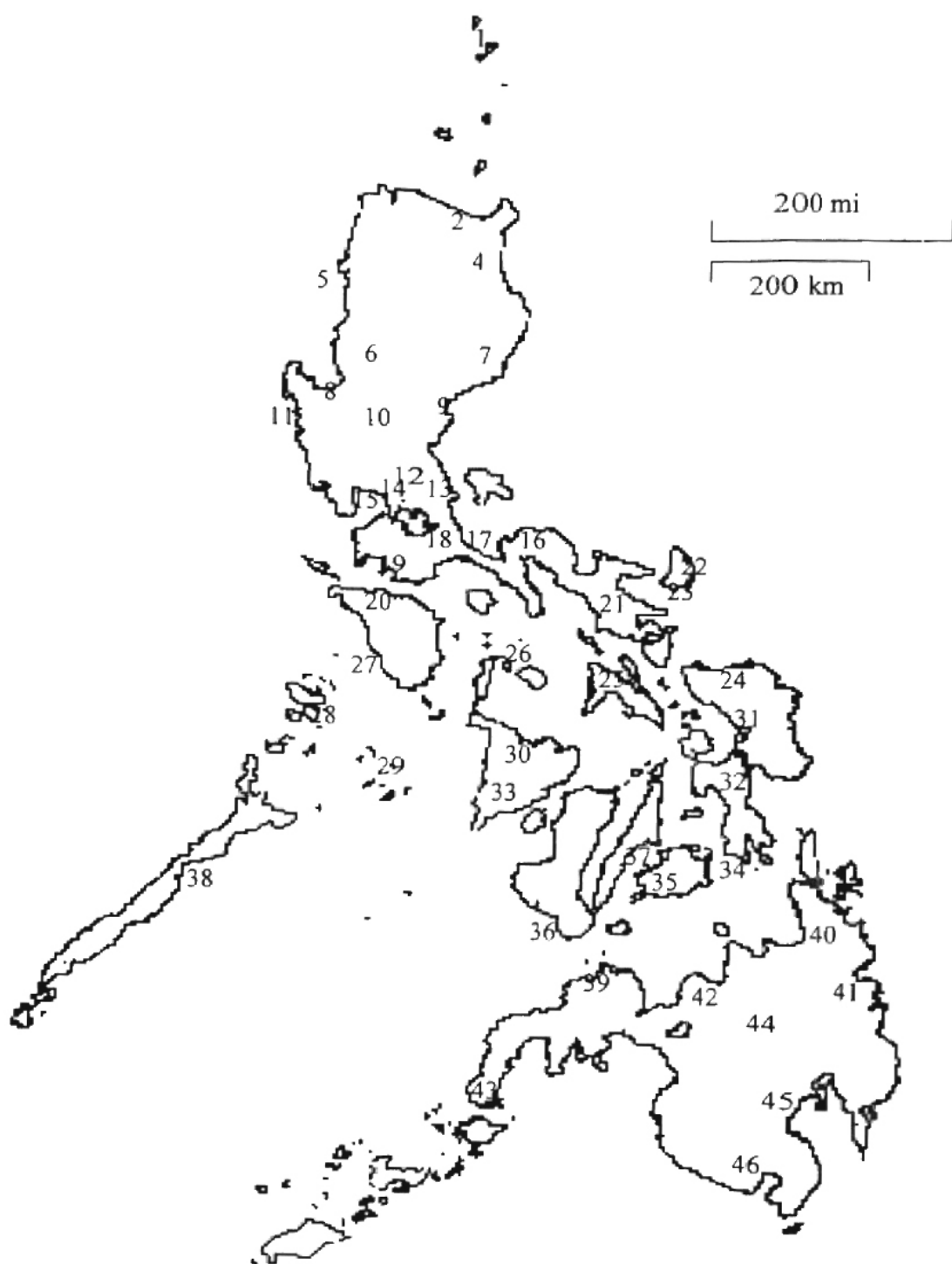


Figure 1. Location of Rainfall Stations.

Table 1. Location of Rainfall stations and its 40-year mean record.

Stations		Mean (mm)	Stations		Mean (mm)
No.	Name		No.	Name	
1	Basco, Batanes	2836.6	24	Catarman, Northern Samar	3317.8
2	Appari, Cagayan	2042.2	25	Masbate, Masbate	1958.9
3	Laog City, Ilocos Norte	2094.9	26	Romblon, Romblon	2015.6
4	Tuguegarao, Cagayan	1714.5	27	San Jose, Occidental Mindoro	2356.5
5	Vigan, Ilocos Sur	2379.7	28	Coron, Palawan	2547.2
6	Baguio City, Benguet	3872.4	29	Cuyo, Palawan	2297.4
7	Casiguran, Quezon	3518.9	30	Roxas City, Aklan	2036.1
8	Dagupan City, Pangasinan	2416.0	31	Catbalogan, Western Samar	2624.6
9	Baler, Quezon	3321.4	32	Tacloban City, Leyte	2378.1
10	Cabanatuan, Nueva Ecija	1897.4	33	Iloilo City, Iloilo	2101.6
11	Iba, Zamabales	3652.4	34	Maasin, Southern Leyte	1840.1
12	Science Garden, Quezon City	2485.3	35	Tagbilaran City, Bohol	1367.6
13	Infanta, Quezon	4041.4	36	Dumaguete City, Negros Oriental	1186.6
14	NAIA, Pasay	1693.4	37	Mactan Airport, Cebu	1521.5
15	Port Area, Manila	2114.0	38	Puerto Princesa, Palawan	1512.0
16	Daet, Camarines Norte	3311.6	39	Dipolog, Zamboanga del Norte	2316.4
17	Alabat, Quezon	3205.3	40	Butuan City, Agusan del Norte	2031.7
18	Tayabas, Quezon	3152.8	41	Hinatuan, Surigao	4189.7
19	Ambulong, Batangas	1898.1	42	Cagayan de Oro, Misamis	1575.9
20	Calapan, Oriental Mindoro	2053.5	43	Zamboanga City, Zamboanga Sur	1181.2
21	Legaspi City, Albay	3392.6	44	Malaybalay, Bukidnon	2566.0
22	Virac Radar, Catanduanes	3545.4	45	Davao City, Davao del Sur	1764.2
23	Virac synop, Catanduanes	2846.8	46	General Santos City, South Cotabato	953.1

Station Description

Aside from the different sources of rainfall, the location, elevation, and the surrounding land features will also contribute to the climatic variability. Hence, the aerial descriptions of the 46 stations used in this study are provided below to help understand the differences in rainfall distribution.

Station 1 – Basco, Batanes is located in the northern group of islands. The geographic location is $20^{\circ}27'$ N latitude and $121^{\circ}58'$ E longitude and the station's elevation is 36 ft above mean sea level (MSL). A mountain, 3,300 feet high, is located northeast of this station. This station receives moderate effects of the Northeast monsoon, Southwest monsoon, and cyclonic storm.

- Station 2 – Appari, Cagayan is situated in the northernmost part of the country. The geographic location is $18^{\circ}22'$ N latitude and $121^{\circ}38'$ E longitude, the station's elevation is 10 feet above MSL. There are mountain ranges on both eastern and western sides. To the north is an open sea.
- Station 3 – Laoag City, Ilocos Sur is located near the west coast part of Luzon. Latitude is $18^{\circ}11'$ N and $120^{\circ}32'$ E longitude and the station's elevation is 16 feet above MSL. To the west is the South China Sea and to the east side is a mountain with a height of 3,424 feet. Generally, it is sheltered from the Northeast monsoon by mountain ranges. However, it is open to the Southwest monsoon and cyclonic storms.
- Station 4 - Tuguegarao, Cagayan is situated in a valley in the northern part of Luzon at $17^{\circ}37'$ N latitude and $121^{\circ}44'$ E longitude. The station's elevation is 202 ft above MSL. Mountain ranges, reaching 7,300 feet, cover both the eastern and western aspects of the station.
- Station 5 - Vigan, Ilocos Sur is located in northern part of the country at $17^{\circ}34'$ N latitude and $120^{\circ}23'$ E longitude. The station's elevation is 108 feet above MSL. On the west is the South China Sea and to the east side are mountain ranges. Generally, it is sheltered from the Northeast monsoon by mountain ranges. However, it is open to both the Southwest monsoon and cyclonic storms.
- Station 6 – Baguio City, Benguet is situated in the mountainous region of Cordillera mountain range. Latitude is $16^{\circ}25'$ N and $120^{\circ}36'$ E longitude and the station's elevation is 4,920 feet above MSL. The location is close to the west

coast and thus not protected from the Southwest monsoon. Generally, this station follows the Type I rainfall pattern. It gets the highest amount of rainfall in the country.

Station 7 - Casiguran, Quezon is along the east coast of the northern part of the Philippines. At $16^{\circ} 17'$ N latitude and $122^{\circ} 07'$ E longitude, the station's elevation is 13 feet. To the east is the Philippine Sea and to the west is the Sierra Madre mountain range. Although located in the east coast, it evades the center of the Northeast monsoon route. Hence, it only receives a moderate effect of the Northeast monsoon.

Station 8 - Dagupan City, Pangasinan is situated in a valley in the northern part of the country. At $16^{\circ} 03'$ N latitude and $120^{\circ} 20'$ E longitude, the station's elevation is 6.5 feet above MSL. It is sheltered by mountain ranges on the east and west side. To the north part is an open sea.

Station 9 – Baler, Quezon is situated along the east coast of the northern island of the Philippines. At $15^{\circ} 46'$ N latitude and $121^{\circ} 34'$ E longitude, the station's elevation is 20 feet above MSL. To the east is the Philippine Sea and to the west are mountain ranges. Although located in the east coast, it evades the center of the Northeast monsoon route. Hence, it only receives a moderate effect of the Northeast monsoon.

Station 10 – Cabanatuan, Nueva Ecija is situated in the middle of Luzon island. At $15^{\circ} 29'$ N latitude and $120^{\circ} 28'$ E longitude, the station's elevation is 105 feet above MSL. Mountain ranges cover the east while on the west, mountains are

so far from the station that it is not sheltered from the Southeast monsoon and cyclonic storms.

Station 11 - Iba, Zambales is located on the west coast in Luzon Island at $15^{\circ}20'$ N latitude and $119^{\circ}58'$ E longitude. The station's elevation is 42 feet above MSL. To the west is the South China Sea and to the east are mountain ranges. Generally, it is sheltered from the Northeast monsoon by mountain ranges. However, it is open to the Southwest monsoon and cyclonic storms.

Station 12 - Science Garden, Quezon City is located on the west of Luzon Island. At $14^{\circ}39'$ N latitude and $121^{\circ}03'$ E longitude, the station's elevation is 141 feet above MSL. To the west is Manila Bay and to the east are mountain ranges. It is sheltered from Northeast monsoon, but not from Southwest monsoon and cyclonic storms.

Station 13 - Infanta, Quezon is situated along the east coast of Luzon Island. At $14^{\circ}45'$ N latitude and $121^{\circ}39'$ E longitude, the station's elevation is 23 feet above MSL. To the east is the Philippine Sea (Pacific Ocean) and to the west is the Sierra Madre mountain range. It is along the Northeast monsoon route.

Station 14 - NAIA, Pasay is located on the west of Luzon Island at $14^{\circ}31'$ N latitude and $121^{\circ}01'$ E longitude. The station's elevation is 69 feet above MSL. To the west is Manila Bay and to the east are mountain ranges. It is sheltered from Northeast monsoon but not from the Southwest monsoon and cyclonic storms.

Station 15 - Port Area, Manila is located on the west area of Luzon Island at $14^{\circ}35'$ N latitude and $120^{\circ}59'$ E longitude. The station's elevation is 52.5 feet above

MSL. To the west is Manila Bay and to the east are mountain ranges. It is sheltered from Northeast monsoon but not from the Southwest monsoon and cyclonic storms.

Station 16 - Daet, Camarines Norte is located along the southeastern coast of Luzon Island. At $14^{\circ}07'$ N latitude and $122^{\circ}59'$ E longitude, the station's elevation is 13 feet above MSL. To the east is the Philippine Sea (Pacific Ocean) and to the west is a mountain of 5,064 feet. It is along the Northeast monsoon route.

Station 17 - Alabat, Quezon is located in a small island situated in the west side of Luzon. At $14^{\circ}01'$ N latitude and $122^{\circ}01'$ E longitude, the station's elevation is 16 feet above MSL. To the east is the Philippine Sea (Pacific Ocean) and to the west is Lopez Bay. It is along the Northeast monsoon route. Somehow, the mountains on the mainland and other islands to the southwest sheltered this station from the Southwest monsoon.

Station 18 - Tayabas, Quezon is located in the southern area of Luzon Island and is closer to the east coast than the west coast. At $14^{\circ}02'$ N latitude $121^{\circ}35'$ E longitude, the station's elevation is 517 feet above MSL. To the east are low-lying mountains and on the west is a mountain 7,078 feet high. To the south is Tayabas Bay. This station is along the Northeast monsoon route.

Station 19 - Ambulong, Batangas is located close to the west coast in the southern part of Luzon Island. At $14^{\circ}05'$ N latitude and $121^{\circ}03'$ E longitude, the station's elevation is 33 feet above MSL. It is sheltered from the Northeast monsoon by mountains on the east but is open on the west.

Station 20 – Calapan, Oriental Mindoro is located on an island situated in the west of Visayas group of islands. At $13^{\circ}25'$ N latitude and $121^{\circ}11'$ E longitude, the station's elevation is 133 feet above MSL. A mountain is seen from west to southwest of the station. Sited on the east is the tail of the southern portion of Luzon.

Station 21 - Legaspi, City, Albay is located along the southeastern coastal area of Luzon Island. At $13^{\circ}08'$ N latitude and $123^{\circ}44'$ E longitude, the station's elevation is 58 feet. The Philippine Sea (Pacific Ocean) is on the east of the station and on the west are low laying mountains.

Station 22 - Virac Radar, Catanduanes is located on an island situated on the west of Luzon. At $13^{\circ}59'$ N latitude and $124^{\circ}19'$ E longitude, the station's elevation is 764 feet. To the east is the Philippine Sea (Pacific Ocean) and to the west side are low-lying mountains. It is along the Northeast monsoon route.

Station 23 - Virac Synop, Catanduanes is located on an island situated on the west side of Luzon at $13^{\circ}35'$ N latitude and $124^{\circ}14'$ E longitude. The station's elevation is 131 feet above MSL. Open sea is on both the east and south sides. There are low-lying mountains on the north and west.

Station 24 - Catarman, Northern Samar is located on an island situated on the west side of Visayas. At $12^{\circ}29'$ N latitude and $124^{\circ}38'$ E longitude, the station's elevation is 164 feet above MSL. To the north is the Philippine Sea (Pacific Ocean) and there are no mountains surrounding this station. Far south however, is a mountain that reaches 2,798 feet high. It is along the Northeast monsoon route.

Station 25 - Masbate, Masbate is located on an interior island of Visayas at $12^{\circ} 22' N$ Latitude and $123^{\circ} 37' E$ longitude. The station's elevation is 20 feet above MSL. To the west are mountain ranges and on southwest are big islands with high mountain ranges that shelter this area from the Southwest monsoon. To both the north and eastern side is Masbate Pass. However, to the far northeast is the tail of Luzon Island and other islands that protect this station from the strongest magnitude of the Northeast monsoon. Thus, it receives moderate effects of both the Southwest and Northeast monsoons.

Station 26 - Romblon, Romblon is a small interior island of Visayas. At $12^{\circ} 35' N$ latitude and $122^{\circ} 16' E$ longitude, the station's elevation is 154 feet above MSL. From the north to west is Romblon Pass and to the far south to southwest are big islands with high mountain ranges that shelter this area from the Southwest monsoon. However, to the far northeast is the tail of Luzon Island that protects this station from the strongest of the Northeast monsoon. Thus, it receives moderate effects of both the Southwest and Northeast monsoons.

Station 27 - San Jose, Occidental Mindoro is located on an island on the west of Visayas. At $12^{\circ} 21' N$ latitude and $121^{\circ} 02' E$ longitude, the station's elevation is 1.0 foot above MSL. To the west is the South China Sea and to the north and northeast are mountain ranges. Generally, it is sheltered from Northeast monsoon by mountain ranges. However, it is open to the Southwest monsoon and cyclonic storms.

Station 28 - Coron, Palawan is located on an island on the west side of Visayas at $12^{\circ}00'$ N Latitude and $120^{\circ}12'$ E longitude. The station's elevation is 46 feet above MSL. To the south is a sea and small islands. To the north and northeast side are low-lying mountains. It is sheltered from the Northeast monsoon but it is open to the Southwest monsoon and cyclonic storms.

Station 29 - Cuyo, Palawan is located on a small interior island of Visayas. At $10^{\circ}51'$ N latitude and $121^{\circ}02'$ E longitude, the station's elevation is 13 feet above MSL. To the north, west, and south is the Cuyo West Pass and small islands. It is sheltered from Northeast monsoon, but is open to Southwest monsoon and cyclonic storms.

Station 30 - Roxas City, Aklan is located on an interior island of Visayas. At $11^{\circ}35'$ N latitude and $122^{\circ}45'$ E longitude, the station's elevation is 13 feet above MSL. This station is situated on the northeast side of Panay Island. To the southwest is a mountain range that shelters this station from the Southwest monsoon. To the north, west, and east is the Sibuyan Sea. However, to the far northeast is the tail of Luzon Island and other islands that protect this station from the strongest of the Northeast monsoon. Thus, it receives moderate effects of both the Southwest and Northeast monsoons.

Station 31 - Catbalogan, Western Samar is an island located on the east of Visayas. At $11^{\circ}47'$ N latitude and $124^{\circ}53'$ E longitude, the station's elevation is 16 feet above MSL. There are only narrow mountains on the east, leaving this station unprotected from Northeast monsoon, trade winds and cyclonic

storms. To the west and southwest are islands with higher mountains that shelter this station from the Southwest monsoon.

Station 32 - Tacloban City, Leyte is an island located on the east of Visayas. At $11^{\circ} 14'$ N latitude and $125^{\circ} 02'$ E longitude, the station's elevation is 10 ft above MSL. It is open to the Northeast monsoon, trade winds and cyclonic storms. To the west and southwest are islands with higher mountains that shelter this station from the Southwest monsoon.

Station 33 - Iloilo City, Iloilo is located on the west side of Visayas. At $10^{\circ} 42'$ N latitude and $122^{\circ} 34'$ E longitude, the station's elevation is 26 feet above MSL. To the southwest side is the Sulu Sea. To the north and northeast are small mountain ranges and islands. Generally, it is sheltered from the Northeast monsoon by mountain ranges. However, it is open to Southwest monsoon and cyclonic storms.

Station 34 – Maasin, Southern Leyte is situated on the interior of Visayas island. At $10^{\circ} 08'$ N latitude and $124^{\circ} 50'$ E longitude, the station's elevation is 234 feet above MSL. Islands are seen on the west and western sides and low-lying mountains are also seen northeast of the station.

Station 35 – Tagbilaran, Bohol is located in the interior of Visayas Island. At $9^{\circ} 38'$ N latitude and $123^{\circ} 52'$ E longitude, the station's elevation is 20 feet above MSL. It is surrounded by other islands of Visayas on all sides except to the south, which is the island of Mindanao.

Station 36 - Dumaguete City, Negros Oriental is located on an island situated in the southwest of Visayas group of islands. At $9^{\circ} 18'$ N latitude and $123^{\circ} 18'$ E

longitude, the station's elevation is 26 feet above MSL. A mountain is seen from the west to the southwest of the station. Sited on the east are other islands of Visayas.

Station 37 - Mactan Airport, Cebu is located on the south-central portion of the Visayas group of islands. At $10^{\circ}18'$ N latitude and $123^{\circ}58'$ E longitude, the station's elevation is 42 feet above MSL. This station is surrounded by other islands in all directions.

Station 38 - Puerto Princesa, Palawan is located in the westernmost part of the country. At $09^{\circ}45'$ N latitude and $118^{\circ}44'$ E longitude, the station's elevation is 52 feet above MSL. To the southwest are mountain ranges and on the east is an open sea.

Station 39 - Dipolog, Zamboanga del Norte is located in the northwest Mindanao. At $08^{\circ}45'$ N latitude and $123^{\circ}21'$ E longitude, the station's elevation is 13 feet above MSL. To the southwest are mountain ranges and on the north is an open sea. However, far north are the islands of Visayas.

Station 40 - Butuan City, Agusan del Norte is located in the north-northeast of Mindanao. At $08^{\circ}56'$ N latitude and $125^{\circ}31'$ E longitude, the station's elevation is 59 feet above MSL. To the southwest are mountains and on the northeast are mountain ranges. To the north is an open sea.

Station 41 - Hinatuan, Surigao is situated on the easternmost portion of Mindanao at $08^{\circ}22'$ N latitude and $126^{\circ}20'$ E longitude. The station's elevation is 10 feet above MSL. Far west are mountain ranges and on the eastern side is the Pacific Ocean.

Station 42 - Cagayan de Oro, Misamis is located on the north coast of Mindanao. At $08^{\circ}29'$ N latitude and $124^{\circ}38'$ E longitude, and the station's elevation is 20 feet above MSL. From southwest through the northeast are mountain ranges. Up north is the Bohol Sea and the islands of Visayas.

Station 43 - Zamboanga City, Zamboanga Sur station is the only station located in the westernmost part of Mindanao. At $06^{\circ}54'$ N latitude and $122^{\circ}04'$ E longitude, the station's elevation is 20 feet above MSL. To the east, west, and south are all sea. To the north however, are mountains.

Station 44 - Malaybalay, Bukidnon is situated in the mountainous central part of Mindanao. At $08^{\circ}09'$ N latitude and $125^{\circ}05'$ E longitude, the station's elevation is 2,056 feet above MSL. It is surrounded by mountain ranges in all directions.

Station 45 - Davao City, Davao del Sur is located in the southeast part of Mindanao. At $07^{\circ}07'$ N latitude and $125^{\circ}39'$ E longitude, the station's elevation is 59 feet above MSL. This station is surrounded by mountains on the east, north, and west. To the south is the Davao gulf.

Station 46 - General Santos City, South Cotabato is last station situated on the southernmost part of Mindanao. At $06^{\circ}07'$ N latitude and $125^{\circ}11'$ E longitude, the station's elevation is 49 feet above MSL. This station is surrounded by mountains in the north, west, and eastern part. To the south is the Celebes Sea.

Long Term Stations

Eight sets of rainfall data were found from the record of the Philippines Weather Bureau (Selga,1935). These stations have the same latitude and longitude as some of the stations gathered from the PAGASA, but their exact location and history is not available. Most of the data was from 1902 to 1937 except for Station 15 (Manila station), which was from 1865 to 1937. These provide an unusually long time series. Table 2 lists each.

Table 2. Stations with Long term Records

Station		Years of Record
Number	Name	
2	Appari, Cagayan	1902-1937 & 1961-2000
5	Vigan, Ilocos Sur	1903-1937 & 1961-2000
8	Dagupan City, Pangasinan	1902-1937 & 1961-2000
15	Port Area, Manila	1865-1937 & 1961-2000
23	Virac Synop, Catanduanes	1908-1937 & 1961-2000
25	Masbate, Masbate	1904-1937 & 1961-2000
33	Iloilo City, Iloilo	1902-1937 & 1961-2000
34	Maasin, Southern Leyte	1903-1937 & 1971-2000

Apparent Errors in Rainfall Data

It was observed that there was an apparent error in the 1961 to 1970 rainfall data for stations 7 (Casiguran, Quezon) and 9 (Baler, Quezon). The data for these nearby stations is exactly the same. Clearly, one or both are in error. Also, the zero rainfall record in station 14 (NAIA, Pasay) in 1994 was suspicious considering that the nearby stations had substantial rainfall recorded. Unfortunately, there were no means to verify or correct this data during the conduct of this study.

Stream Flow

The stream flow data used for correlation and sensitivity analysis was gathered from the Pampanga River basin located in Luzon. There were eight rivers with streamflow data but only the Sulipan river had a 15 year continuous record. The remaining seven stations had a shorter data recorded and numerous missing values. Hence, the Sulipan River streamflow were chosen for this preliminary rainfall-streamflow study. The total catchment's area is 7,849 square kilometers. Data was given as gage height at the Sulipan river station. A separate rainfall record, which came along with the streamflow data, was used solely for the purpose of rainfall and streamflow analysis.

CHAPTER 3

ANALYSIS METHODS

Classification of Stations by Type

Unlike the Natural Resources and Conservation Services (NRCS) storm type, which was based from the daily rainfall, the classification of stations by rainfall type in this study, was based from geographic location, rainfall source to which it is exposed, and the rainfall pattern that it showed. In general, areas located in the western side of the country are expected to belong to Type 1 due to the Southwest monsoon. The eastern regions are expected to fit Type 2 due to the Northeast monsoon exposure. Areas located in the central part of the country, which receives moderate effects of the Southwest monsoon, Northeast monsoon, and frequent cyclonic storms, are expected to possess Type 3 characteristics. Areas that receive only moderate effects of all sources of rainfall should be in Type 4. In addition, the effects of mountain ranges were also considered. Station 38 (Puerto Princesa, Palawan) for example is expected to be under Type 1 since it is situated in the west side of the country. However, the station was sheltered by the mountains from the southwest monsoon and lies within the route of cyclonic storms. Hence, it falls under Type 3. This is the only station that does not fall to the classification where it is expected to be, based on location.

Computation Procedures and Analysis

The analysis for rainfall data was done by computing the annual and 40-year means, the eleven-year moving average, the seasonal eleven-year moving averages, and the Precipitation Index (PI) for all rainfall data sets. The annual means were computed by adding the total precipitation for the whole year. Interannual variations were normalized by taking the eleven-year moving averages. The average of the five-year rainfall before and after a particular year constitutes the 11-year moving average value. Moreover, the 11-year averages of the annual rainfall were used to determine the wet and dry years based on the 40-year mean.

Seasonal Variation

There are only two climatic seasons prevailing in the Philippines; the summer season and the rainy season. However in this study, a year was divided into four quarters to determine in which months of the year changes occur. For Type 1 and Type 2 rainfall patterns, the first quarter is January, February, and March, and the second quarter starts in April. For Type 3 and 4 however, the quarters that would give more or less similar rainfall amounts start in February. This segmentation was based from the visual inspection of the 40-year annual curves of every rainfall station.

Precipitation Index

Due to the complexity of comparing the rainfall trend at individual stations, a Precipitation Index was calculated to simplify the analysis. All stations that belong to the same rainfall pattern were grouped together and any stations with less than 40 years record were discarded. Each annual total was divided by the sum of the forty years annual rainfall. Then, the quotients were multiplied by 40 to get the normalized values.

The Precipitation Index is the 11-year moving average computed from the normalized values.

Streamflow Analysis

The gage heights data from Sulipan River station in Pampanga River Basin (Figure 2) was used as a specimen for an analysis of streamflow sensitivity and correlation to rainfall. Simulation of data from PAGASA yields a polynomial equation (Equation 1) that was used to convert gage heights into stream discharges.

$$Q = 106.6h^2 - 14.5h + 96.8 \quad (1)$$

where Q is the stream discharge (m^3/s), and h is the gage height (m).

To determine the response of streamflow to rainfall changes, relative sensitivity, (S_r) was calculated using the numerical approximation from the sensitivity analysis presented by Douglas and Burges (1982).

$$S_r = (P/O) \times [(O_2 - O_1)/(P_2 - P_1)] \quad (2)$$

P is the average monthly rainfall, O is the average monthly streamflow, P_1 is the average rainfall during dry months, P_2 is the average rainfall during the wet months, O_1 is the average streamflow during dry months, and O_2 is the average streamflow during the wet months.

Filling Missing Data

Hydrologic data usually has gaps or missing observations. Factors such as mishandling of records by the field personnel, extreme weather conditions such as hurricanes, typhoons, and other problems like war and equipment failure are among the contributory factors for missing data. Most hydrologic models do not work with missing

observations and therefore, different approaches have been developed to fill-in incomplete data sets.

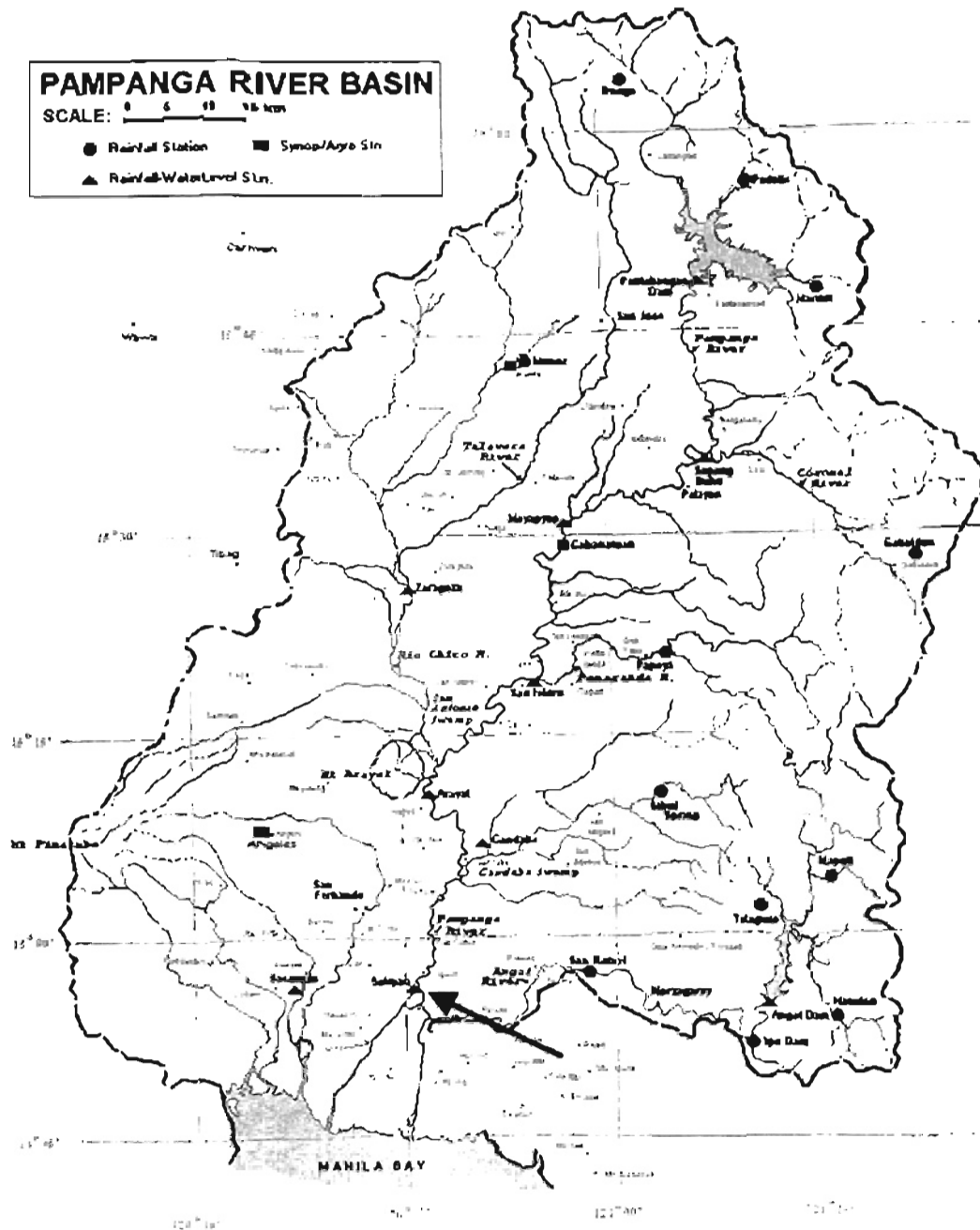


Figure 2. Pampanga River Basin

Kuligowski (1999) states that “Numerous schemes for replacing missing data have been proposed, ranging from simple weighted average of data points that are nearby in time and space to complex statistically-based interpolation methods and function fitting schemes”. However, for non-consecutive and sparsely distributed missing data in a long historical record, simple interpolation is satisfactory to fill-in the missing data (Elshorbagy, 2001). Interpolation may be classified as time average interpolation and nearby station interpolation. The time average method is simply done by taking the average of the data before and the day after the missing data. Similarly, the nearby station interpolation uses the average value of the data taken on the same date but from nearby gauge stations.

The fraction of missing data ranges from 0 to 6.88 percent over the stations. In this study, the time average and the nearby stations interpolation were used to fill missing values for rainfall data.

The time average interpolation was used only if there are values before and after the missing data. The result of the interpolation or the replacement value was calculated using,

$$D_r = (D_b + D_a) / 2 \quad (3)$$

Where D_r is the replacement value, D_b is the value before the missing data, and D_a is the value after the missing data.

The nearby stations interpolation was used when there are two or more succeeding missing values. Two nearby stations were identified and used to replace the missing data. The replacement value would be the average value of the data taken the same, date but from the nearby stations.

$$D_r = (D_{s1} + D_{s2}) / 2 \quad (4)$$

where D_{s1} and D_{s2} are the values of the data taken the same date but from the selected nearby stations.

CHAPTER 4

RESULT AND DISCUSSION

Rainfall Trends

Four types of rainfall patterns were found in the analysis (Figure 3). Fourteen stations out of the 46 have a Type 1 rainfall pattern. Rainy months are from May to November and dry months are from December to April. This pattern was observed in most of the stations situated in the western part of the country, which is open to the Southwest monsoon. Fourteen stations follow the Type 2 rainfall pattern. It has no dry season but has three months of prominent rainfall from October to December.

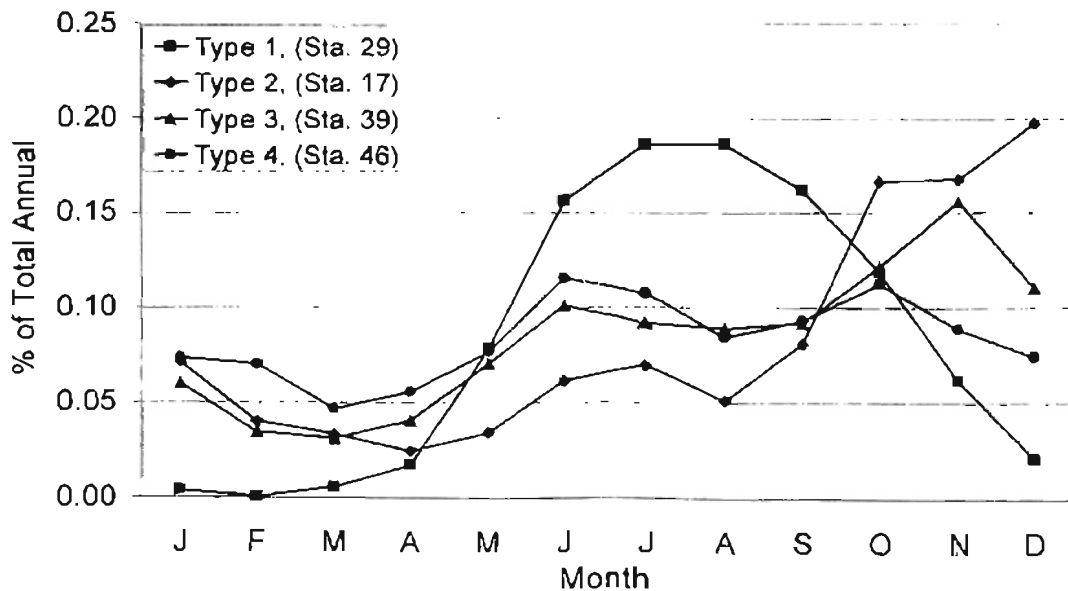


Figure 3. Philippines Rainfall Patterns.

This is widely observed in stations in the eastern part of Luzon and Visayas. In eastern Mindanao however, rainfall peaks from December to February. The Type 3 rainfall pattern has no pronounced rainy period and around three to four months of dry season. The dry period usually falls from February to April, though some stations start the dry period as early as January and end in March or April. Fifteen stations fall under this pattern and they are located mostly in the interior of the country. Type 4 has a uniformly distributed pattern and is composed of only three stations. These are stations located at the northern most and southern most part of the country.

Table 3. List of Stations by Type of Rainfall Pattern

Type 1	Type 2
Station 3 - Laog City, Ilocos Norte	Station 7 - Casiguran, Quezon
Station 5 - Vigan, Ilocos Sur	Station 9 - Baler, Quezon
Station 6 - Baguio City, Benguet	Station 13 - Infanta, Quezon
Station 8 - Dagupan City, Pangasinan	Station 16 - Daet, Camarines Norte
Station 10 - Cabanatuan, Nueva Ecija	Station 17 - Alabat, Quezon
Station 11 - Iba, Zamabales	Station 18 - Tayabas, Quezon
Station 12 - Science Garden, Quezon City	Station 21 - Legaspi City, Albay
Station 14 - NAIA, Pasay	Station 22 - Virac Radar, Catanduanes
Station 15 - Port Area, Manila	Station 23 - Virac synop, Catanduanes
Station 19 - Ambulong, Batangas	Station 24 - Catarman, Northern Samar
Station 27 - San Jose, Occidental Mindoro	Station 31 - Catbalogan, Western Samar
Station 28 - Coron, Palawan	Station 32 - Tacloban City, Leyte
Station 29 - Cuyo, Palawan	Station 40 - Butuan City, Agusan del Norte
Station 33 - Iloilo City, Iloilo	Station 41 - Hinatuan, Surigao
Type 3	Type 4
Station 2 - Apari, Cagayan	Station 1 - Basco, Batanes
Station 4 - Tuguegarao, Cagayan	Station 45 - Davao City, Davao del Sur
Station 20 - Calapan, Oriental Mindoro	Station 46 - General Santos City, S. Cotabato
Station 25 - Masbate, Masbate	
Station 26 - Romblon, Romblon	
Station 30 - Roxas City, Aklan	
Station 34 - Maasin, Southern Leyte	
Station 35 - Tagbilaran City, Bohol	
Station 36 - Dumaguete City, Negros Oriental	
Station 37 - Mactan Airport, Cebu	
Station 38 - Puerto Princesa, Palawan	
Station 39 - Dipolog, Zamboanga del Norte	
Station 42 - Cagayan de Oro, Misamis	
Station 43 - Zamboanga City, Zamboanga Sur	
Station 44 - Malaybalay, Bukidnon	

Comparing the 11-year moving averages against the 40-year mean showed stations receiving above average rainfall and stations experiencing dry periods. The discussion below is based on the annual and seasonal curves developed from the data. It elaborates which seasons and what years changes in rainfall occurred at every station.

Station 1 – Basco, Batanes (Type 4)

At Basco, Batanes, the 40-year average was 2,836.57 mm, the wettest year was 1974 with 6,926.5 mm, and the driest year was 1977 with 1,621.5 mm rainfall. This station had a fluctuating rainfall distribution. The dry years were from 1961 to 1967 and most of the years from 1980 to 2000. This dryness could be due to the declining rainfall trend of the first, second and fourth seasons. The third season had a great increase of rainfall from 1969 to 1979 that obviously brought the area into a wet condition.

Station 2 – Aparri, Cagayan (Type 2)

This station had a rainfall greater than the 76-year average from 1961 to 1972 and drought years from 1987 to 1999. The 40-year average was 2,147.4 mm, the wettest year was 1934 with 3,278 mm, and the driest year was 1997 with 1,090 mm rainfall. The seasonal analysis showed that the continuous decline of rainfall during the second and fourth season had caused the dry period at this station. The third season was fluctuating but its effect cannot be seen due to the impact of the second and fourth seasons. The first season was fairly stable.

Station 3 – Laoag City, Ilocos Sur (Type 1)

Laoag City, Ilocos Sur had a 40-year average of 2,094.9 mm, a maximum rainfall of 3,641.1 mm in 1961, and a minimum rainfall of 1,163.1mm in 1976. The eleven-year moving average showed that rainy years were from 1961 to 1969. However, during these

years. the third season's average already shows a declining trend. Hence, from 1973 to 1985, this station was in a dry condition. Seasonal analysis showed that the decline of rainfall during the third season clearly caused this dry period. In 1981 however, the third seasons rainfall started to increase bringing the condition back to normal or within the average value. The second season had also shown a generally continuous decline from 1961 to 2000.

Station 4 - Tuguegarao, Cagayan (Type 3)

This station had a 40-year average of 1,714.5 mm, a maximum rainfall of 2,696.4 mm in 1971, and a minimum rainfall of 996.8 mm in 1983. Specifically, this station had received an above average rainfall from 1966 to 1971 and in 1996 to 2000. The dry years were from 1977 to 1988. Seasonal analysis revealed that the fourth season rainfall trend had the greatest influence on the overall trend of this station. The third season was constantly moving against the direction of the fourth season, but the later still prevailed. The first and second seasons were relatively constant.

Station 5 - Vigan, Ilocos Sur (Type 1)

At Vigan, Ilocos Sur, the 76-year average was 2,562.1 mm, the wettest year was 1911 with 4,693.3 mm, and the driest year was 1975 with 1,192.6 mm rainfall. The dry years have been observed in 1974 to 1980 and this seemed to be the result of the rainfall decline in the third season long-term average. Dry years were observed from 1992 to year 2000. However, this time, it could be a combined result of the declining rainfall of the second and third season. The 1961 to 1970 wet years were also influenced by the third season's initial high rainfall average.

Station 6 – Baguio City, Benguet (Type 1)

Baguio City, Benguet had a 40-year average of 3,872.4 mm, a maximum rainfall of 7,165.9 mm in 1972, and a minimum rainfall of 2,180.6 mm in 1995. This station had wet years from 1967 to 1973. The trend is attributed to the increase of the long-term average in the third and fourth seasons. The 1978 to 1984 dry years were primarily due to the drastic drop of rainfall in the third season. Despite an increase in the long-term rainfall average in the fourth season of 1993 to 2000, the simultaneous and continuous drop of the second and third season from 1992 to 2000 put this station below the 40-year mean.

Station 7 – Casiguran, Quezon (Type 2)

At Casiguran, Quezon, the 40-year average was 3,518.9 mm, the wettest year was 1971 with 6,844.3 mm, and the driest year was 1968 with 1,352.6 mm rainfall. It seemed that the fluctuation of the long term average at this station is controlled by the fourth season rainfall. Although the first season average showed an increase from 1983 to 2000, it did not show any significant effect to the drought trend induced by the fourth season average. Nevertheless, it may have effects during the 1992 to 2000 wet years.

Station 8 - Dagupan City, Pangasinan (Type 1)

This station had a 76-year average of 2,443.4 mm, a maximum rainfall of 4,660.0 mm in 1972, and a minimum rainfall of 1,315.3 mm in 1987. The dry years were from 1978 to 1994 and had an above average rainfall during 1967 to 1977. The 40-year (1961 to 2000) declining trend of the second season's long-term average seemed to have caused this phenomenon. The drastic drop of rainfall in the third season of 1978 may have helped pull down the rainfall average.

Station 9 – Baler, Quezon (Type 2)

At Baler, Quezon, the 40-year average was 3,321.4 mm, the wettest year was 1966 with 5,665.4 mm, and the driest year was 1968 with 1,352.6 mm rainfall. The 11-year moving averages for this station showed a fairly uniform rainfall. There was no great deviation of rainfall from the 40-year mean. However, there were changes as to the timing of occurrence. The fourth season had a steady decline, balanced by increases in the other three.

Station 10 – Cabanatuan, Nueva Ecija (Type 1)

The 11-year moving average for this station showed that the only significant long dry period was from 1990 to 1994. The rest of the years move around the 40-year average. The second season shows some decline in the long-term analysis, but it was not significant enough to bring the condition to a dry period. The 40-year average was 1,897.4 mm, the wettest year was 2000 with 2,622.2 mm, and the driest year was 1979 with 1,235.1 mm rainfall

Station 11 - Iba, Zambales (Type 1)

This station had a 40-year average rainfall of 3,652.4 mm, a maximum rainfall of 5,481.3 mm in 1961, and a minimum rainfall of 1,972.5 mm in 1968. The wet years from 1974 to 1983 seemed to have been dictated by the rainfall during the third season. The dry period that occurred from 1990 to 2000 was brought by the second and third season's rainfall decline. The fourth season showed a small increase from 1968 to 1981 but was countered by the declining trend of the second season. The first season was relatively stable.

Station 12 - Science Garden, Quezon City (Type 1)

This station had an interesting change of precipitation during the year. The second season and the fourth seasons seemed to have had an opposite trends from 1961 to 2000. The second season's trend was declining while the third season's pattern was increasing in almost the same intensity. In effect, the third season was the one controlling the rainfall trend of this station. The first season had a fairly constant trend. The 40-year average rainfall was 2,485.3 mm, the maximum rainfall was 4,073.2 mm in 2000, and the minimum rainfall was 1,628.1 mm in 1987.

Station 13 - Infanta, Quezon (Type 2)

There was not much fluctuation in this station. The longest dry period occurred from 1962 to 1965, while the rest of the years are all close to the 40-year mean. In the seasonal analysis, the first, second, and the third season had a constant trend. The third season seemed to have manipulated the overall rainfall trend. The 40-year average rainfall was 4,041.4 mm, the maximum rainfall was 6,596.3 mm in 1971, and the minimum rainfall was 2,263.5 mm in 1968.

Station 14 - NAIA, Pasay (Type 1)

At NAIA, Pasay, the 40-year average was 1,693.4 mm, the wettest year was 1972 with 3,401.7 mm, and the driest year was 1994 with 0.0 mm rainfall. The station's rainfall trend almost divides the forty years record into three equal divisions. 1961 to 1977 were wet years, average rainfall occurred from 1978 to 1990, and from 1991 to 2000 were dry years. The third season rainfall dictates this entire trend. The long-term seasonal curve seems almost identical to the annual 11-year moving average curve. The rest of the seasonal curve is relatively constant.

Station 15 - Port Area, Manila (Type 1)

This station experienced a very long dry period from 1869 to 1913. Then in 1914, it started to become wet until 1937 (end of the initial record). The variation of rainfall is prominent in the third season. There was however, a slight change in the second season that augmented the shift from dry years to rainy years. However, from 1961 to 2000, the trend is more erratic. Although the fluctuation still depended primarily on the third season, the wet and dry years are much shorter compared to the 1865-1937 record. It had dry years in 1963 to 1968 and 1978 to 1989. The wet years were from 1972 to 1976 and 1978 to 1989. The maximum annual rainfall received at this station was 3,920.6 mm in 1919 and the minimum rainfall was 9,06.5 mm in 1885. The 113-year average rainfall was 2,095.7 mm.

Station 16 - Daet, Camarines Norte (Type 2)

The wet years at this station were from 1966 to 1978 and the dry years from 1982 to 1996. The trend however from 1992 was increasing. The fourth season was the controlling season for this station. The first, second, and the third seasons were fairly stable. The 40-year average rainfall was 3,311.6 mm, the maximum rainfall was 5,417.8 mm in 1999, and the minimum rainfall was 1,738.3 mm in 1968.

Station 17 - Alabat, Quezon (Type 2)

There were no significant wet years at this station. Dry years however, started in 1979 to 1993. The precipitation trend from 1992 was increasing. The fourth season is the controlling season for this station, while the first, second, and the third seasons were relatively stable. The 40-year average rainfall was 3,205.3 mm, the maximum rainfall was 5,065.1 mm in 1964, and the minimum rainfall was 2,062.3 mm in 1968.

Station 18 - Tayabas, Quezon (Type 2)

This station had experienced quite a long drought from 1977 to 1989. It only had wet years in 1961 to 1963 and 1995 to 2000. As with the previous station, the rainfall trend was increasing starting the middle of the drought years (1986). The wet years were in 1991 and 1995- 2000. The fourth season was also controlling the rainfall trend of this station. Although there was a decline in rainfall for the second season from 1977 to 2000, it did not have much of an impact on the total rainfall received at this station. The 30-year average rainfall was 3,152.8 mm, the maximum rainfall was 4,340.5 mm in 1996, and the minimum rainfall was 1,983.5 mm in 1982.

Station 19 - Ambulong, Batangas (Type 1)

The dry years at this station were from 1961 to 1970 and the wet years from 1974 to 1977. The rest of the years are fairly close to the 40-year average. The third season dictates the rainfall trend of this station. The second season had a declining trend but it was balanced by the increase of the fourth season. The 40-year average rainfall was 1,898.1 mm, the maximum rainfall was 2,601.4 mm in 1976, and the minimum rainfall was 1,179.2 mm in 1965.

Station 20 – Calapan, Oriental Mindoro (Type 3)

The forty years record for this station was divided into two periods; dry years from 1961 to 1983 and wet years in 1985 to 2000, with 1984 being average. In 1961, the second, third, and the fourth season were level. In 1970, the third season average started to increase until it stabilized in 1983. On the other hand, the second and fourth season also decreased in 1970 until somewhere in 1979 and 1980. Then, both started to climb until their combined magnitude brought this station into wet years starting in 1985 and

continuing up to 2000. The 40-year average rainfall was 2,053.5 mm, the maximum rainfall was 3,149.9 mm in 1995, and the minimum rainfall was 1,045.2 mm in 1968.

Station 21 - Legaspi, City, Albay (Type 2)

This station had two periods of dry years and two periods of wet years for its forty years of records. The dry years were 1961 to 1967 and 1981 to 1990. The wet years were 1974 to 1978 and 1995 to 2000. The fourth season obviously dominated the rainfall trend of this station. The first season however, follows the same pattern with the fourth season but the magnitude of its fluctuations was lesser. The second and third seasons showed a correlated declining trend from 1961 to 2000. The 40-year average rainfall was 3,392.6 mm, the maximum rainfall was 4,727 mm in 1995, and the minimum rainfall was 2,036.5 mm in 1968.

Station 22 - Virac Radar, Catanduanes (Type 2)

There was not much fluctuation in the rainfall trends in this station. The dry season was observed from 1961 to 1963. The wet years were from 1994 to 2000. The rest of the years were fairly normal or within the average value. The first and fourth seasons were the controlling season for this station. The second and third seasons were stable throughout the 40 years record. The 33-year average rainfall was 3,545.4 mm, the maximum rainfall was 5,862.2 mm in 1995, and the minimum rainfall was 1,795.5 mm in 1968.

Station 23 - Virac Synop, Catanduanes (Type 2)

Unlike Virac Radar, rainfall trends at this station are different. Dry years were observed from 1962 to 1967 and 1982 to 1992. There was a short wet period from 1974 to 1976 and then again from 1995 to 2000. The first and fourth seasons were the controlling

seasons for this station with the fourth season being the dominant. The second season climbed up from 1971 to 1981 but did not have much influence in the overall trend. The third season was relatively stable. The 76-year average rainfall was 2,894.8 mm, the maximum rainfall was 5,036.8 mm in 1995, and the minimum rainfall was 1,537.1 mm in 1968.

Station 24 - Catarman, Northern Samar (Type 2)

The fluctuation of rainfall trends at this station was minimal. The eleven-year moving average stayed just below the 40-year mean from 1962 to 1979. There was a short wet period from 1984 to 1986, which was brought by the increase of rainfall in the fourth season. The increase of rainfall in the first and fourth seasons of 1998 to 2000 brought this station back to wet years. The third and second seasons were quite stable. The 40-year average rainfall was 3,317.8 mm, the maximum rainfall was 5,078.9 mm in 1999, and the minimum rainfall was 1,886.2 mm in 1997.

Station 25 - Masbate, Masbate (Type 3)

This station had dry years from 1961 to 1964 and wet years from 1983 to 1991 and 1998 to 2000. The fourth season seemed to have influenced the wet years, while the third season is the one pulling down the rainfall trend in dry years. The first and second seasons were comparatively stable except in 1994. First season's increases were offset by second season's decreases. The 76-year average rainfall was 1,904.6 mm, the maximum rainfall was 3,142.2 mm in 2000, and the minimum rainfall was 927 mm in 1914.

Station 26 - Romblon, Romblon (Type 3)

There was not much fluctuation in the rainfall trend in this station. The eleven-year moving averages were moving around the 40-year mean. From the seasonal analysis, it was observed that the first and second seasons were fairly constant throughout the 40 years records. The third and fourth seasons were offsetting each other from 1961 to 1967 when the third season dropped down while the fourth season climbed up. The same trend was observed from 1987 to year 2000. From 1968 to 1986, the two seasons were moderately stable. The 40-year average rainfall was 2,015.6 mm, the maximum rainfall was 3,025 mm in 2000, and the minimum rainfall was 1,131.2 mm in 1997.

Station 27 - San Jose, Occidental Mindoro (Type 1)

This station has 20 years of record. The eleven-year moving average was just above the 20-year mean from 1983 to 1991. From 1994 to 2000, the eleven-year moving averages were just below the 20-year mean. The seasonal analysis showed that the second season was apparently the one dominating the trend of rainfall at this station. The 20-year average rainfall was 2,356.5 mm, the maximum rainfall was 3,061.1 mm in 1988, and the minimum rainfall was 1,728.1 mm in 1983.

Station 28 - Coron, Palawan (Type 1)

From 1961 to 1967, this station experienced above average rainfall. Then from 1968, quite dry years were observed up to 2000. Seasonal analysis showed that the third season was governing the rainfall trend. However, the second season may have helped develop this trend. The 40-year average rainfall was 2,547.2 mm, the maximum rainfall was 3,905.9 mm in 1962, and the minimum rainfall was 1,745.2 mm in 1986.

Station 29 - Cuyo, Palawan (Type 1)

The rainfall trend in this station was generally stable. The eleven-year moving averages were around the 40-year mean, although from 1991 to 2000, the 11-year moving average curve went down as low as 152 mm based from the 40-year mean. From the seasonal analysis, the first season curve showed a small increase however, the combined decline of the second, third and fourth seasons dominated, causing this dryness. The 40-year average rainfall was 2,297.4 mm, the maximum rainfall was 3,057.7 mm in 1984, and the minimum rainfall was 1,622.3 mm in 1981.

Station 30 - Roxas City, Aklan (Type 3)

This station had wet years from 1966 to 1975 and 1998 to 2000. Dry years were from 1977 to 1995. The fourth season seemed to have the most influence on the general rainfall trend. The third season went down from 1961 to 1979. It slightly increased from 1980 to 1990 but the fourth season's declining trend from 1972 to 1994 brought in the dry period. The first and second seasons were comparatively stable except that in 1994, both first and second seasons increased up to 2000. The 40-year average rainfall was 2,036.1 mm, the maximum rainfall was 3,384.5 mm in 1995, and the minimum rainfall was 647.1 mm in 1997.

Station 31 – Catbalogan, Western Samar (Type 2)

The rainfall trend in this station was fairly stable. The eleven-year moving averages were very close to the 40-year mean, although from 1961 to 1978 it was below the 40-year mean. From 1984 to 2000, the 11-year moving averages stayed above the 40-year mean. From the seasonal analysis, the fluctuation can be attributed to the trend of the fourth season. The rest of the seasons are relatively stable. The 40-year average rainfall was

2,624.6 mm, the maximum rainfall was 4,075.9 mm in 2000, and the minimum rainfall was 1,760.9 mm in 1973.

Station 32 - Tacloban City, Leyte (Type 2)

The rainfall trend in this station is divided into three period; dry years from 1961 to 1978, wet years from 1983 to 2000, with 1979 to 1982 being average. Seemingly, the trend is due to the combined increasing trend of the first and fourth seasons. The third and second season also increased but of minimal magnitude. The 40-year average rainfall was 2,378.1 mm, the maximum rainfall was 3,682.6 mm in 1999, and the minimum rainfall was 1,431.2 mm in 1992.

Station 33 - Iloilo City, Iloilo (Type 1)

This station has seventy-six years of rainfall record. Dry periods were experienced from 1910 to 1913, and from 1961 to 1980. The wet years were observed during 1917 to 1937 and from 1983 to 1991. The third season dictated the rainfall trend. The second season followed the third season's trend, but the magnitude was minimal. Nevertheless, it may have helped developed the trend. There was a minimum fluctuation of the fourth season but it does not seem to have a significant effect. The first season was fairly stable. The maximum annual rainfall received at this station was 3,244.5 mm in 1902 and the minimum rainfall was 1,186 mm in 1969. The 76-year average rainfall was 2,219.6 mm.

Station 34 – Maasin, Southern Leyte (Type 3)

This station's sixty-five years of record showed a quite unique trend compared to the other stations. Twenty-seven years out of thirty-five years (initial record) experienced wet conditions. On the other hand, the entire data of the second set of records (1971 to 2000) revealed that the condition was all below the 65-year average. The seasonal curves

showed that all four seasons developed the trend. The 65-year average rainfall was 2,196.6 mm, the maximum rainfall was 3,627.7 mm in 1916, and the minimum rainfall was 756.2 mm in 1979.

Station 35 – Tagbilaran, Bohol (Type 3)

Station 35 had wet years from 1961 to 1972 and from 1995 to 2000. Dry years were from 1977 to 1993. Similar to the previous station, all four seasons contributed to the trend traced by the rainfall distribution. The 40-year average rainfall was 1,367.6 mm, the maximum rainfall was 2,076.8 mm in 1996, and the minimum rainfall was 711.6 mm in 1992.

Station 36 - Dumaguete City, Negros Oriental (Type 3)

This station had dry years from 1980 to 1994 and wet years from 1996 to 2000. 1961 to 1979 was around the 40-year mean. Apparently, the trend from 1961 to 1981 was dominated by the third and fourth season. Then, from 1981 to 2000, it appears that the trend was a result of the combined pattern made by the first, second, and fourth seasons. The 40-year average rainfall was 1,186.6 mm, the maximum rainfall was 2,261 mm in 1999, and the minimum rainfall was 674.5 mm in 1963.

Station 37 - Mactan Airport, Cebu (Type 3)

This station had thirty years of rainfall record. From 1971 to 1993, the 11-year moving average was below the 30-year mean but the deviation was minimal. In 1994 however, it shifted into wet years up to 2000. Seasonal analysis revealed that the trend could be due to the first, second, and the fourth season rainfall distribution. The 30-year average rainfall was 1,521.5 mm, the maximum rainfall was 2,060.8 mm in 1999, and the minimum rainfall was 883.1 mm in 1987.

Station 38 - Puerto Princesa, Palawan (Type 1)

This station had dry years from 1985 to 1995 and wet years from 1997 to 2000. From 1966 to 1980, the rainfall depth was above average, but the deviation from the 40-year mean was minimal. Seasonal curves showed that the trend was due to the fourth season. The second and the third season went in opposite directions but did not have a significant effect on the overall trend of the rainfall. The 40-year average rainfall was 1,512.0 mm, the maximum rainfall was 2,594.0 mm in 1999, and the minimum rainfall was 987.6 mm in 1991.

Station 39 - Dipolog, Zamboanga Del Norte (Type 3)

This station had dry years from 1986 to 1996, wet years from 1967 to 1980 and 1998 to 2000. The 1967 to 1980 rainfall was above average with a minimal deviation from the 40-year mean. Seasonal curves showed that the trend was due to the fourth season with a small effect from the first season. The second had a stable trend. The third season generally showed a continuous decline from 1961 to 2000. The 40-year average rainfall was 2,316.4 mm, the maximum rainfall was 3,748.9 mm in 2000, and the minimum rainfall was 1,417.1 mm in 1997.

Station 40 - Butuan City, Agusan Del Norte (Type 2)

Butuan City station only had 20 years of record. It had dry years from 1986 to 1990 and wet years from 1997 up to 2000. The first season dictated the rainfall trend. The second and third seasons showed an increase from 1981 to 2000 and the fourth season manifested a small fluctuation. However, the later three seasons did not show an impact to the trend. The 20-year average rainfall was 2,031.7 mm, the maximum rainfall was 2,748.0 mm in 1999, and the minimum rainfall was 1,261.3 mm in 1998.

Station 41 - Hinatuan, Surigao (Type 2)

This station's rainfall trend follows a natural cyclic pattern from dry years to wet years. The dry years were from 1961 to 1968 and 1986 to 1993. The rainy years were from 1970 to 1979 and 1996 to 2000. The seasonal curves showed that the first, second, and the fourth seasons set the trend for this station. The third season was relatively constant. The 40-year average rainfall was 4,189.7 mm, the maximum rainfall was 6,101.0 mm in 1999, and the minimum rainfall was 2,338.8 mm in 1963.

Station 42 - Cagayan de Oro, Misamis (Type 3)

There was a little variation of rainfall at this station. The only significant trend is the dry years from 1987 to 1997. It may be said that it was dry, but the deviation of the 11-year average from the 40-year mean was minimal. The third season was the dominant season causing the variation and was augmented by the first season. The second and fourth seasons seemed to offset each other, as the fourth season increased in almost the same magnitude as the second had decreased. The 40-year average rainfall was 1,575.9 mm, the maximum rainfall was 2,187.0 mm in 1999, and the minimum rainfall was 1,039.0 mm in 1998.

Station 43 - Zamboanga City, Zamboanga del Sur (Type 3)

This station's trend fluctuated from dry to wet. The dry years were from 1961 to 1970 and 1985 to 1990. The rainy years were from 1974 to 1979 and 1995 to 2000. The most dominate seasons were the fourth and the third. The first and second seasons were somewhat constant except that the first season showed an increase from 1994 to 2000. The 40-year average rainfall was 1,181.2 mm, the maximum rainfall was 2,148.8 mm in 1999, and the minimum rainfall was 394.6 mm in 1963.

Station 44 - Malaybalay, Bukidnon (Type 3)

The 11-year moving average stayed close to the 40-year mean from 1961 to 2000. Hence, there was no great variation in this station. Consequently, the seasonal analysis showed no variation. The 40-year average rainfall was 2,566.0 mm, the maximum rainfall was 3,654.9 mm in 1999, and the minimum rainfall was 1,864.8 mm in 1998.

Station 45 - Davao City, Davao del Sur (Type 4)

The long-term analysis revealed that although the 11-year moving average did not have a great deviation from the 40-year mean, it still showed fluctuation in rainfall trend. From 1967 to 1976, most years received rain more than the 40-year average, which may have been caused by the third and second seasons. Towards the end of the century (1998 to 2000), there was a change. The third and second seasons had drifted down and the first and fourth season climbed up. Hence, the wetness during these years may have been caused by the first and fourth seasons. Then from 1978 to 1995, most years had a dry condition. Still, it may have been due to the decline of the second and third seasons and the continuous drop of the first season. The 40-year average rainfall was 1,764.2 mm, the maximum rainfall was 2,357.5 mm in 2000, and the minimum rainfall was 1,128.2 mm in 1967.

Station 46 - General Santos City, South Cotabato (Type 4)

This station had wet years from 1961 to 1973. The third season was the only season increasing during these years, all the rest had a declining trend. From then on, the third season declined, and a dry condition prevailed up to 1997. Although the second season had increased from 1978 to 1988, it was not comparable against the three declining

seasons. The 40-year average rainfall was 953.1 mm, the maximum rainfall was 1,346.4 mm in 1999, and the minimum rainfall was 398.5 mm in 1979.

Type Trends

Under the Type 1 rainfall pattern, three stations experienced their wettest year in 1973 and 2 stations in 2000. The rest of the stations had various wet years. Two stations had their driest year in 1983 and another two had it 1987. For the seasonal analysis, nine out of fourteen stations under this type had the third season as the controlling season for its trend. The remaining five stations were controlled by the combination of two or three seasons.

For the Type 2 rainfall pattern, five stations out of fourteen simultaneously experienced their wettest year in 1999, three stations in 1995, and the rest in different years. Six stations had their driest year in 1968, two in 1997, and the rest in different years. For the rainfall trend, five stations were controlled by the fourth season, five stations were dictated by the second and fourth seasons, and the remaining two season were controlled by the combination of the first, second and fourth seasons.

Under the Type 3 rainfall pattern, five stations experienced their wettest year in 1999, three stations in 2000, two stations in 1995, and the rest in different years. Three stations had their driest year in 1983, three in 1968, two in 1963, and two in 1998. For the seasonal analysis, four out of fifteen stations had the fourth season as the controlling season for its trend. The remaining stations were controlled by the combination of second, third, and fourth seasons.

The three stations under Type 4 rainfall pattern experienced their wettest and driest year individually in different years. It was also observed that there was no controlling season for the rainfall trend.

Precipitation Index

Thirteen stations belong to the Type 1 rainfall pattern were considered and their Precipitation Index ranged from 0.95 to 1.05 (Figure 4). For the Type 2 rainfall pattern, eleven stations comprised the calculation and the Precipitation Index ranged from 0.91 to 1.15 (Figure 5). All twelve stations under Type 3 rainfall pattern have 40 years of rainfall record. Their Precipitation Index ranged from 0.94 to 1.13 (Figure 6). The three stations comprising the Type 4 rainfall pattern yielded a Precipitation Index ranging from 0.94 to 1.09 (Figure 7). All these values are the 11-year moving averages.

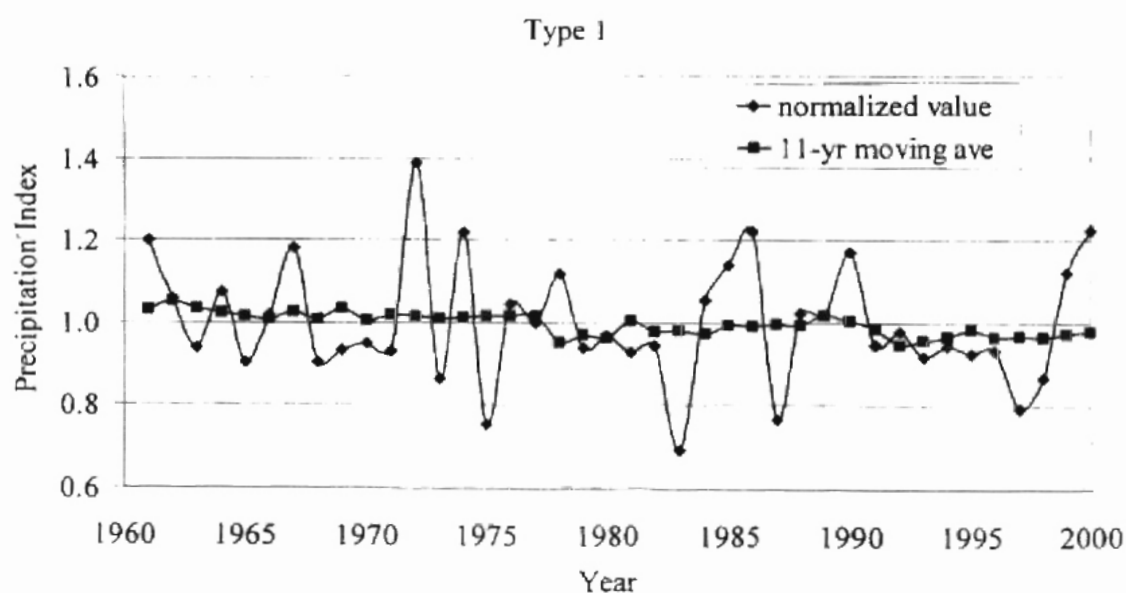


Figure 4. Type 1 Rainfall Precipitation Index

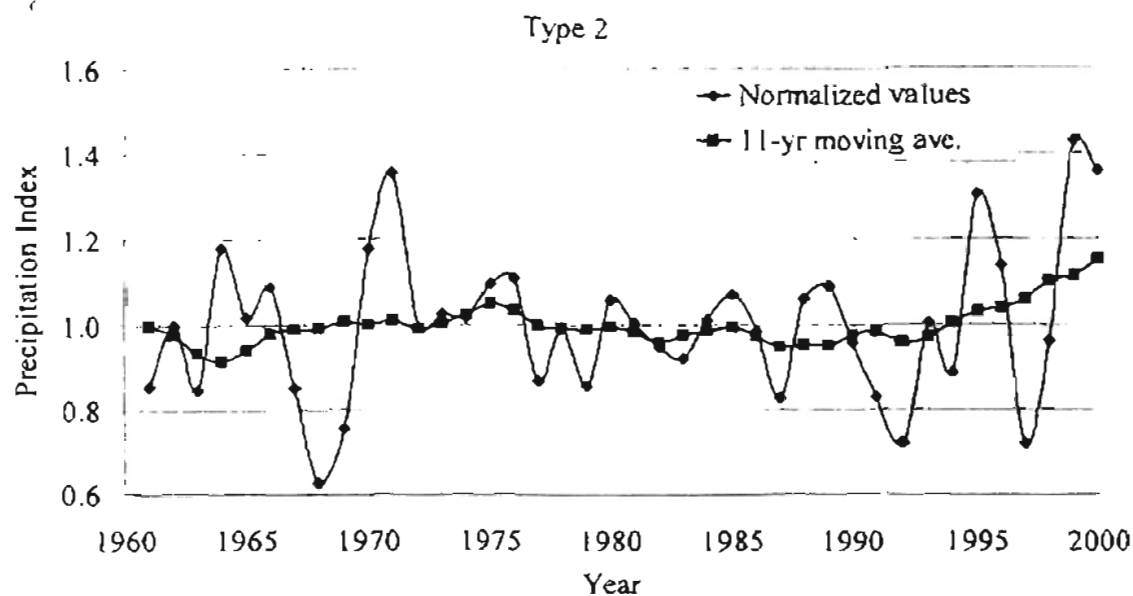


Figure 5. Type 2 Rainfall Precipitation Index

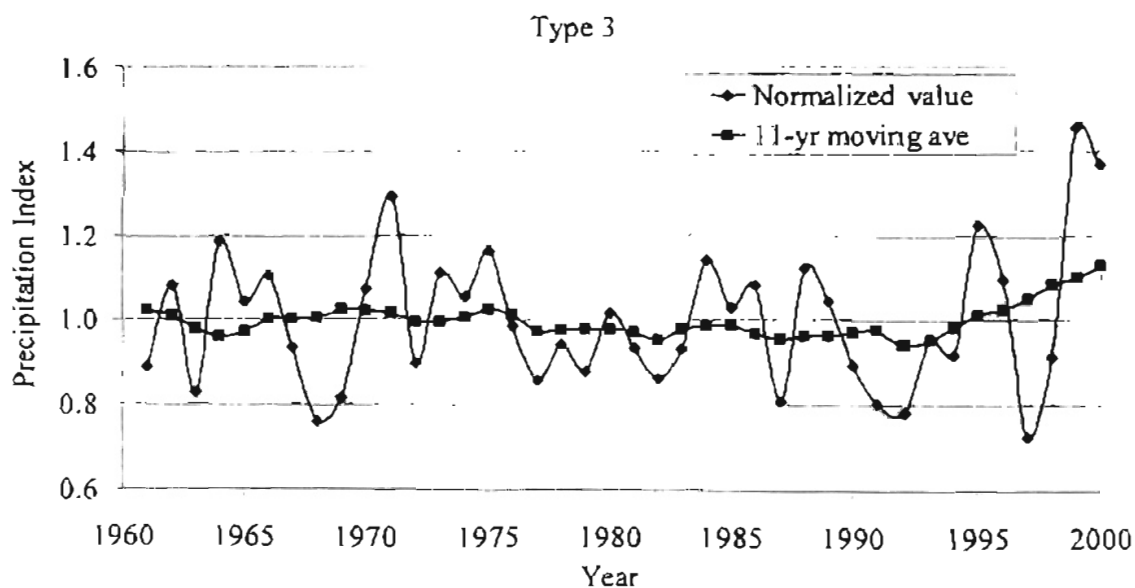


Figure 6. Type 3 Rainfall Precipitation Index

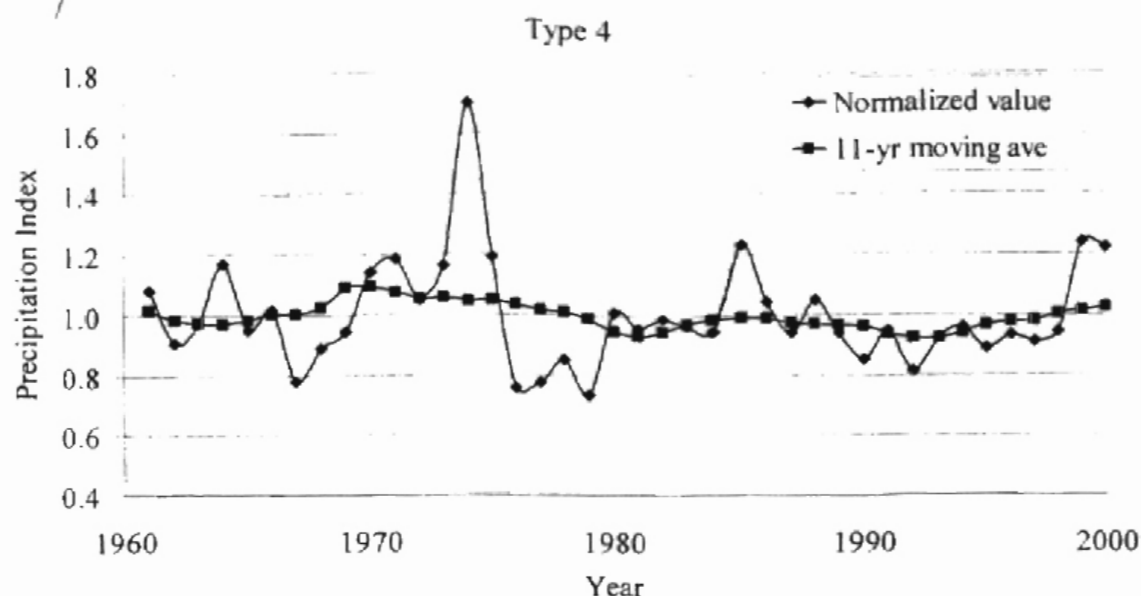


Figure 7. Type 4 Rainfall Precipitation Index

Streamflow Correlation and Sensitivity

Figure 8 shows the time series curves of rainfall and streamflow of the Sulipan River. As can be seen, they follow the same general trend. Figure 9 shows the scatter plots of the 15 years rainfall and streamflow monthly data. Also plotted is the mean monthly data which shows the actual correlation of eighty-eight percent. A linear fit for the monthly mean is also shown which has a linear correlation coefficient of 77 percent. The comparison of rainfall and streamflow monthly mean is shown in Figure 10. The initial values in the streamflow curve (dashed line) could be attributed to the water flowing from upstream. Since the Sulipan station is located near the outlet, it is possible that the Sulipan River continuously receives surface and subsurface flow from the upstream sub-basins. As can be seen in Figure 10, the streamflow curve increases correspondingly as the rainfall began in May in the Sulipan sub-basin. Average monthly sensitivity was 0.33, which means that a unit increase in rainfall would increase the

streamflow by 0.33 percent. This implies that the majority of increased precipitation will leave the watershed by evapotranspiration or groundwater recharge.

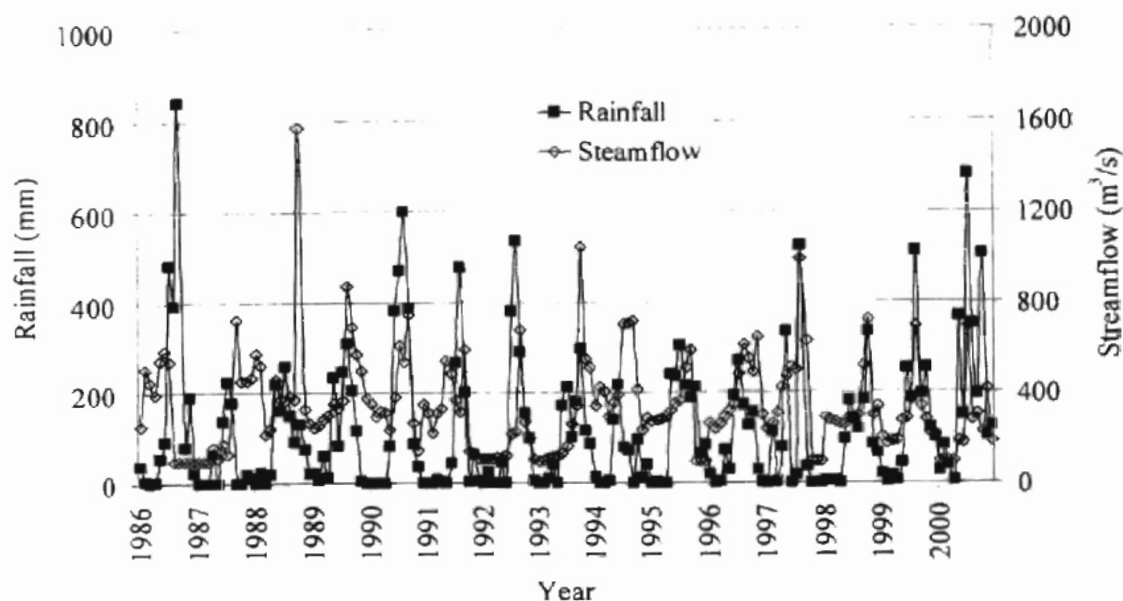


Figure 8. Rainfall and Streamflow Time Series Curves

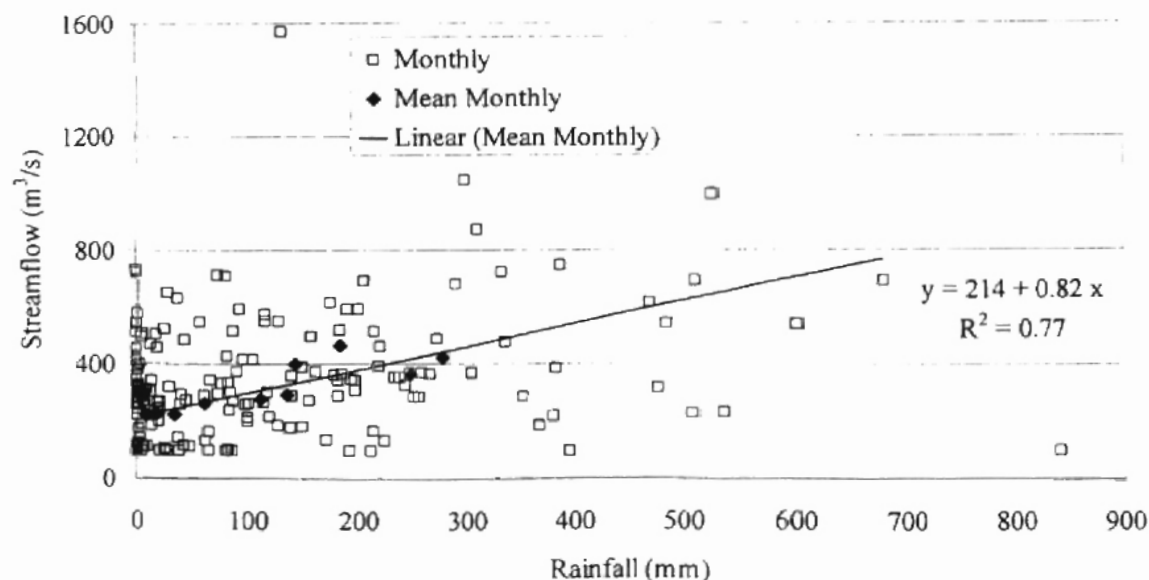


Figure 9. Rainfall and Streamflow Monthly and Mean Monthly Scatter plots

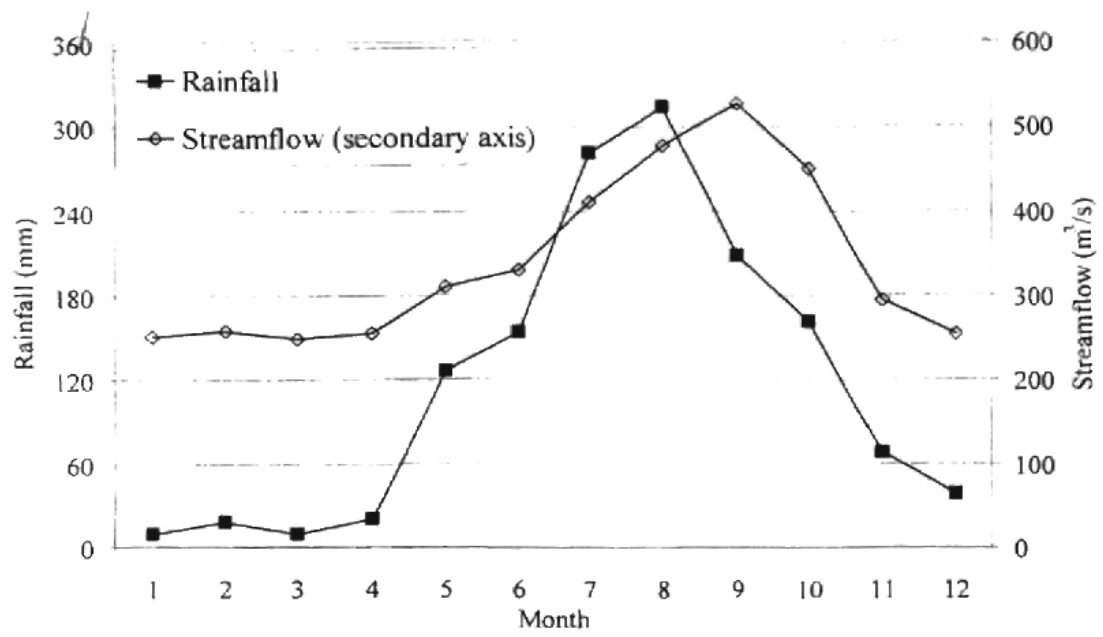


Figure 10. Rainfall and Streamflow Mean Monthly Curves

All attempts to relate the annual rainfall at this station and another station located at the middle of the basin failed to obtain a positive correlation with the mean annual streamflow. The reason for this output could not be determine. It may be a result of significant data error or undefined basin transfers.

CHAPTER 5

CONCLUSION

Rainfall records at 46 stations were analyzed by computing the annual and 40-year means, the 40-year eleven-year moving average, the seasonal eleven-year moving averages, and the Precipitation Index (PI). The rainfall patterns were identified including the possible changes that occurred. Wet and dry years were recognized including the maximum and minimum rainfall occurrence. The controlling season for every station was also established. Moreover, the rainfall pattern was compared to previous studies. The streamflow at one station, Sulipan was correlated to rainfall and its sensitivity was determined.

Rainfall

Station 25 (Masbate station) is the only station that showed an increase in rainfall among the eight stations that have long data sets. Masbate station showed a 114 mm increase based from the 1904-1937 average to the 1961-2000 average. The remaining seven stations showed a decrease in rainfall averages ranging from 28.93 mm for Station 14 (Manila station) to as much as 622 mm from Station 34. Moreover, the 11-year moving averages revealed that Station 14 had a relatively stable pattern from 1865 to

1935 compared to the 1961-2000 pattern. The rest of the stations, including those with 40 years or less of records, showed a relatively natural cyclic pattern.

Rainfall patterns had a slight change based from previous studies. The rainy months for the Type 1 rainfall pattern had advanced from June-November to May-November. The Type 2 rainfall pattern has showed slight changes. The regions that fall under this type were divided into subtypes A, B and C (Table 4). Ten stations composed the subtype A that has a pronounced rainfall during October, November and December. Two stations fall under subtype B, which has a marked maximum rain during the months of November, December and January. Two stations located in eastern Mindanao belong to subtype C. This subtype has a pronounced maximum rain during the months of December, January, and February. This finding is quite different from the previous studies. Other rainfall types have shown no significant changes.

Table 4. Type 2 rainfall subtypes

Station		
Number	Name	SubType
7	Casiguran, Quezon	A
9	Baler, Quezon	A
13	Infanta, Quezon	A
16	Daet, Camarines Norte	A
17	Alabat, Quezon	A
18	Tayabas, Quezon	A
21	Legaspi City, Albay	A
22	Virac Radar, Catanduanes	A
23	Virac synop, Catanduanes	A
31	Catbalogan, Western Samar	A
24	Catarman, Northern Samar	B
32	Tacloban City, Leyte	B
40	Butuan City, Agusan del Norte	C
41	Hinatuan, Surigao	C

Precipitation Index

The Precipitation Index (PI) for all rainfall pattern types had a low of 0.91 and a high of 1.15. These values were observed at Type 2 group of stations. Hence, Type 2

has the wider range of Precipitation Index compare to the rest of the Type groups. In general however, these precipitation index values imply that there was no significant change or variation in rainfall magnitudes among the four types of rainfall pattern.

Streamflow

The monthly average of streamflow and rainfall in the Sulipan river basin showed eighty-eight percent correlation and the streamflow's sensitivity was 0.33. Due to the limitation of the available data, no conclusions could be reached on the sensitivity of the streamflow to changes in precipitation

Recommendations

In future studies related to this work, the following actions are recommended:

1. Analyze daily rainfall distribution and frequency for climate variation;
2. Develop precipitation model for the Philippines to allow forecasting and modeling;
3. Define or obtain an adequate streamflow record which would allow climate variability analysis;
4. Trace records and agencies which may have longer periods of rainfall and streamflow measurements to extend the baseline of this study.

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APPENDIX

**Figures for all the Annual Curves, 11-year Moving Averages, Seasonal Curves, and
Precipitation Index**

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- Figure A5. Station 5, Vigan, Ilocos Sur.
- Figure A6. Station 6, Baguio City, Benguet.
- Figure A7. Station 7, Casiguran, Quezon.
- Figure A8. Station 8, Dagupan City, Pangasinan.
- Figure A9. Station 9, Baler, Quezon.
- Figure A10. Station 10, Cabanatuan, Nueva Ecija.
- Figure A11. Station 11, Iba, Zamabales.
- Figure A12. Station 12, Science Garden, Quezon City.
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- Figure A39. Station 39, Dipolog, Zamboanga del Norte.
- Figure A40. Station 40, Butuan City, Agusan del Norte.
- Figure A41. Station 41, Hinatuan, Surigao.

Figure A42. Station 42, Cagayan de Oro, Misamis Oriental.

Figure A43. Station 43, Zamboanga City, Zamboanga del Sur.

Figure A44. Station 44, Malaybalay, Bukidnon.

Figure A45. Station 45, Davao City, Davao del Sur.

Figure A46. Station 46, General Santos City, South

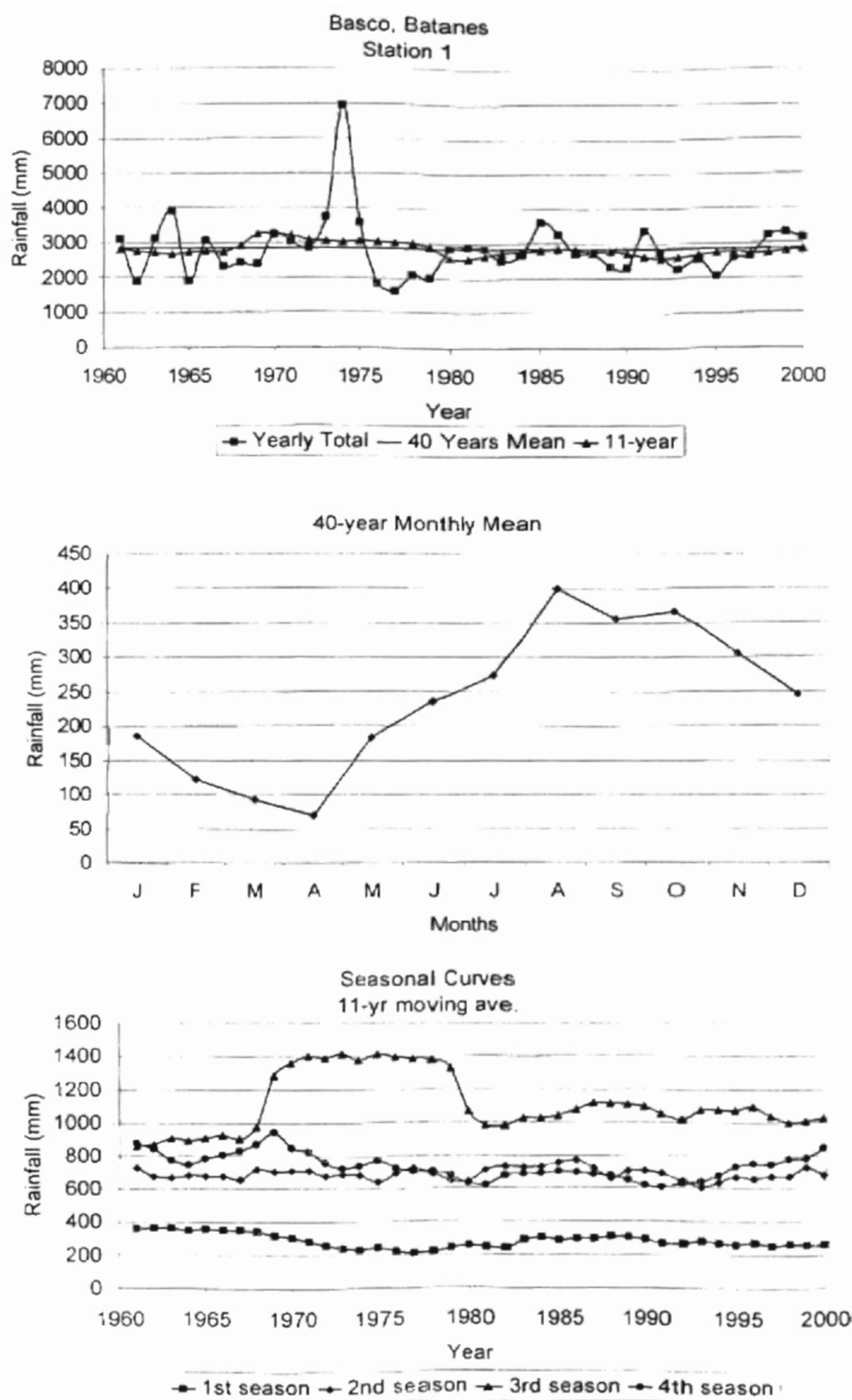


Figure A1 Station 1, Basco, Batanes.

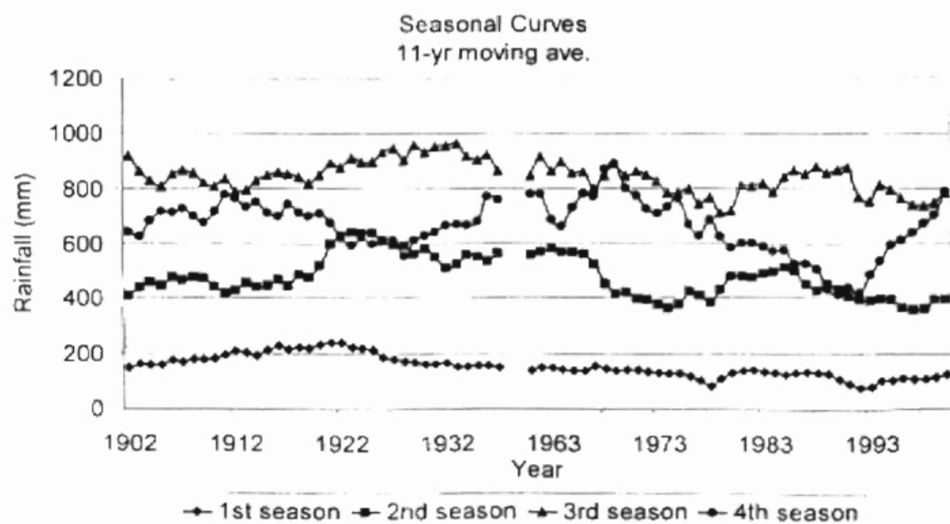
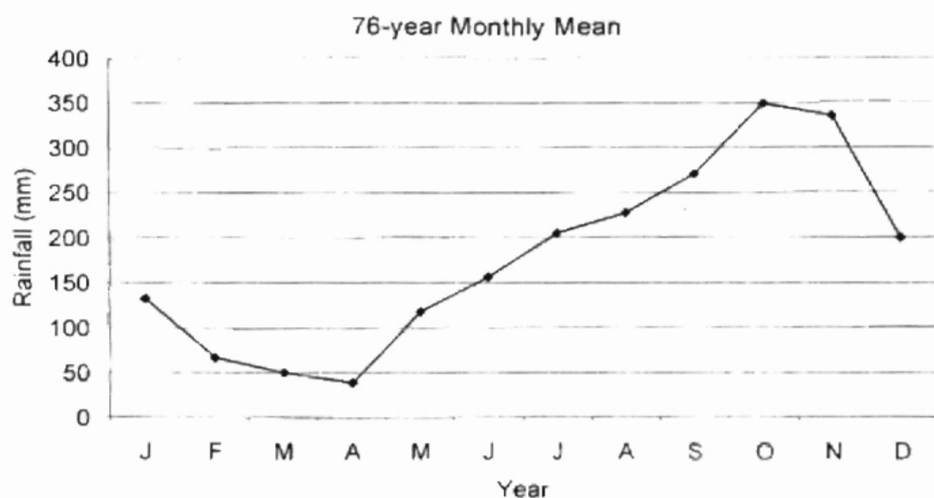
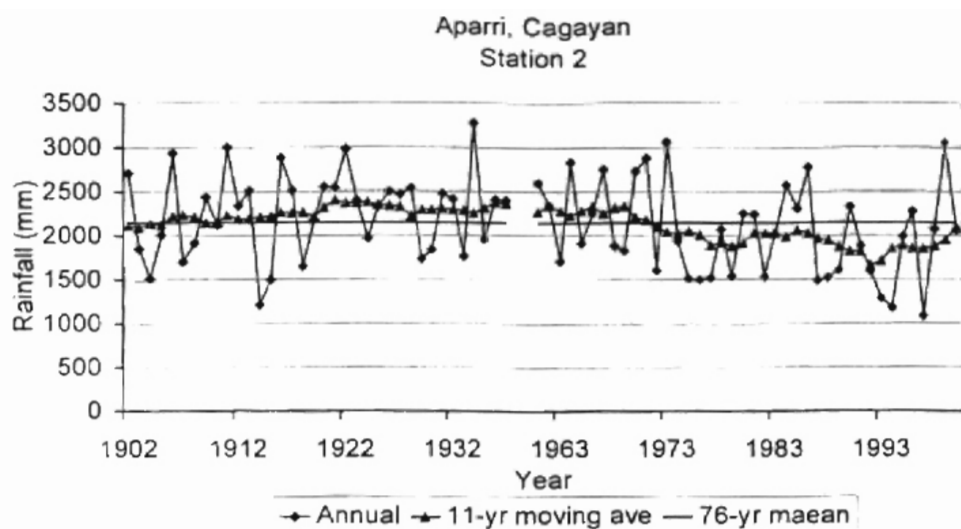


Figure A2. Station 2, Aparri, Cagayan.

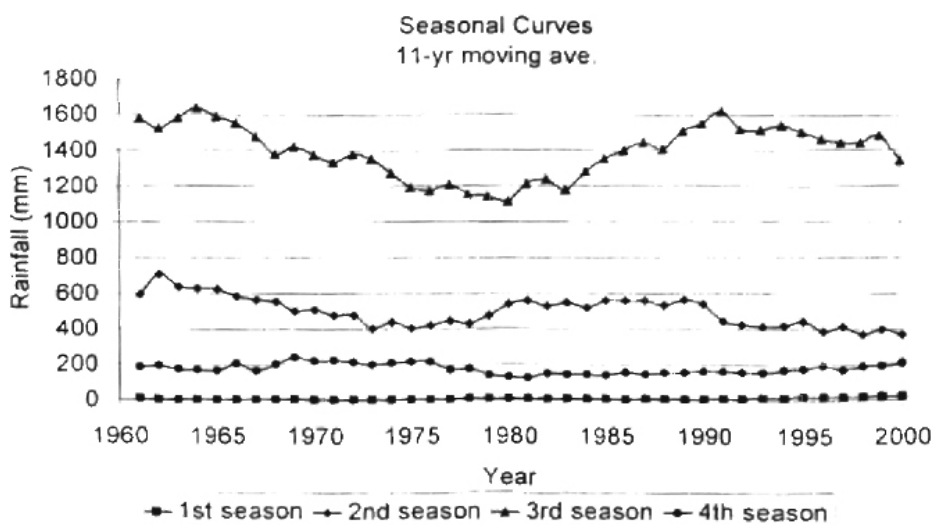
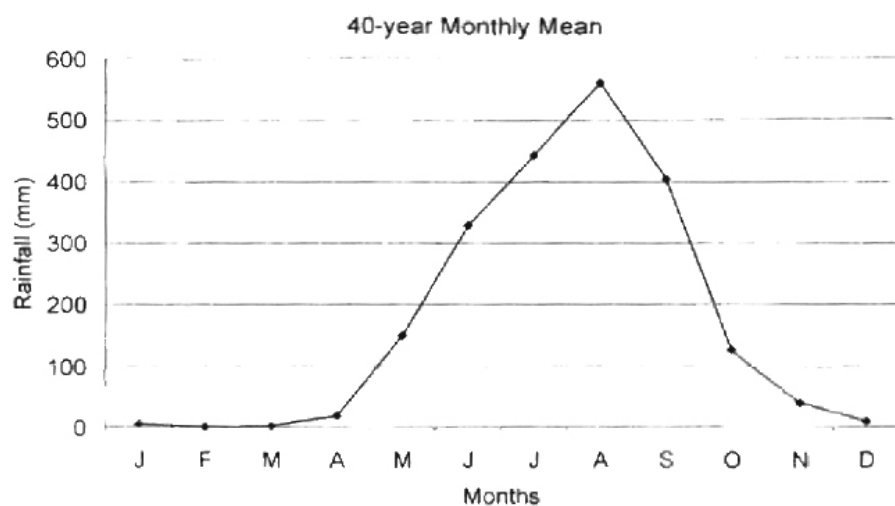
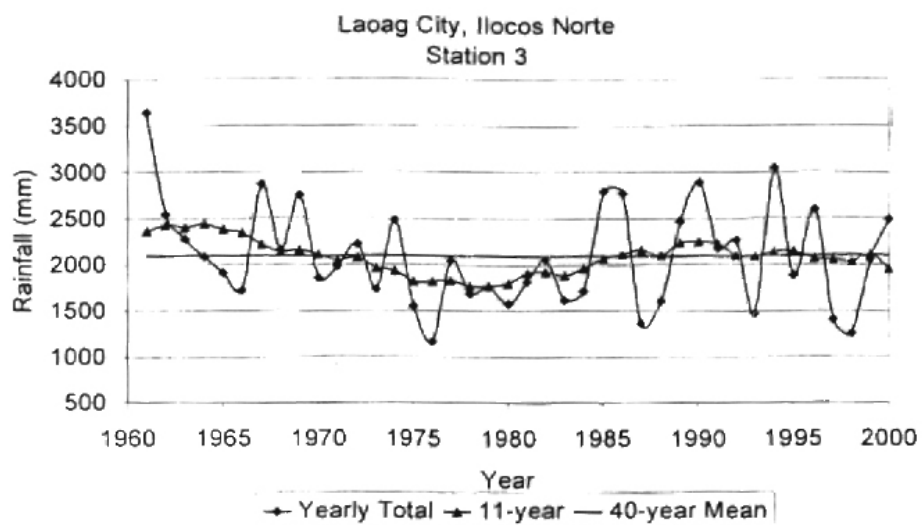


Figure A3. Station 3, Laoag City, Ilocos Norte.

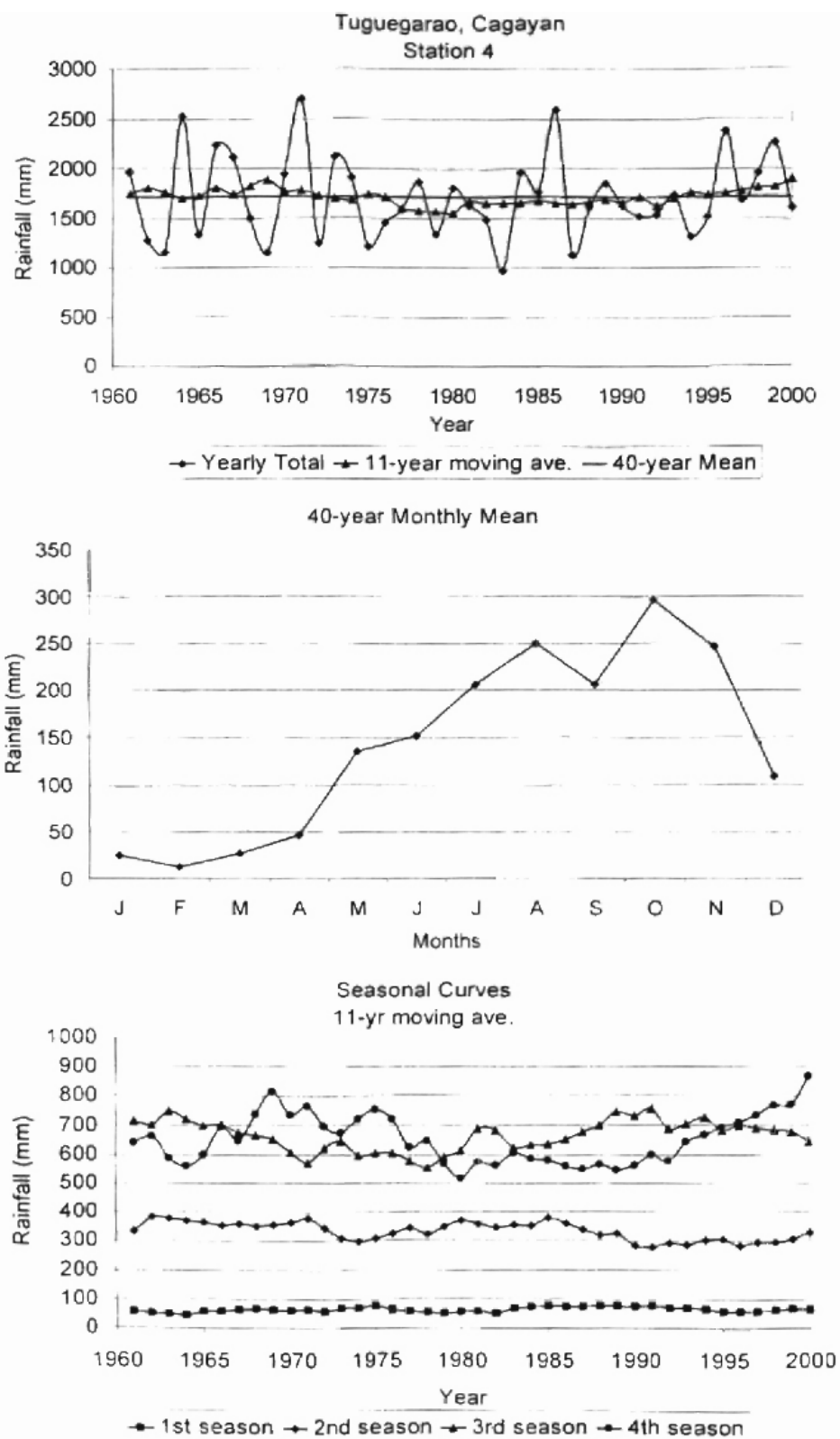


Figure A4. Station 4, Tuguegarao, Cagayan.

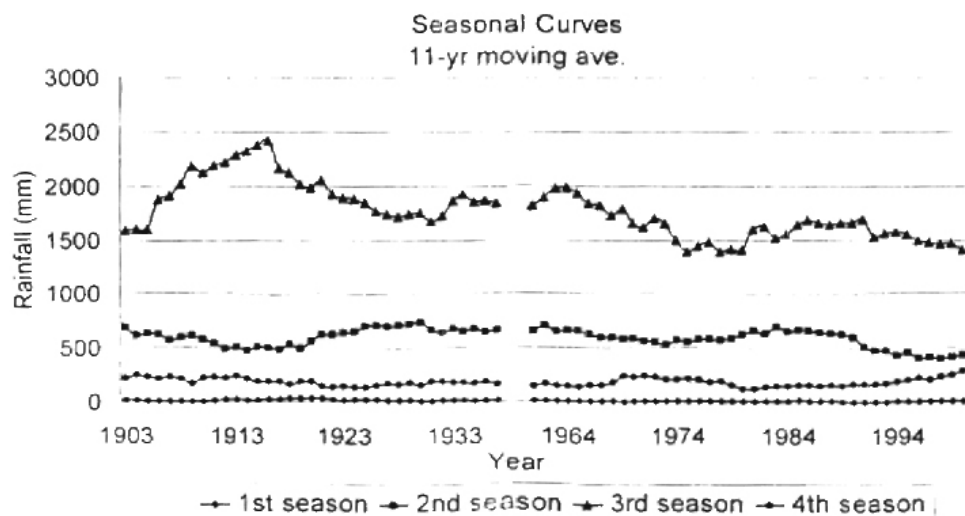
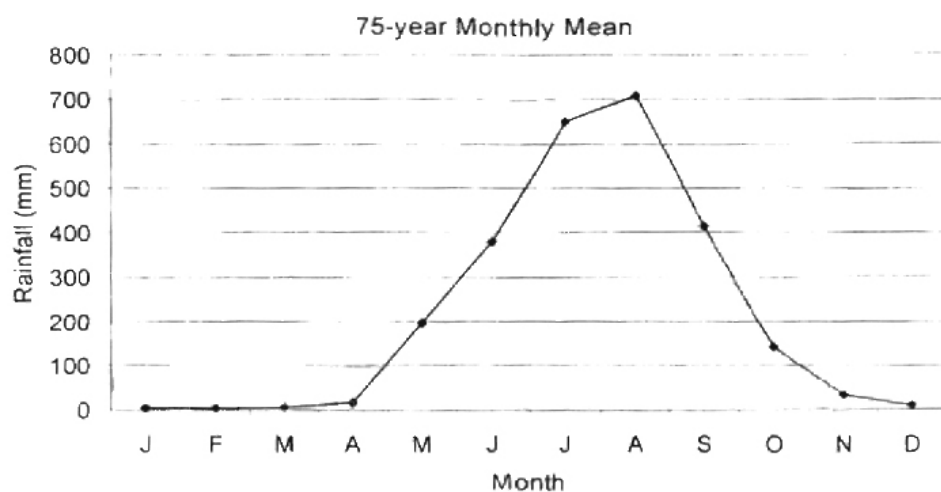
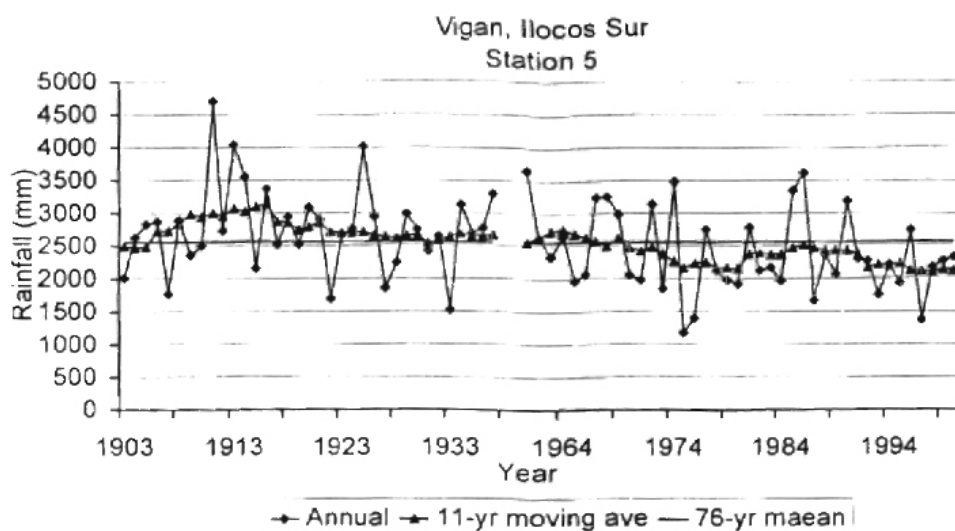


Figure A5. Station 5, Vigan, Ilocos Sur.

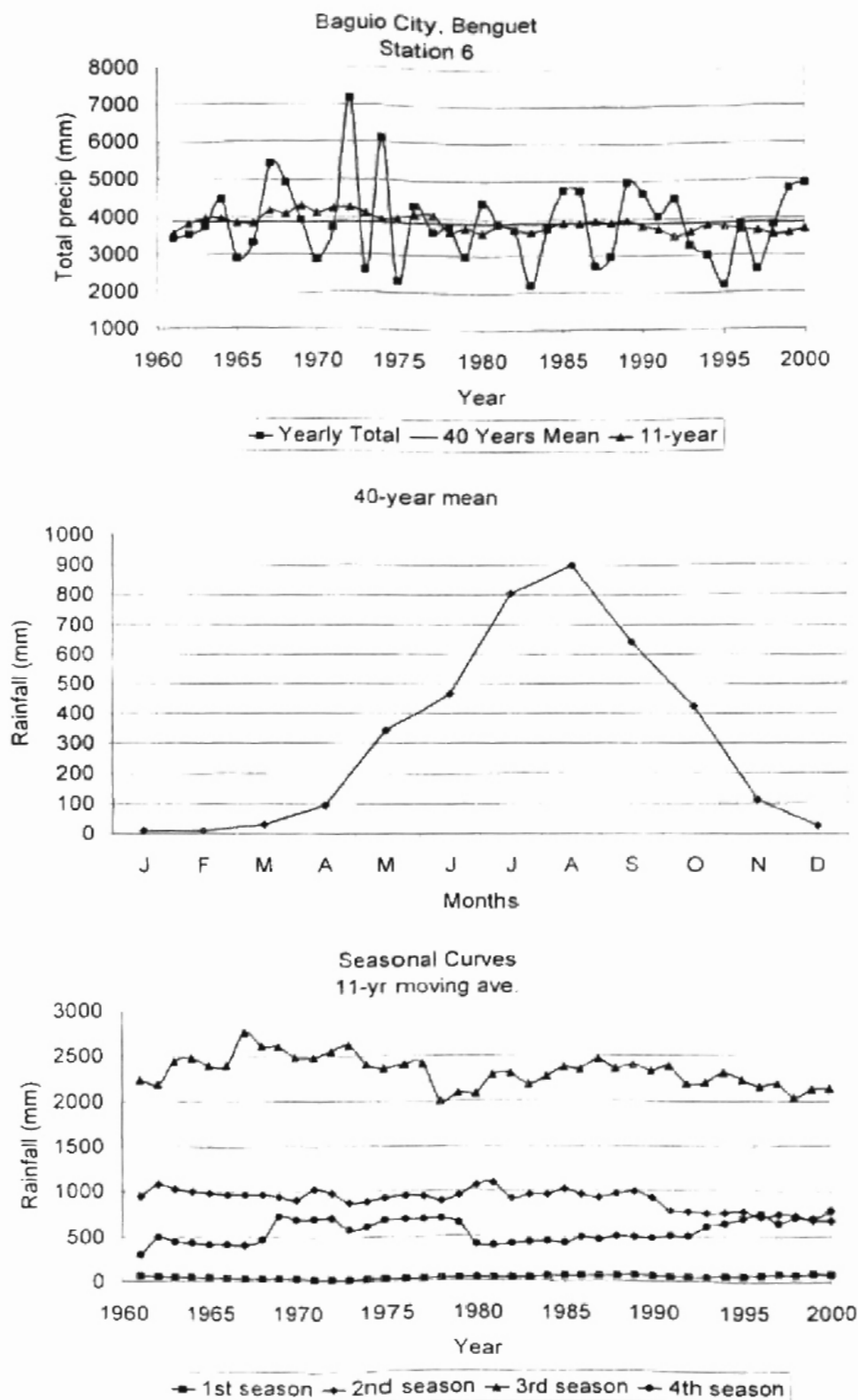


Figure A6. Station 6, Baguio City, Benguet.

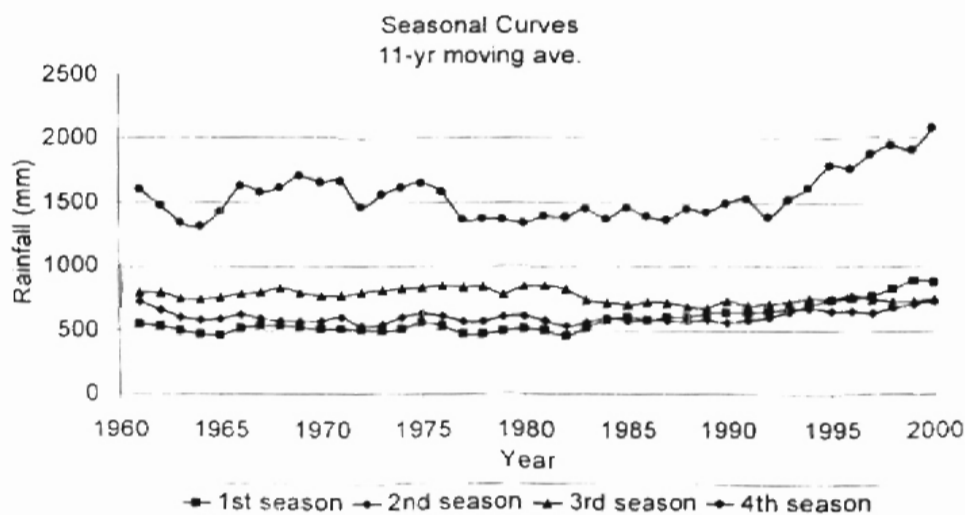
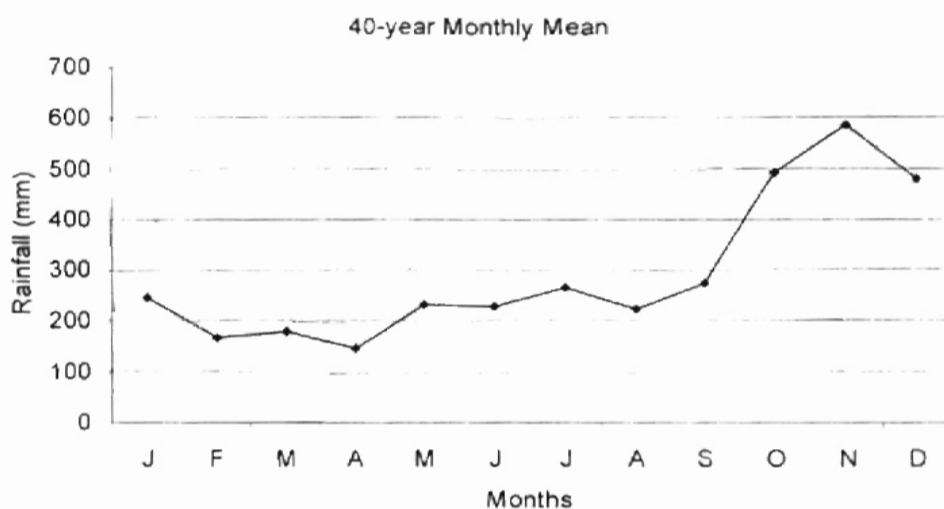
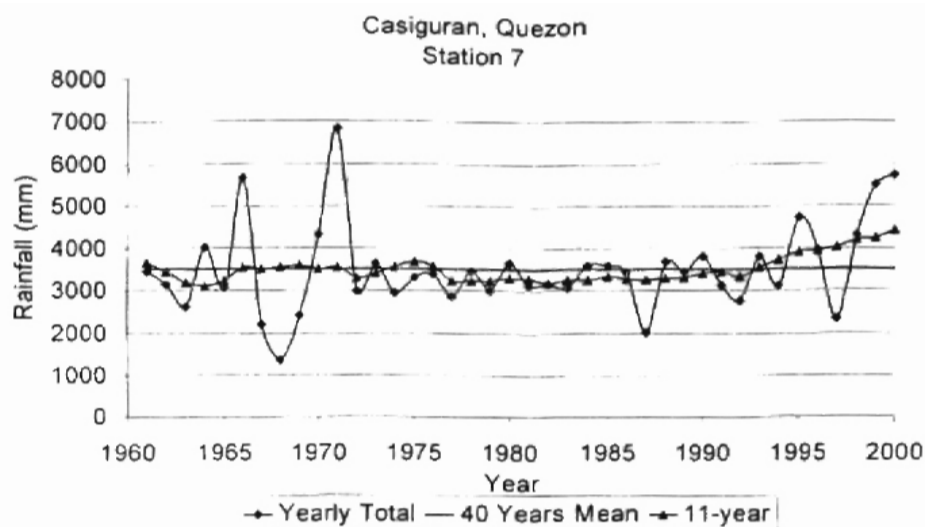


Figure A7. Station 7, Casiguran, Quezon.

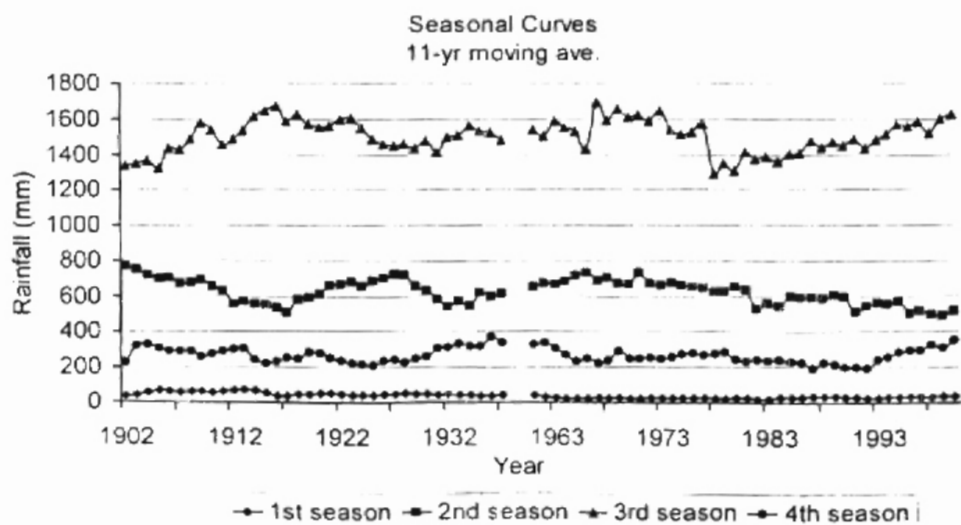
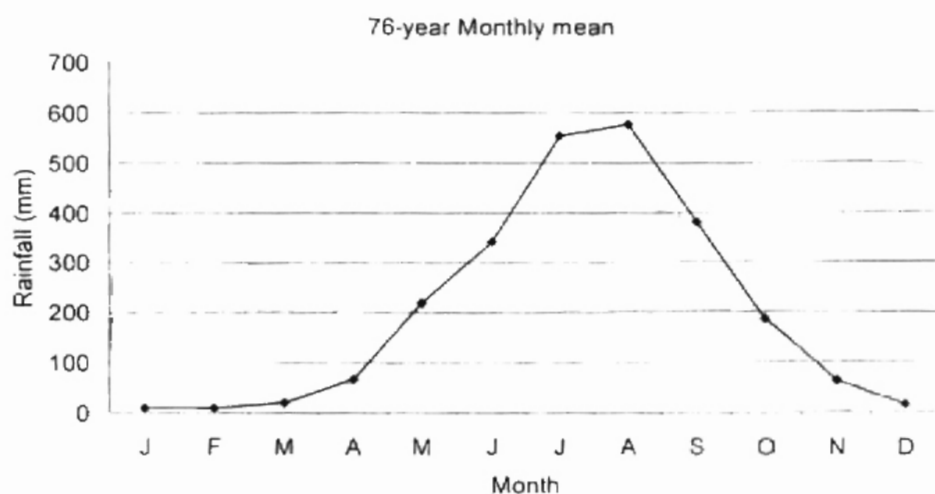
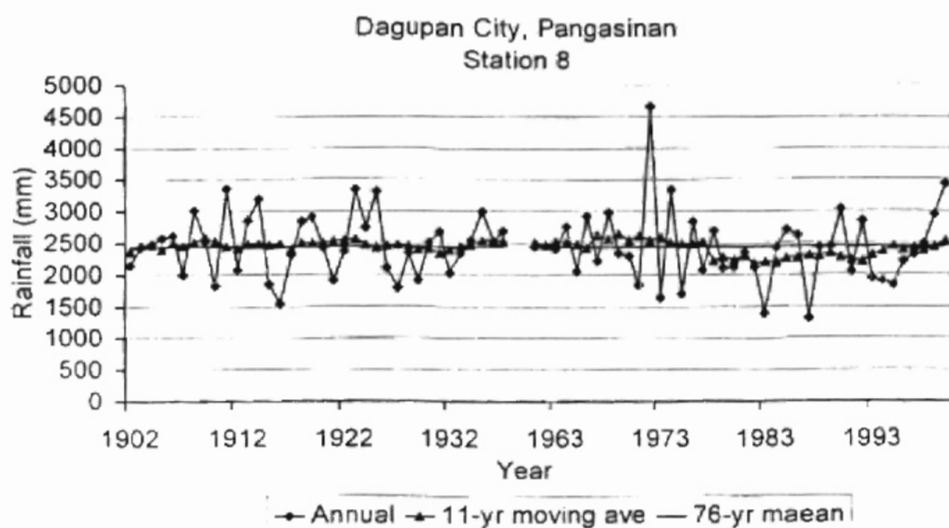


Figure A8. Station 8, Dagupan City, Pangasinan.

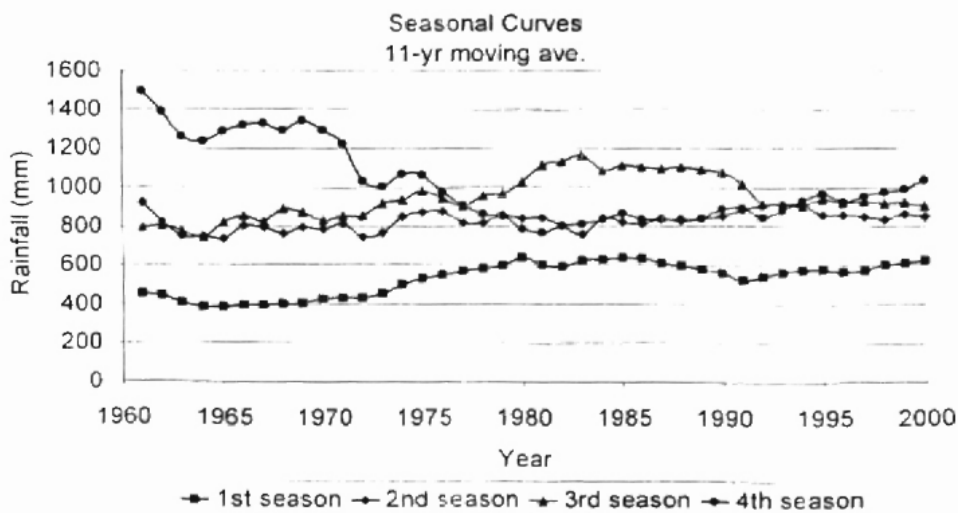
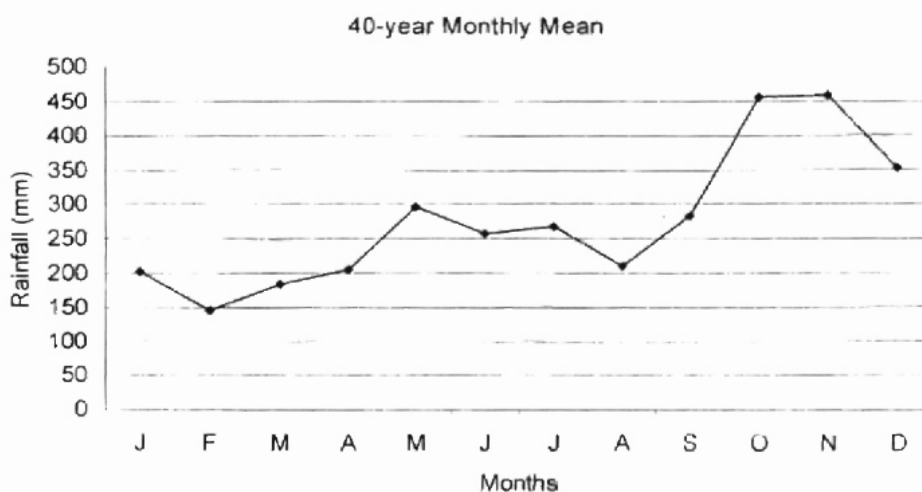
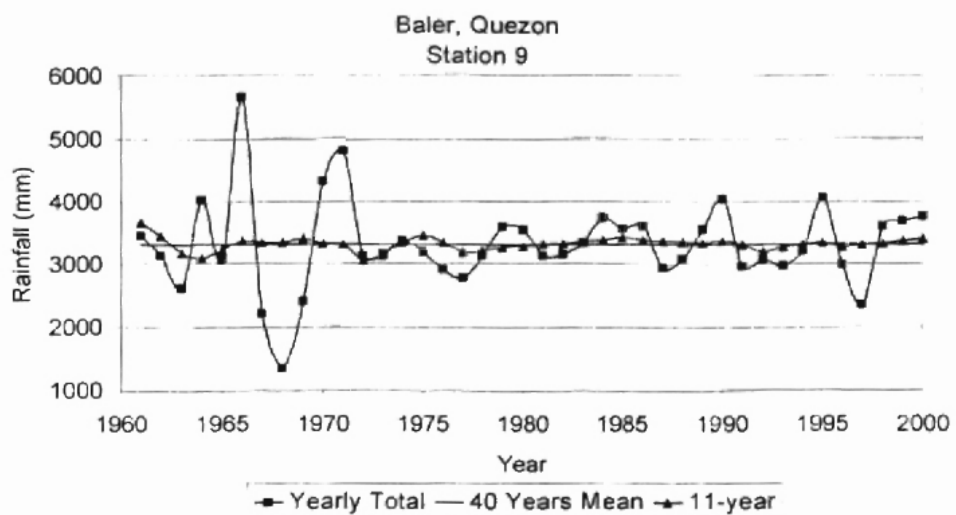


Figure A9. Station 9, Baler, Quezon.

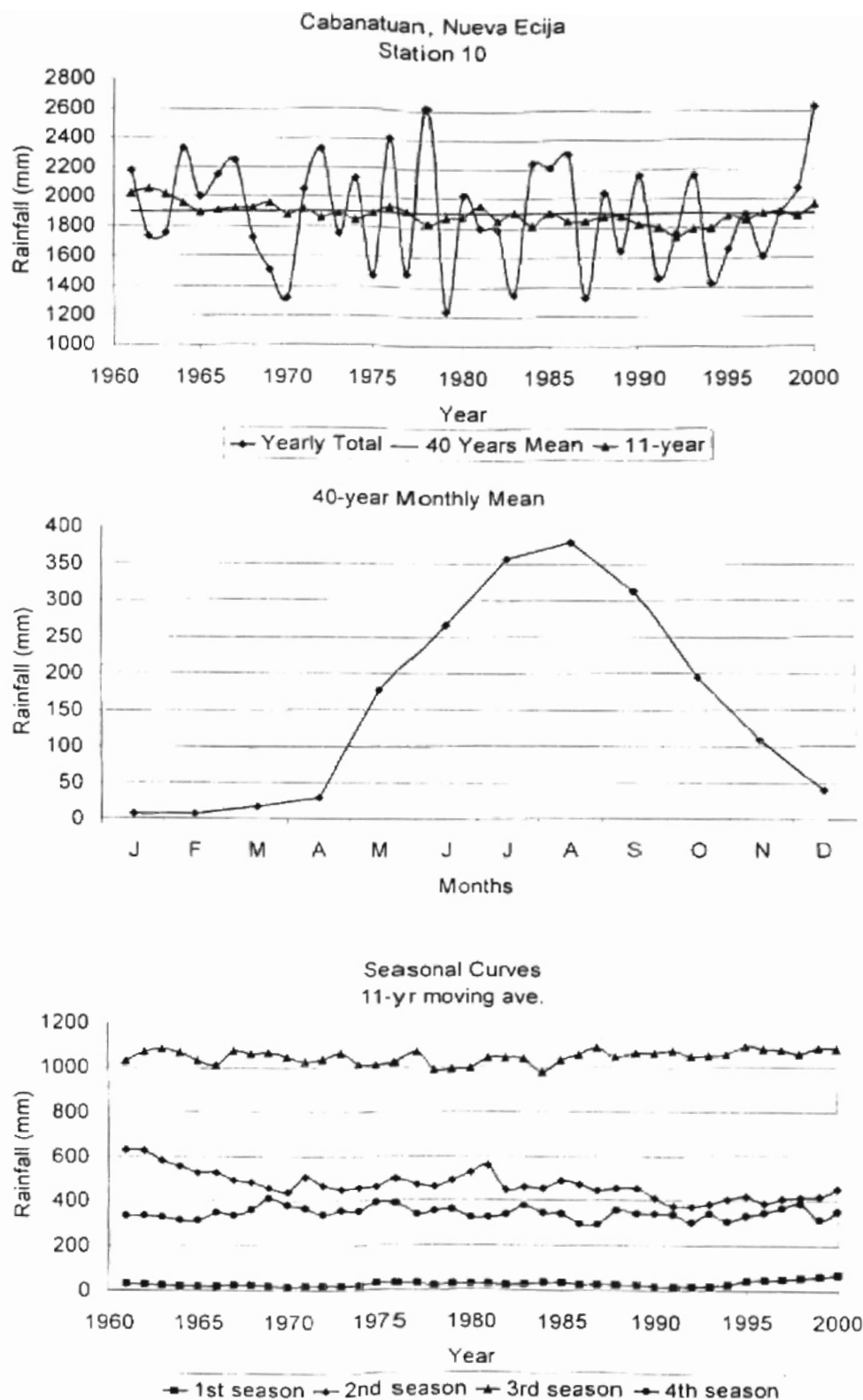


Figure A10. Station 10, Cabanatuan, Nueva Ecija.

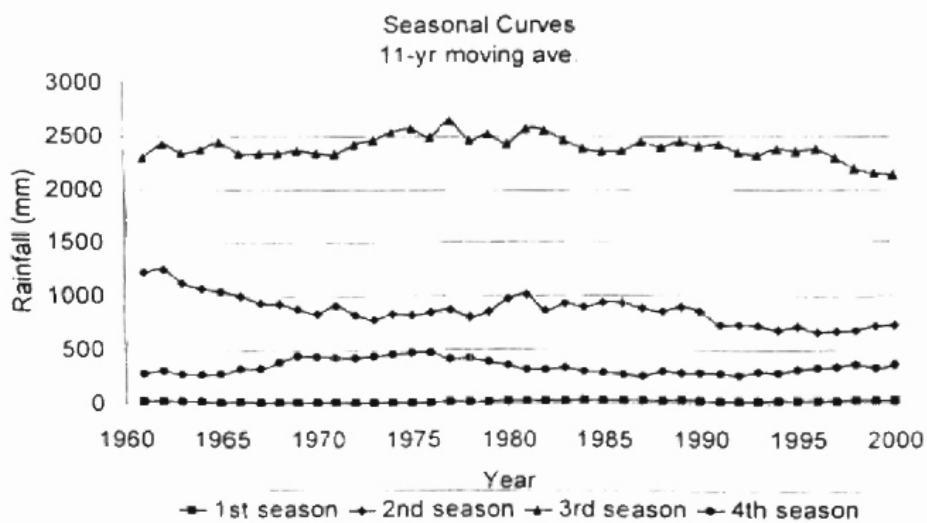
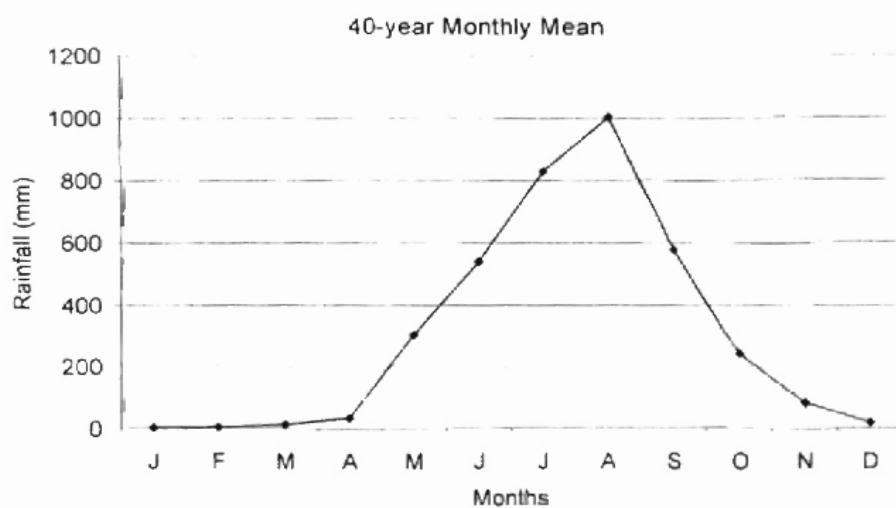
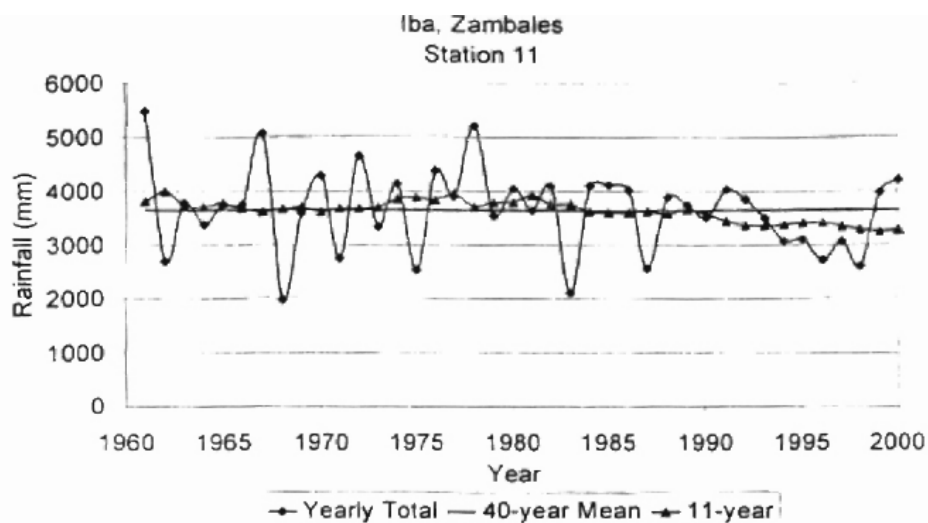


Figure A11. Station 11, Iba, Zamabales.

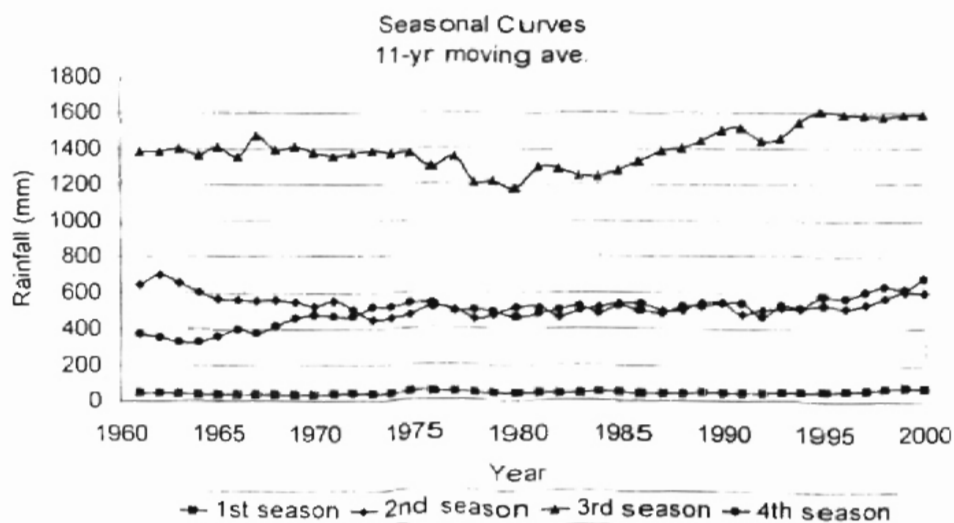
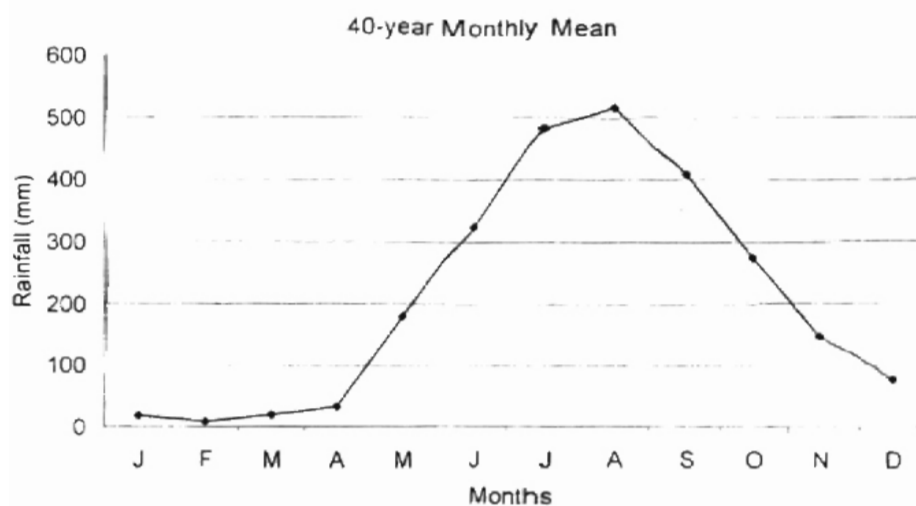
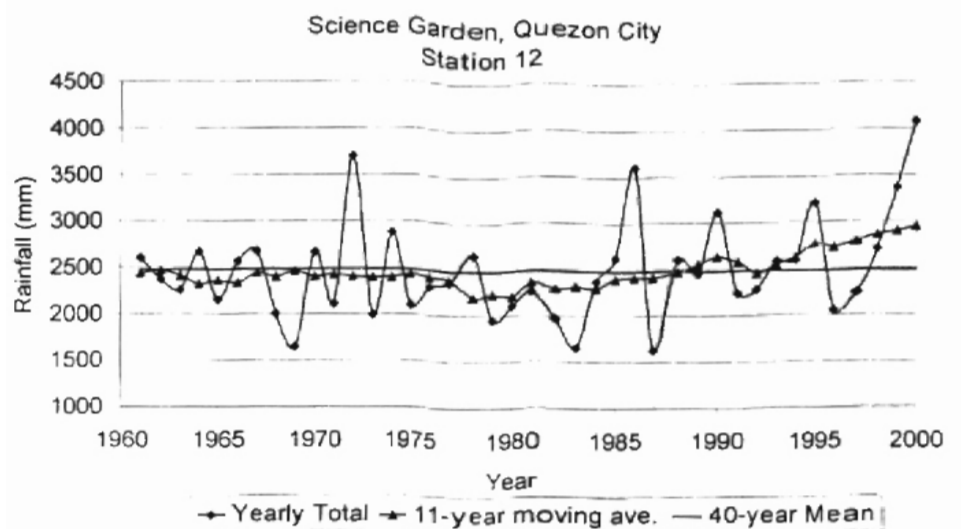


Figure A12. Station 12, Science Garden, Quezon City.

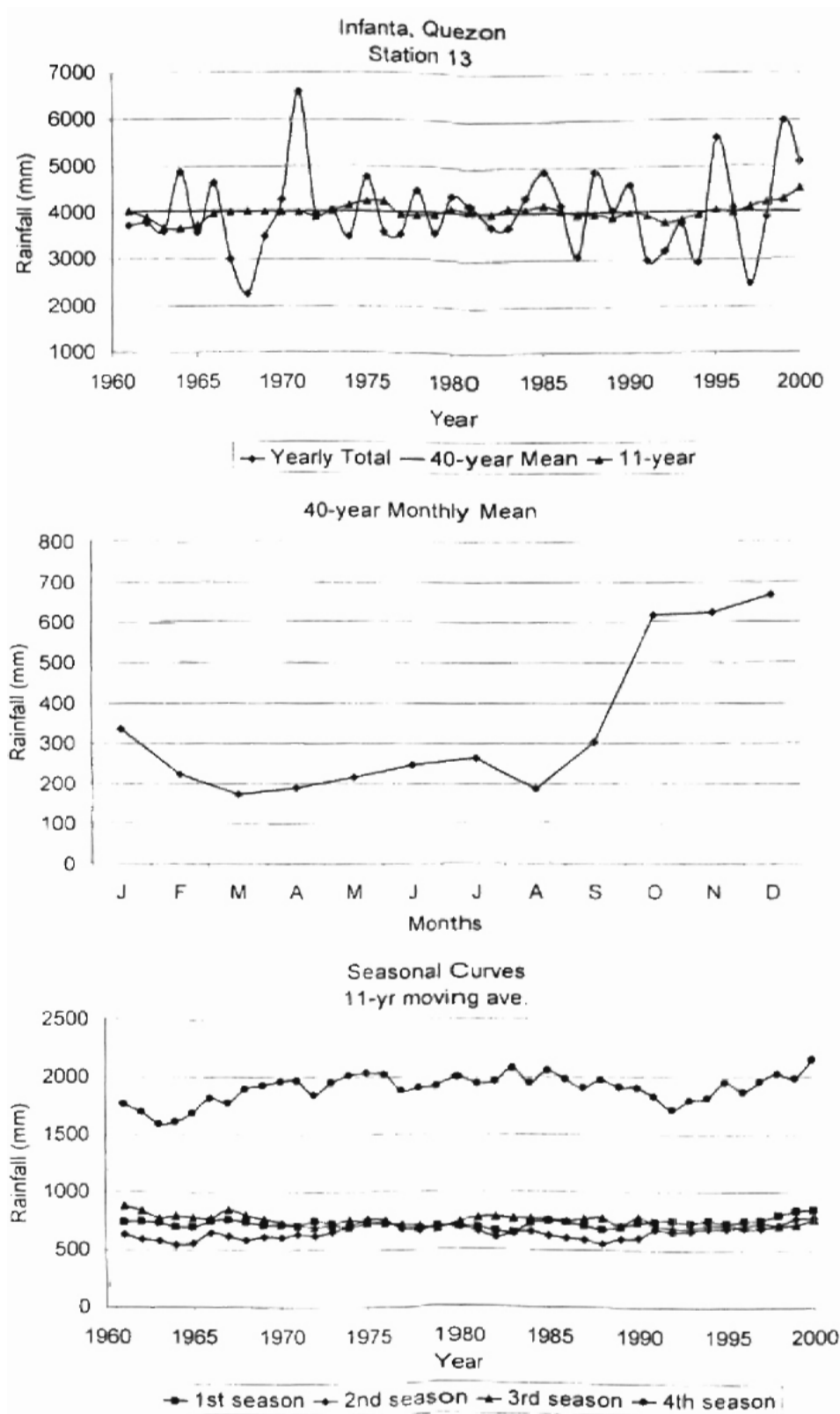


Figure A13. Station 13, Infanta, Quezon.

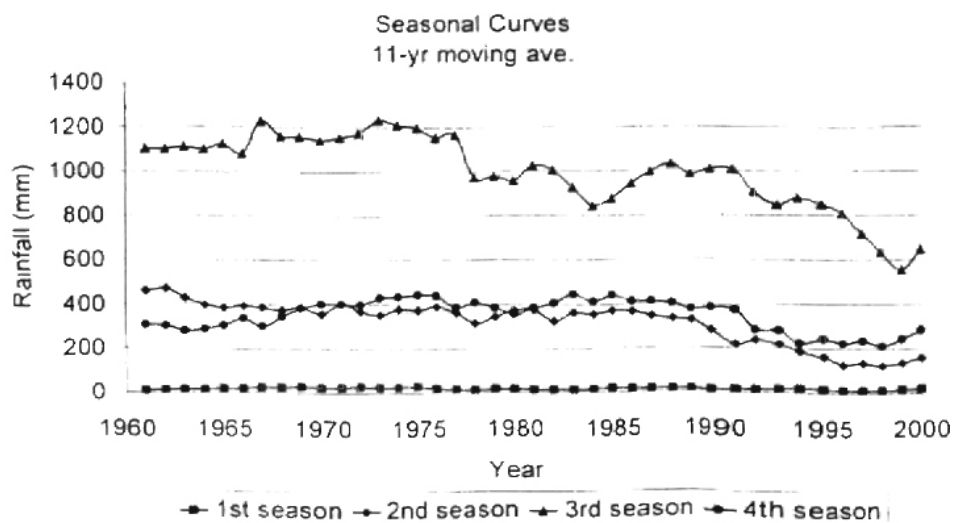
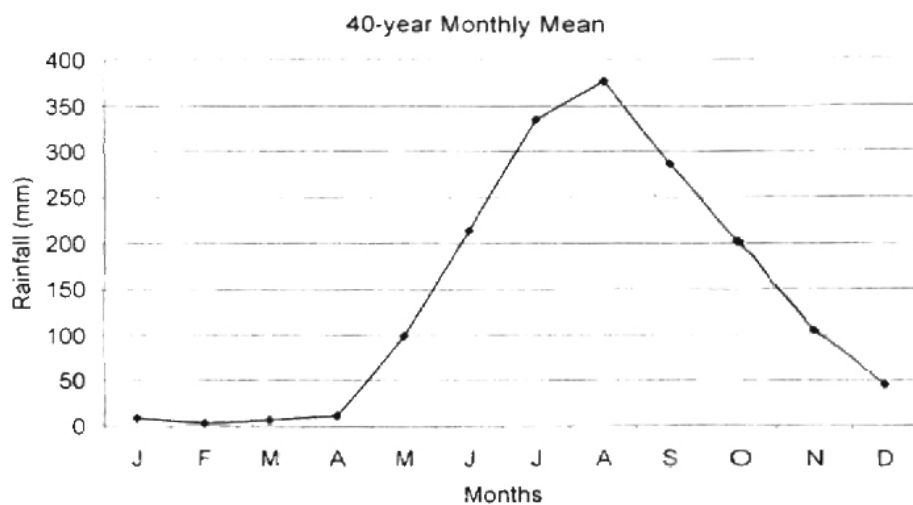
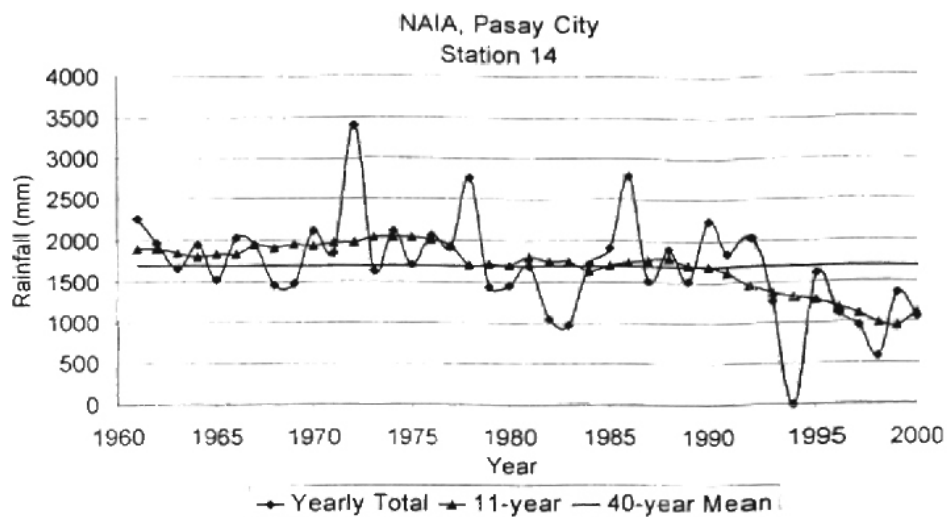
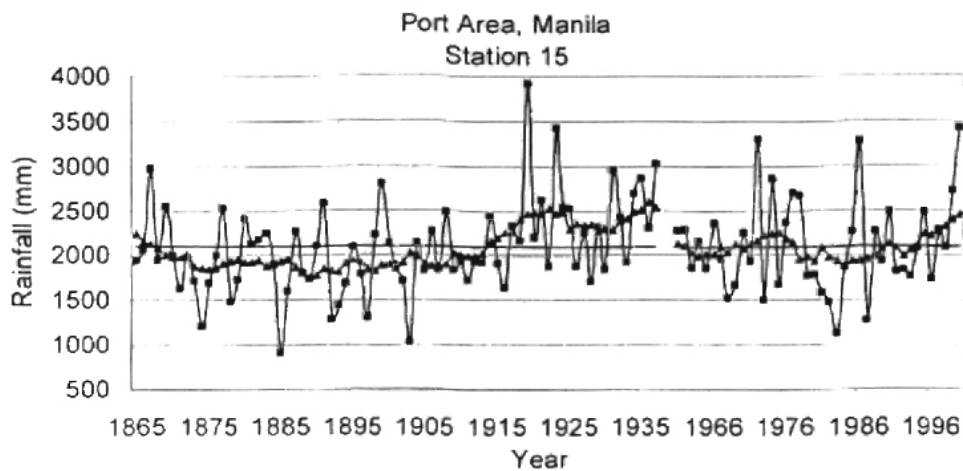


Figure A14. Station 14, NAIA, Pasay City.



— Annual — 11-yr moving ave — 113-yr mean

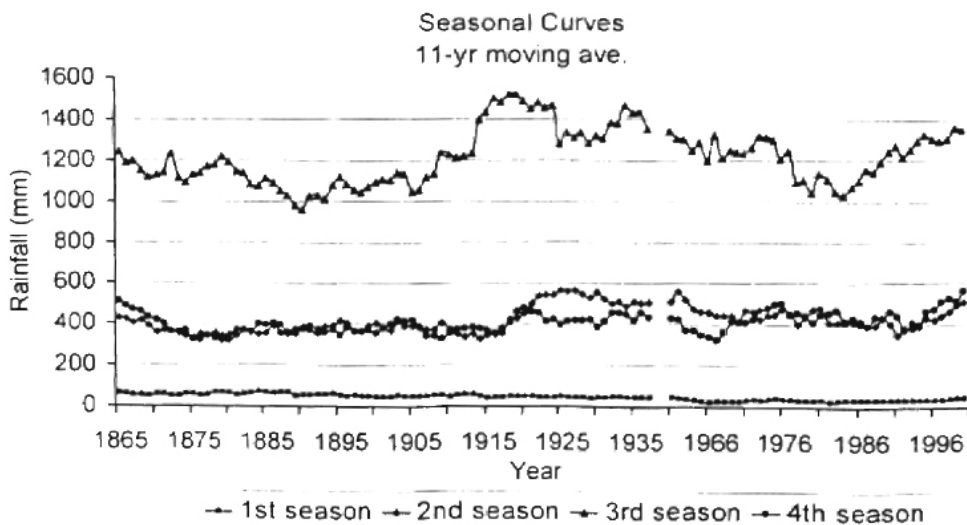
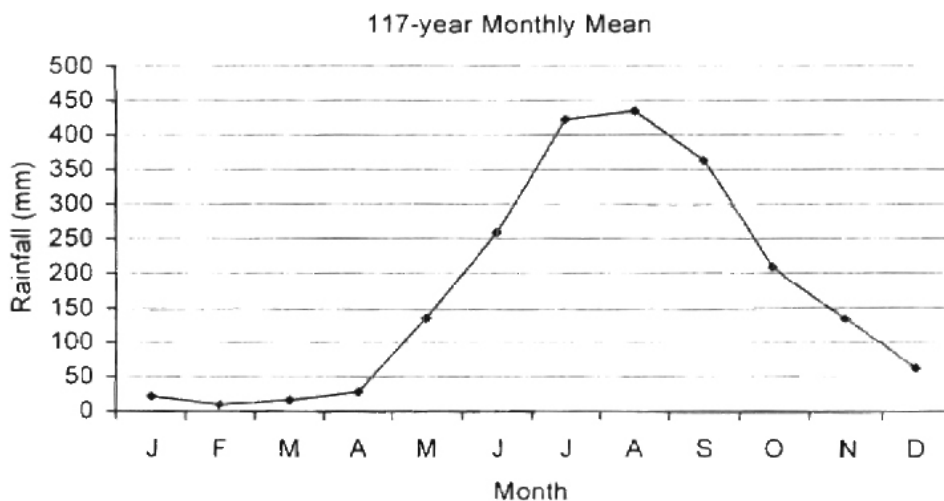


Figure A15. Station 15, Port Area, Manila.

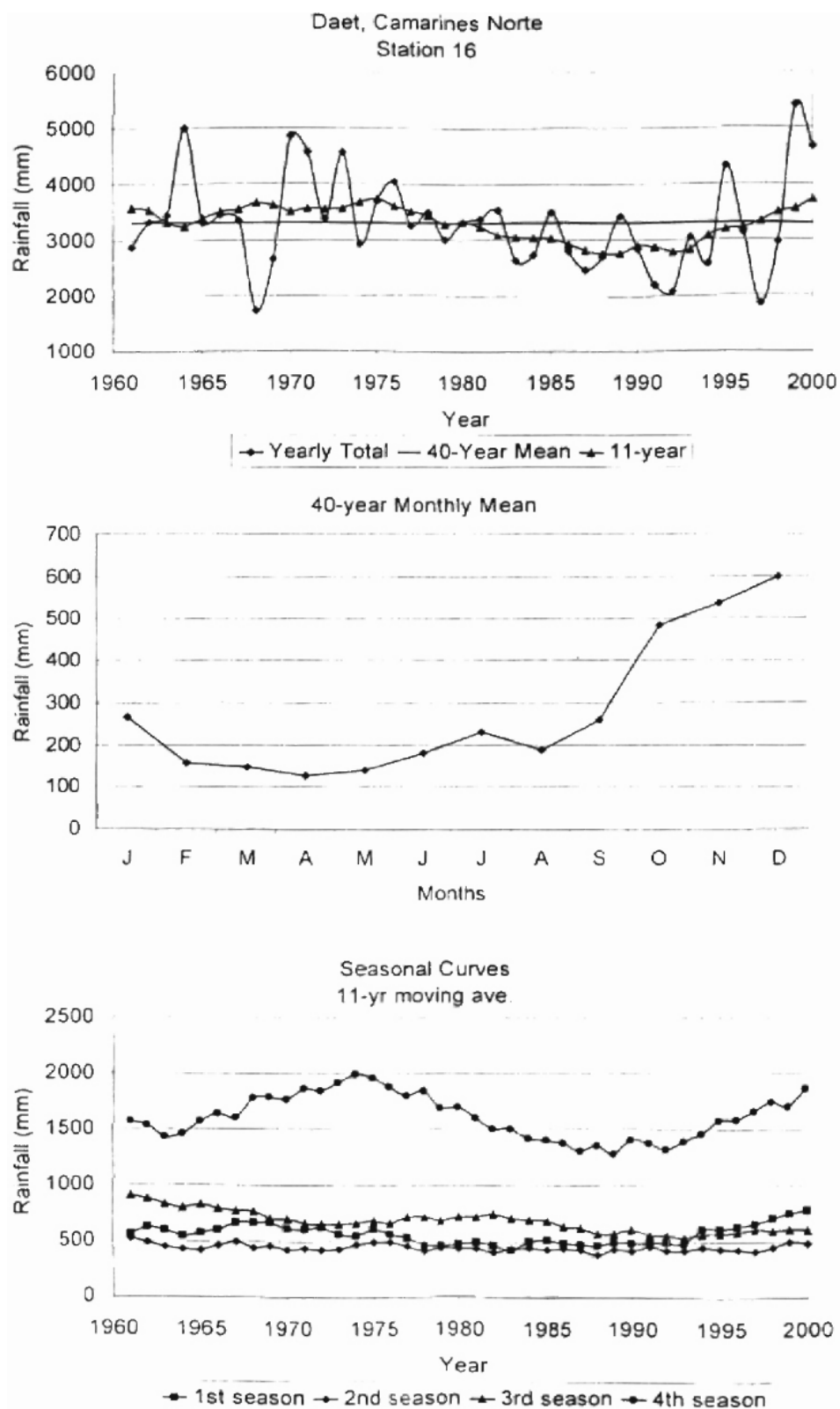


Figure A16. Station 16, Daet, Camarines Norte.

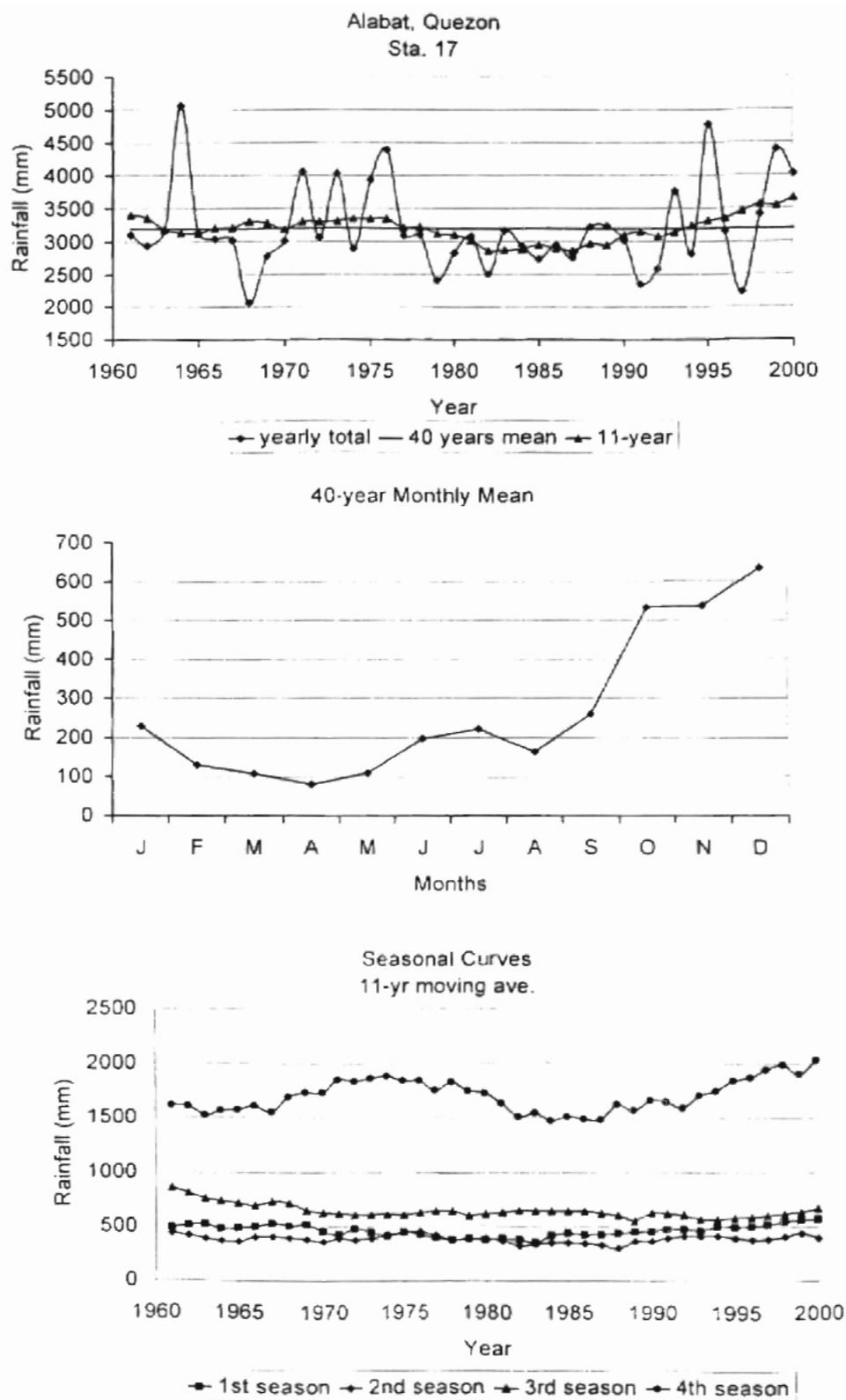


Figure A17. Station 17, Alabat, Quezon.

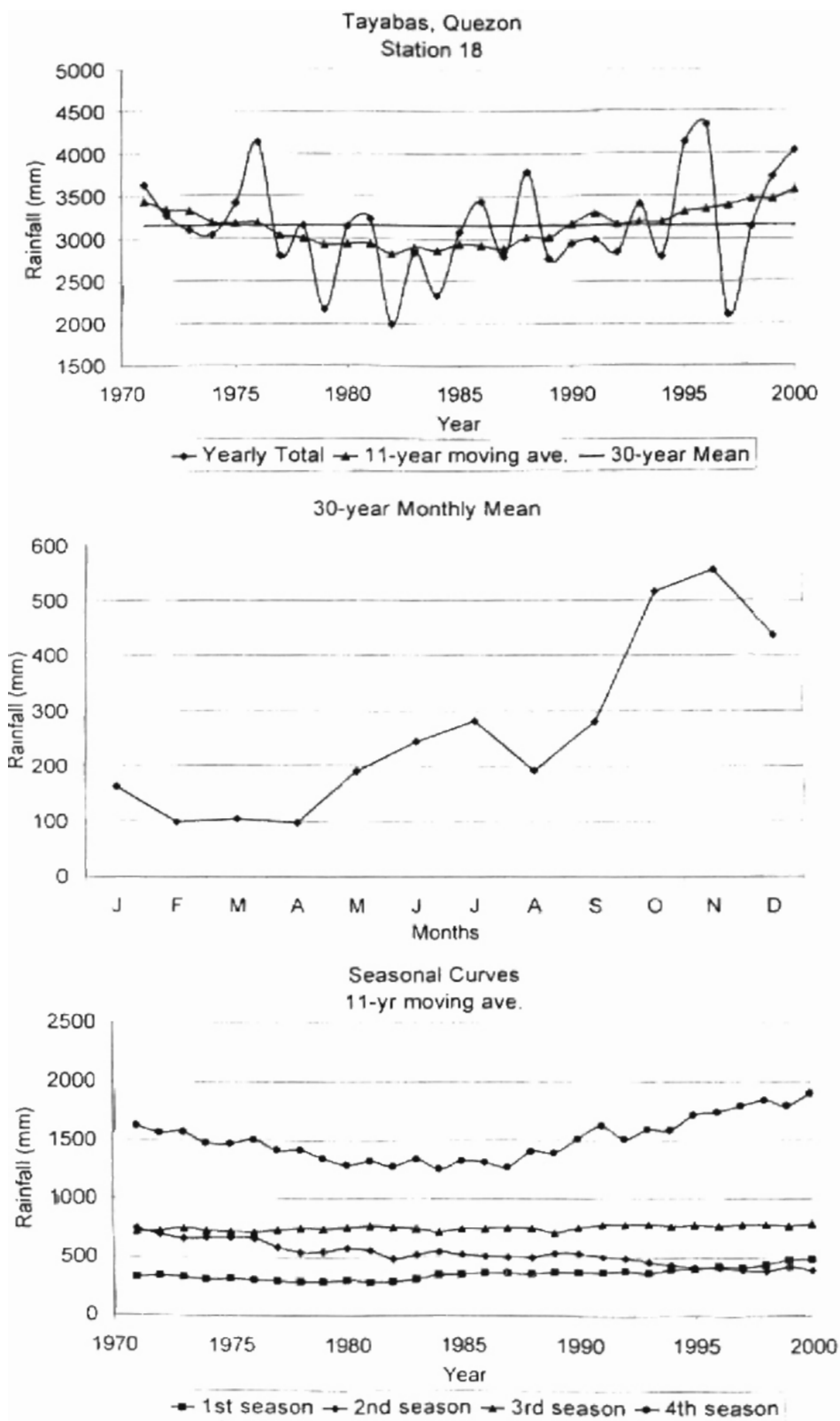


Figure A18. Station 18, Tayabas, Quezon.

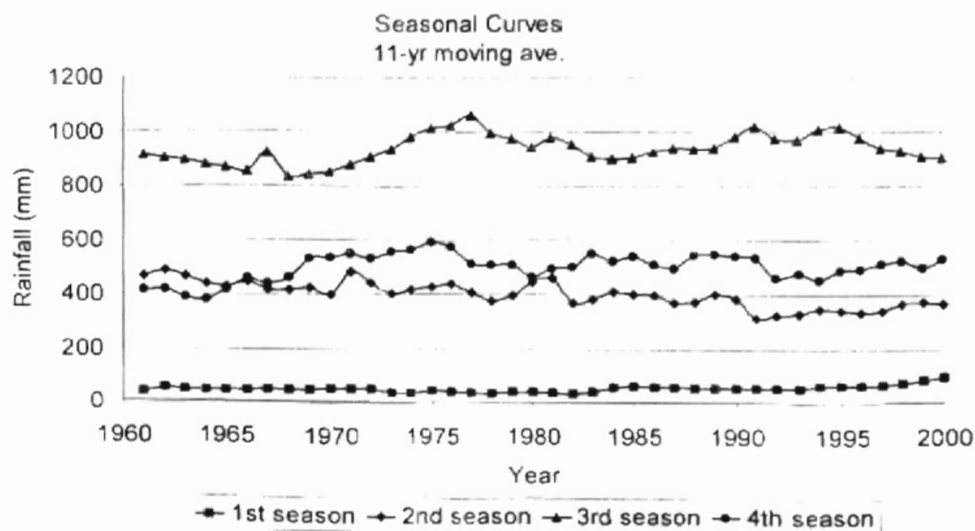
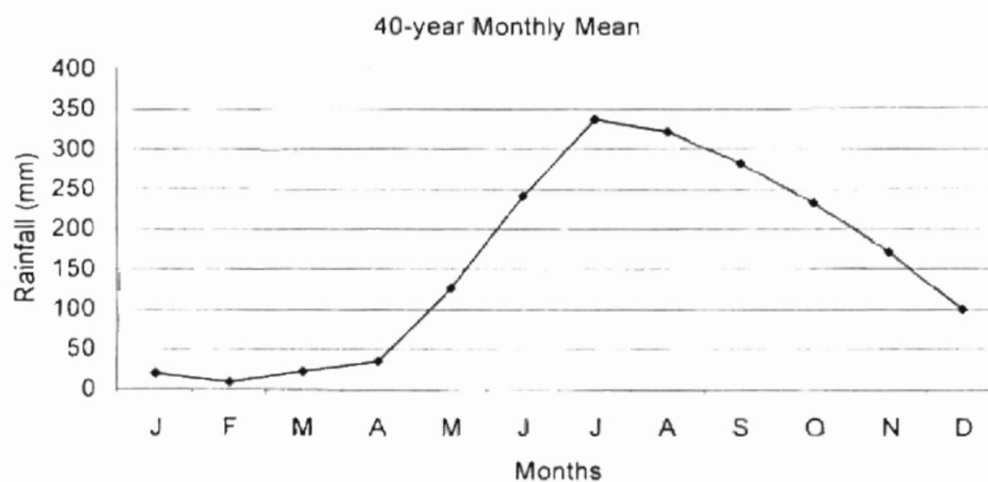
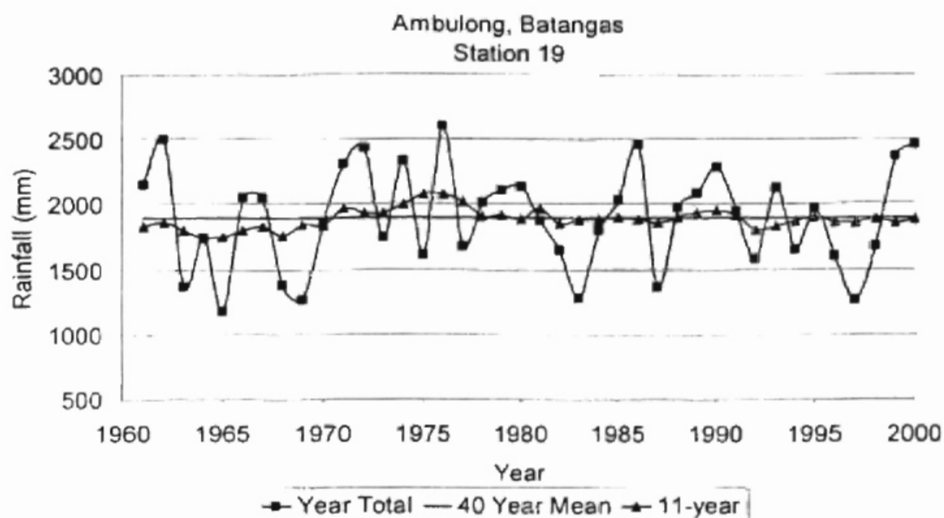


Figure A19. Station 19, Ambulong, Batangas.

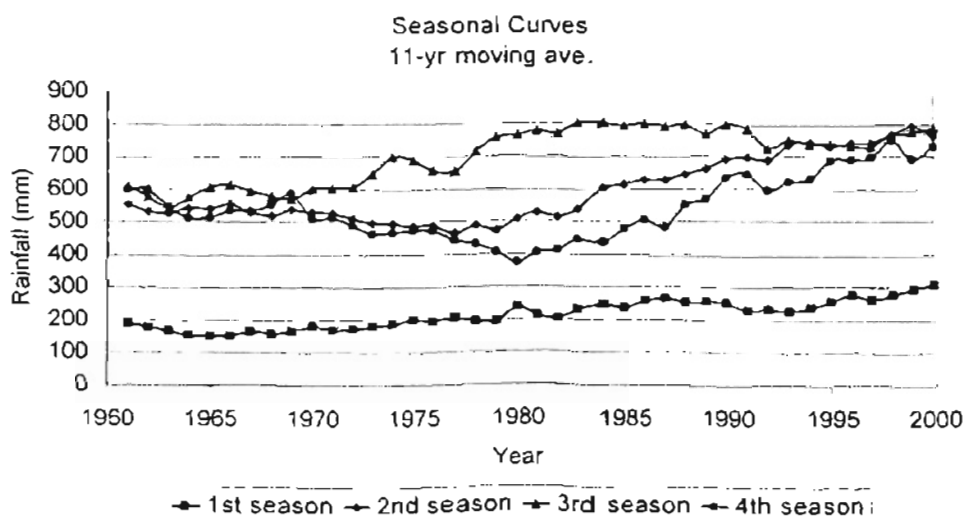
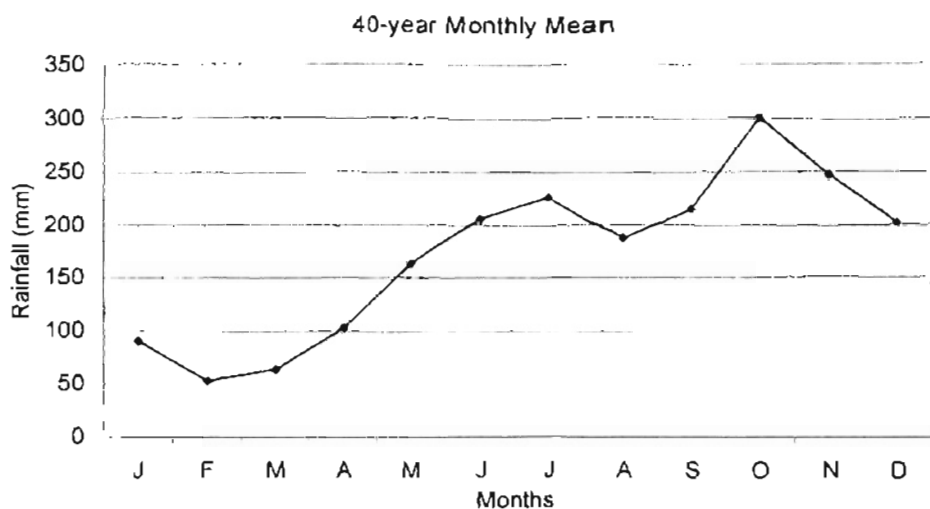
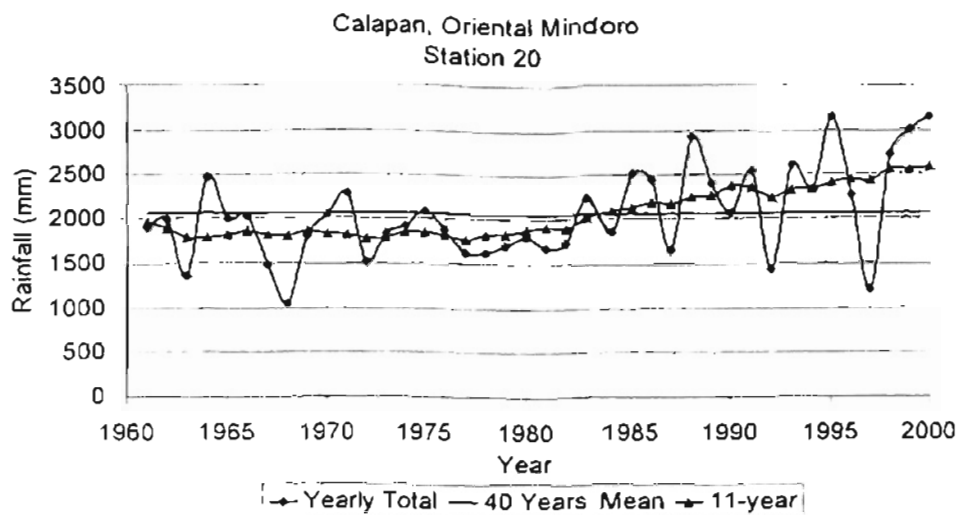


Figure A20. Station 20, Calapan, Oriental Mindoro.

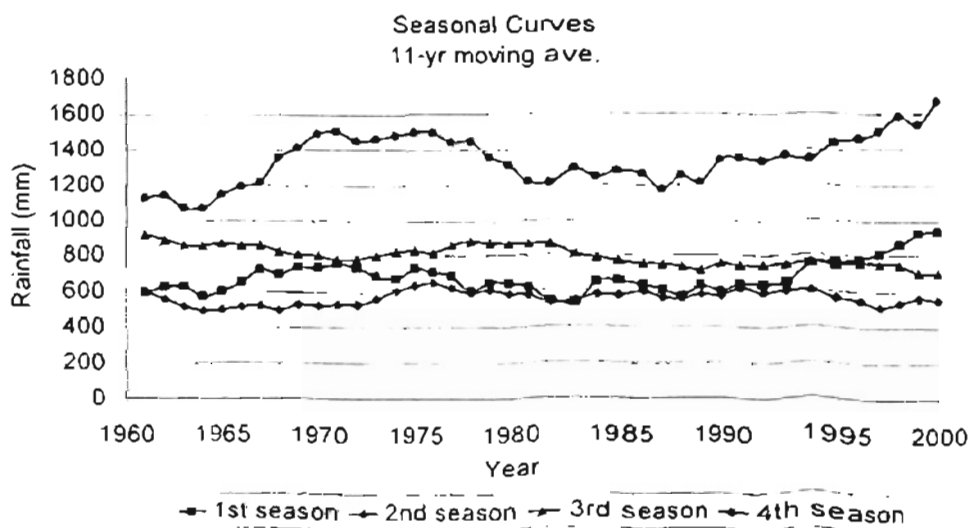
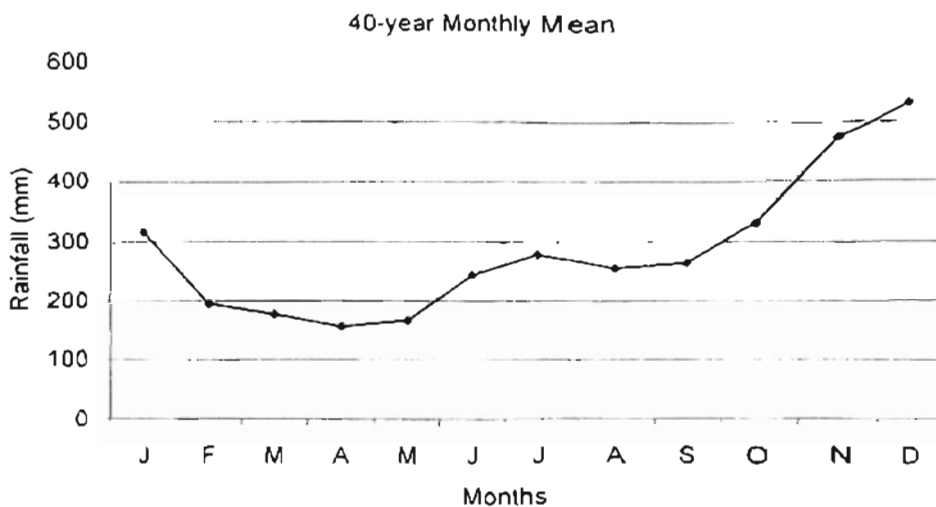
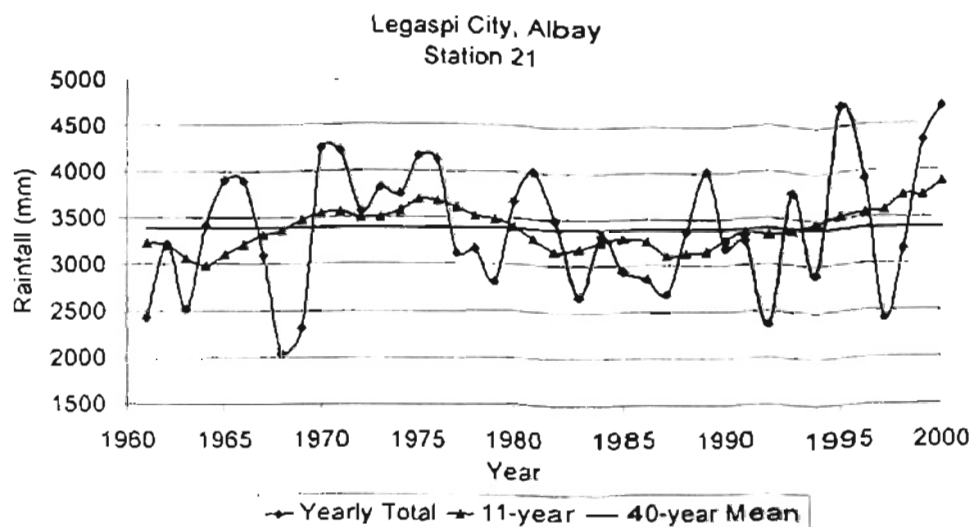


Figure A21. Station 21, Legaspi City, Albay.

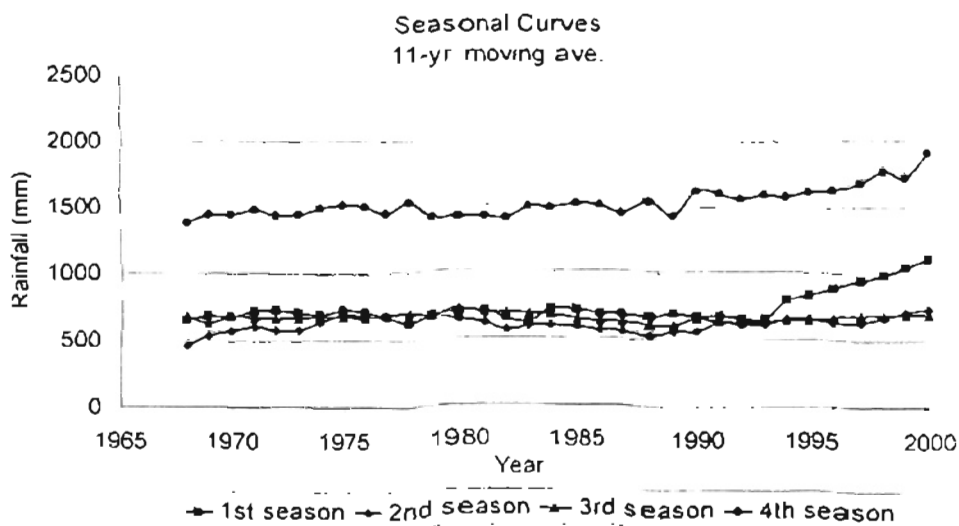
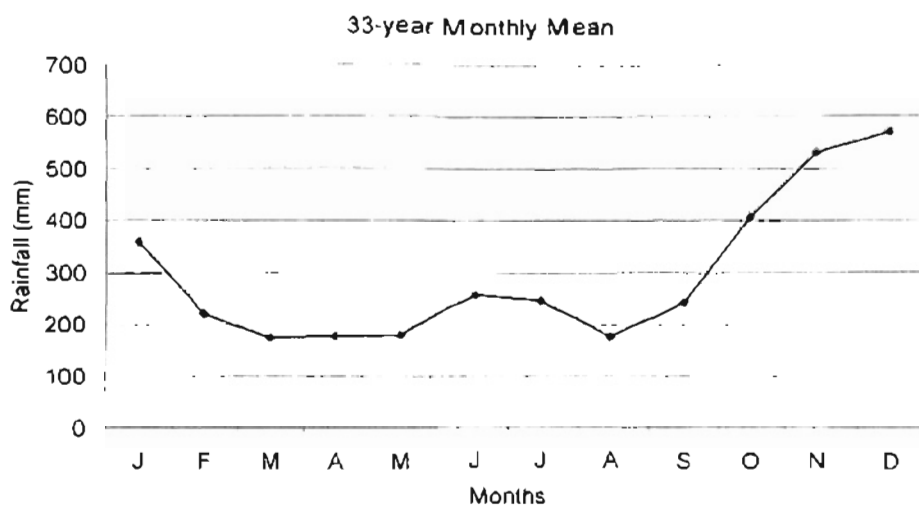
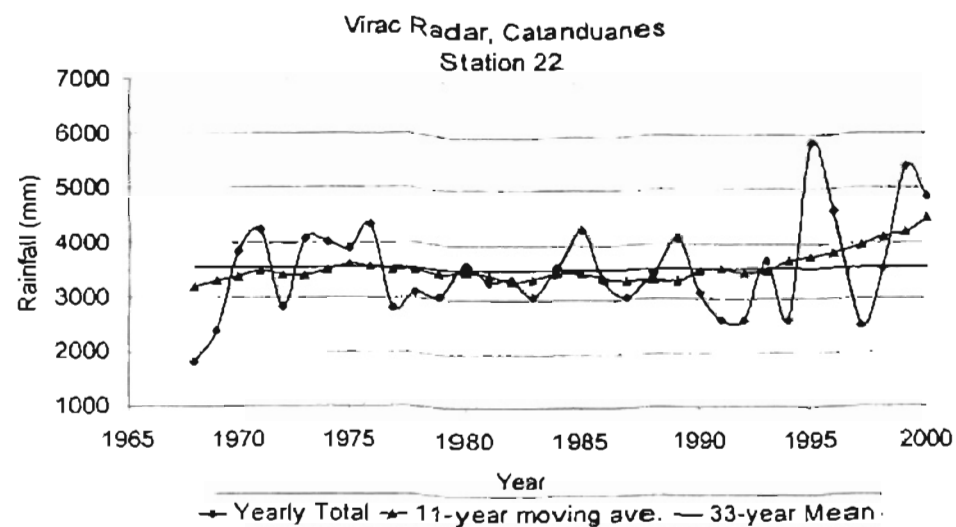


Figure A22. Station 22, Virac Radar, Catanduanes.

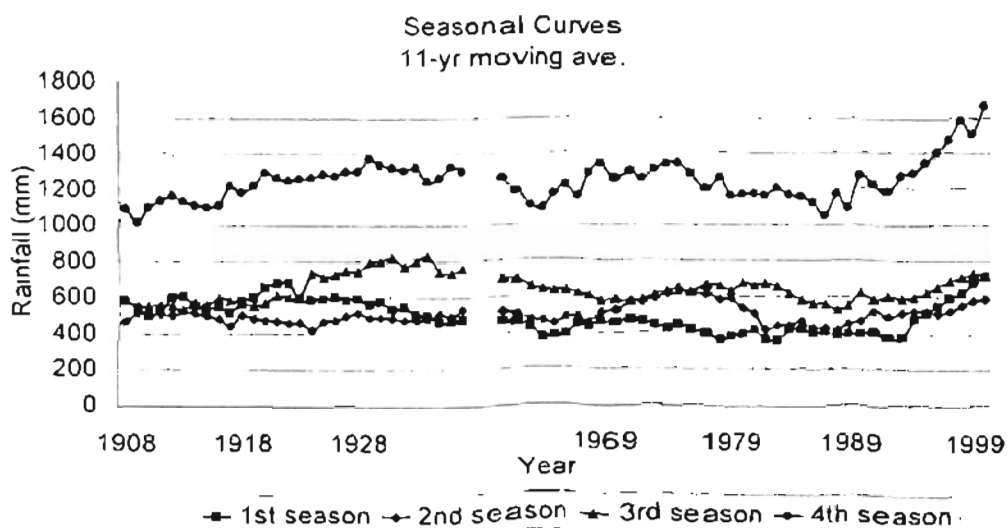
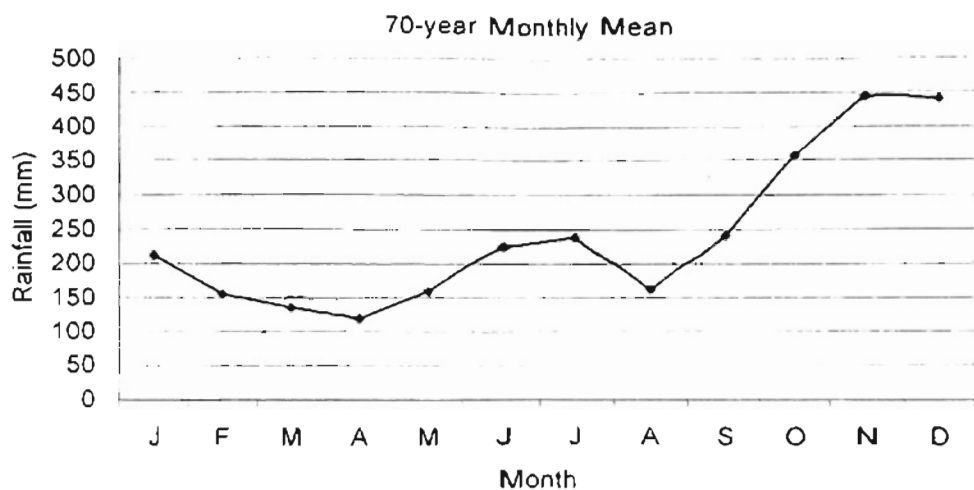
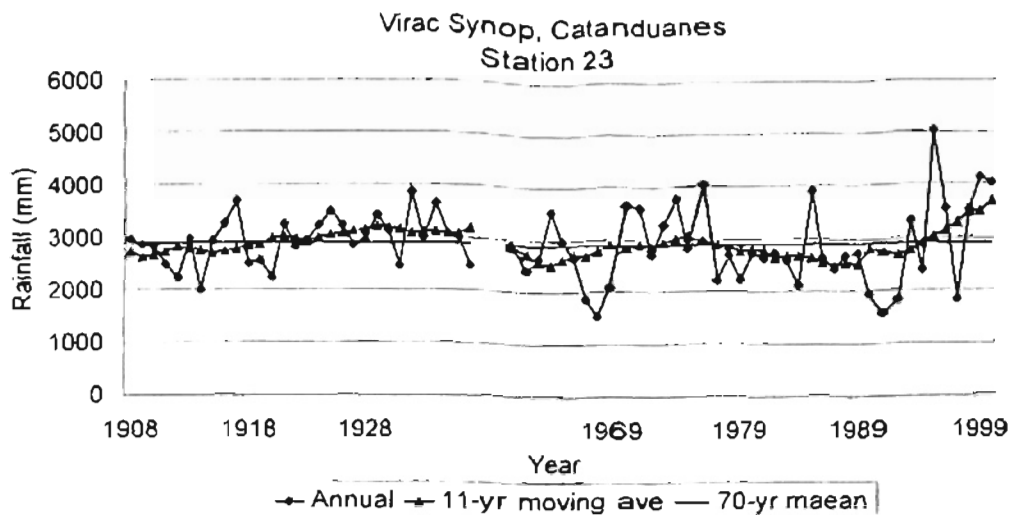


Figure A23. Station 23, Virac Synop, Catanduanes.

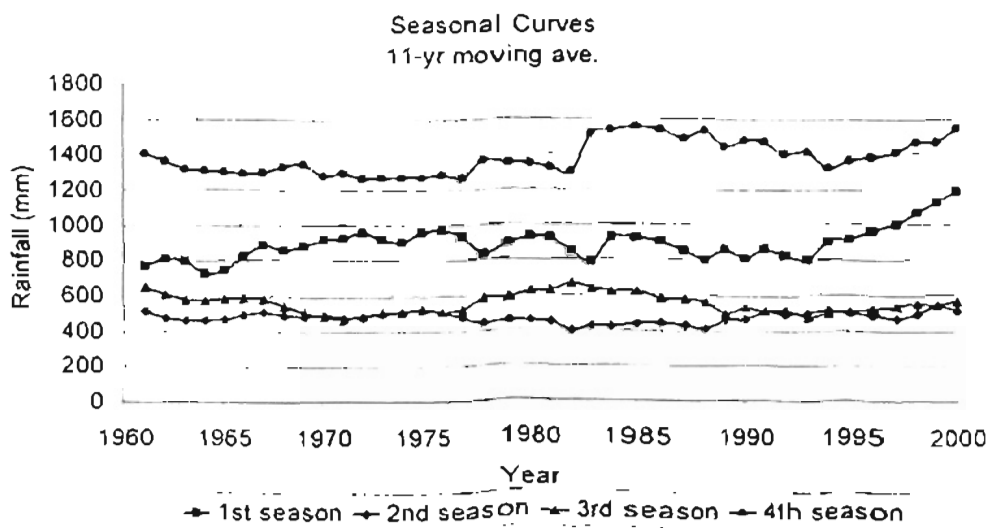
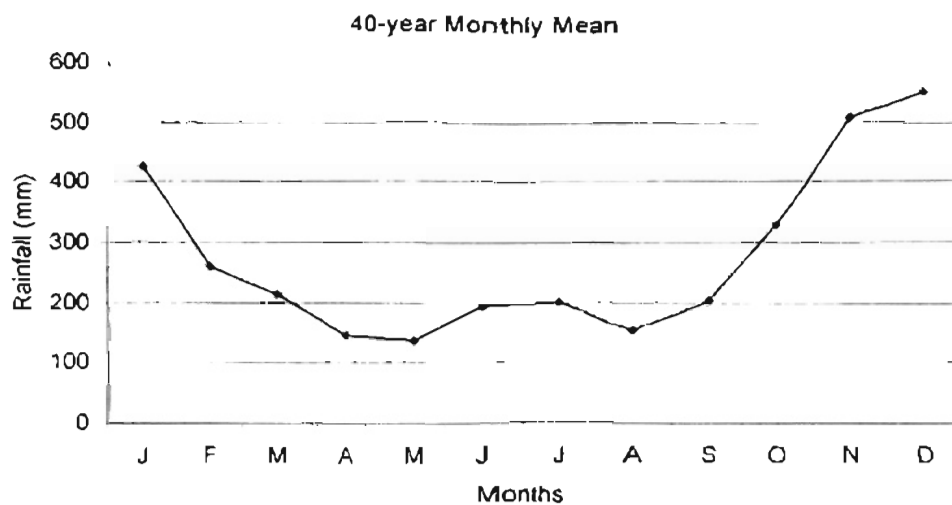
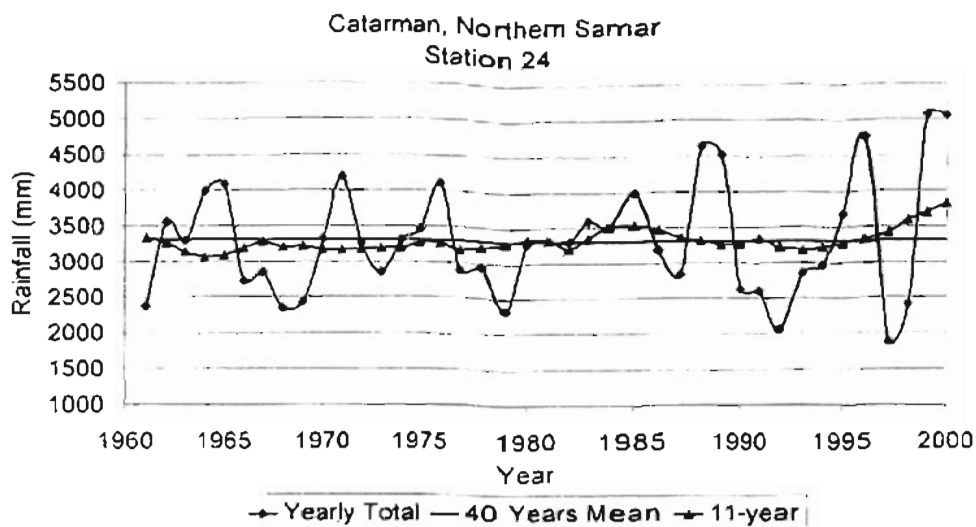


Figure A24. Station 24, Catarman, Northern Samar.

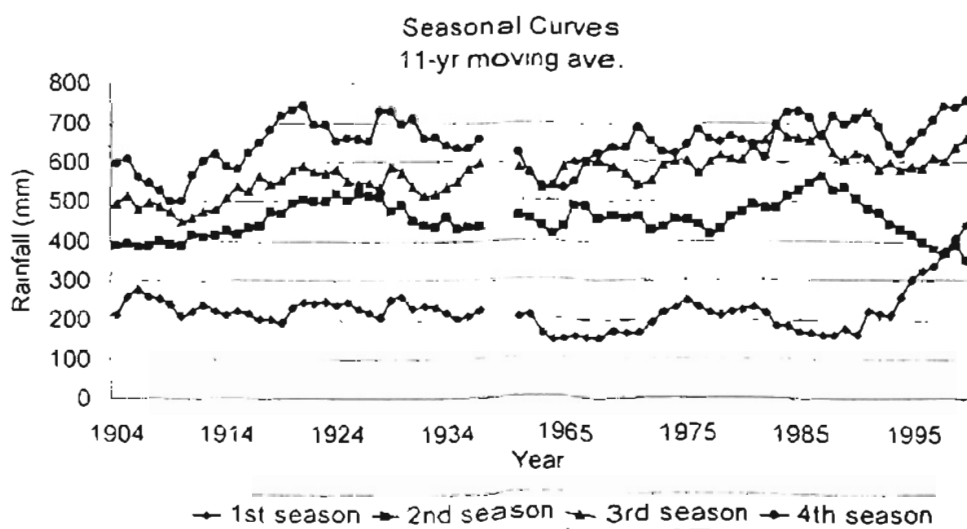
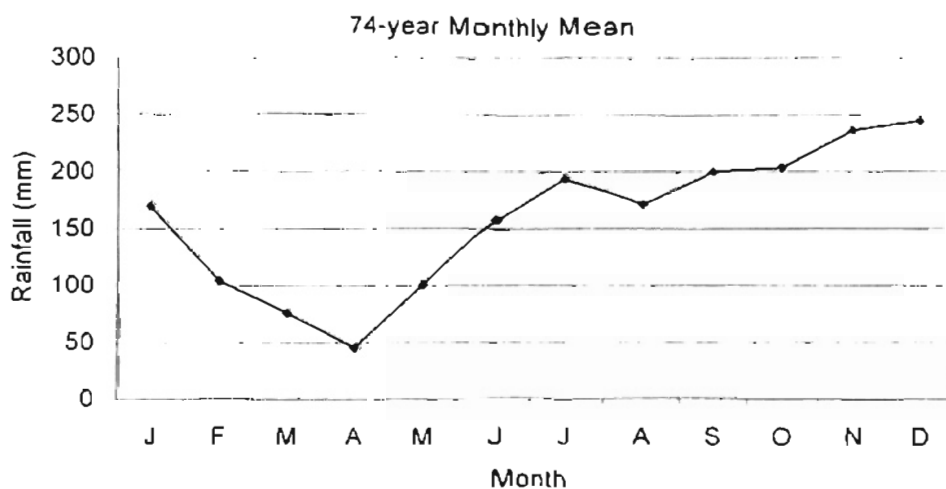
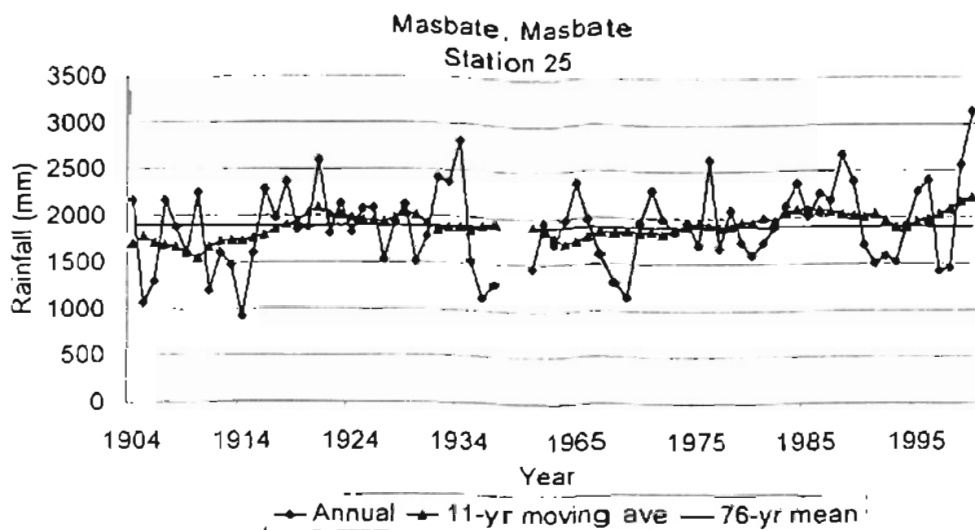


Figure A25. Station 25, Masbate, Masbate.

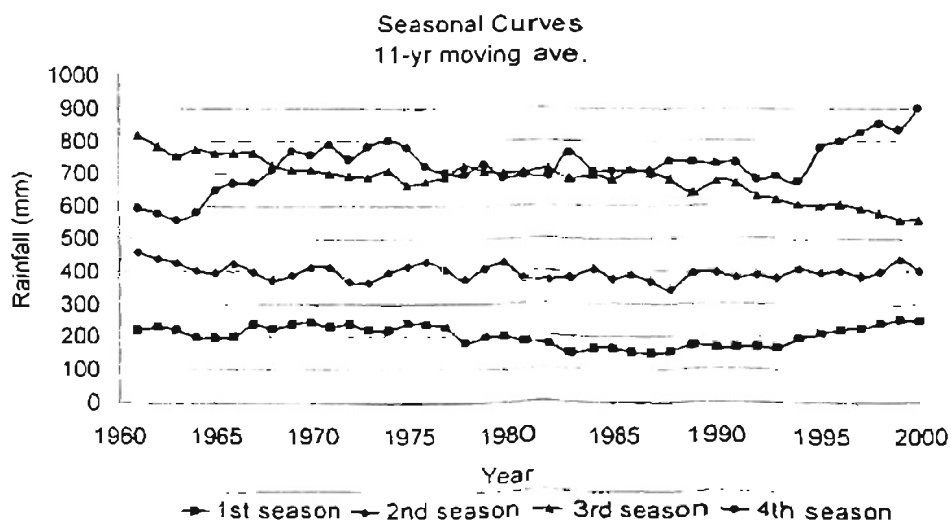
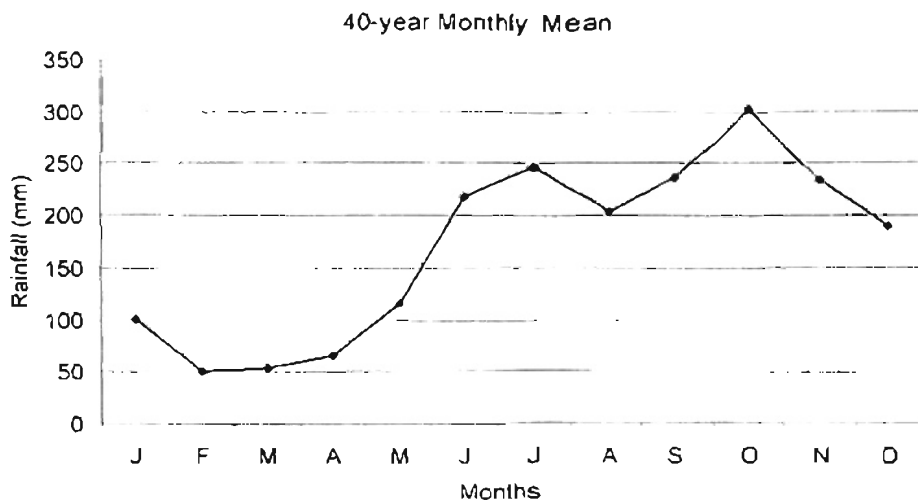
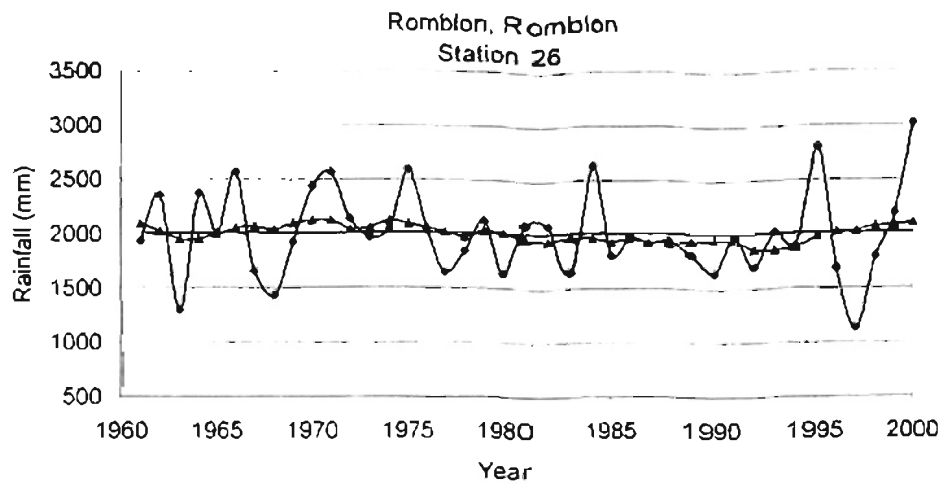


Figure A26. Station 26, Romblon. Romblon.

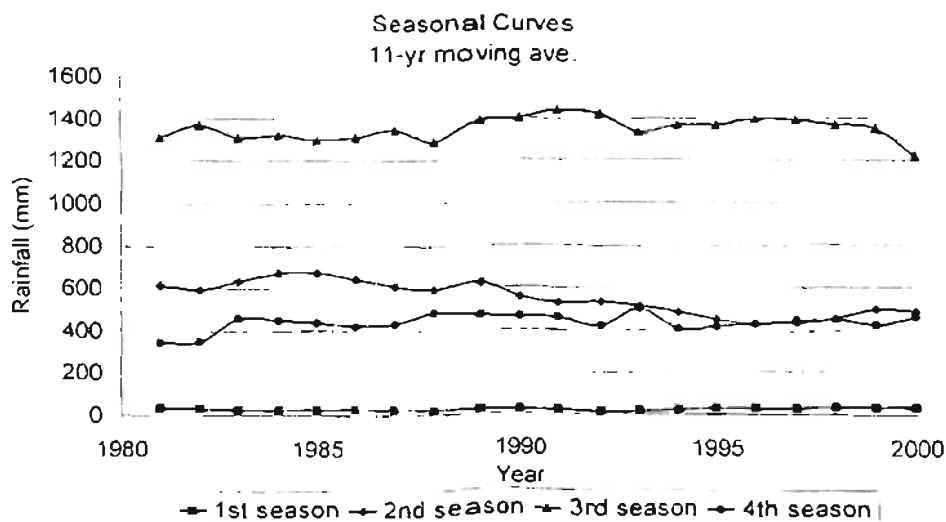
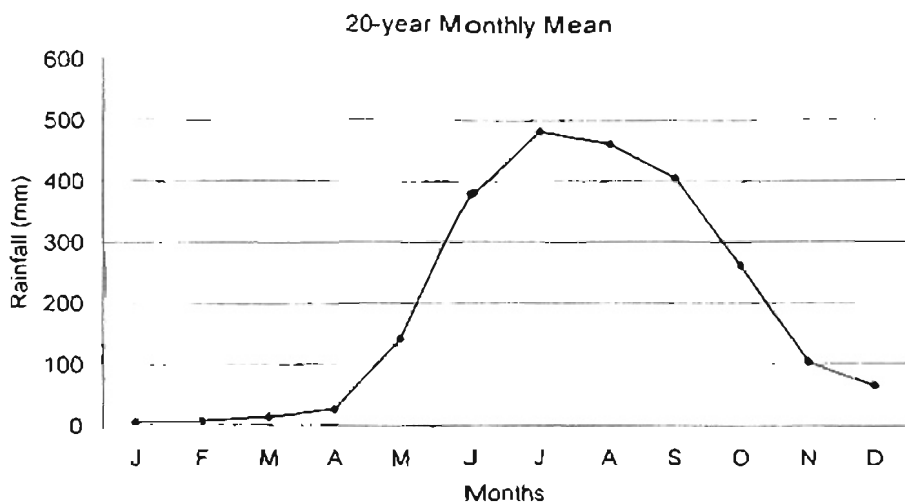
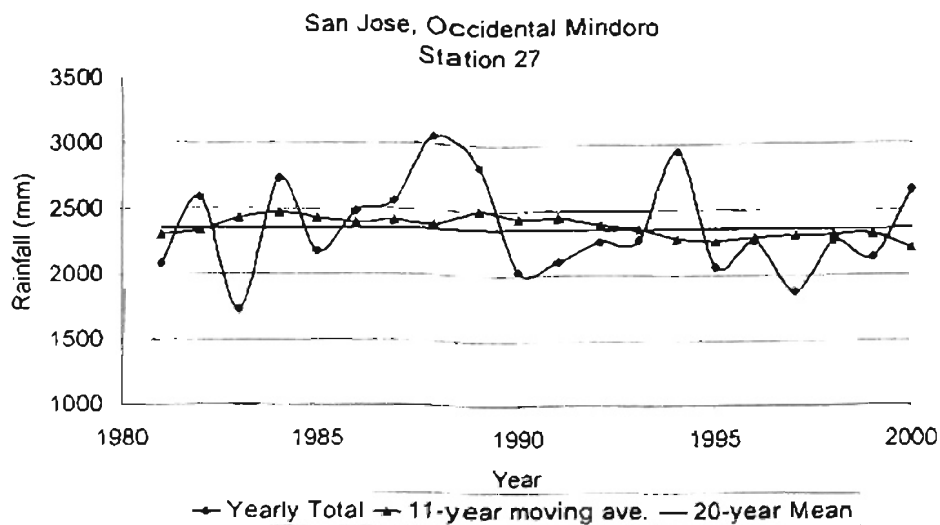


Figure A27. Station 27, San Jose, Occidental Mindoro.

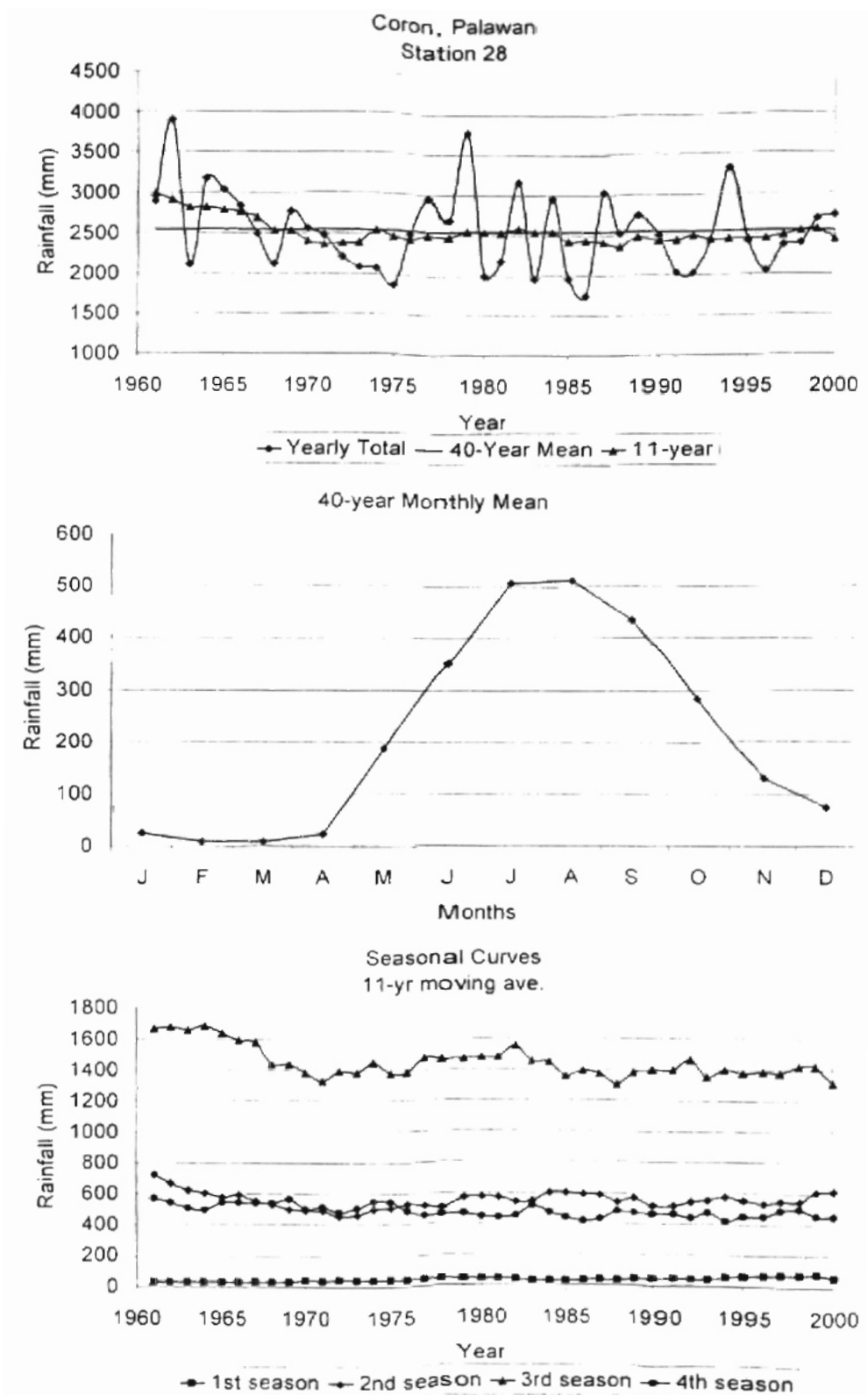


Figure A28. Station 28, Coron, Palawan.

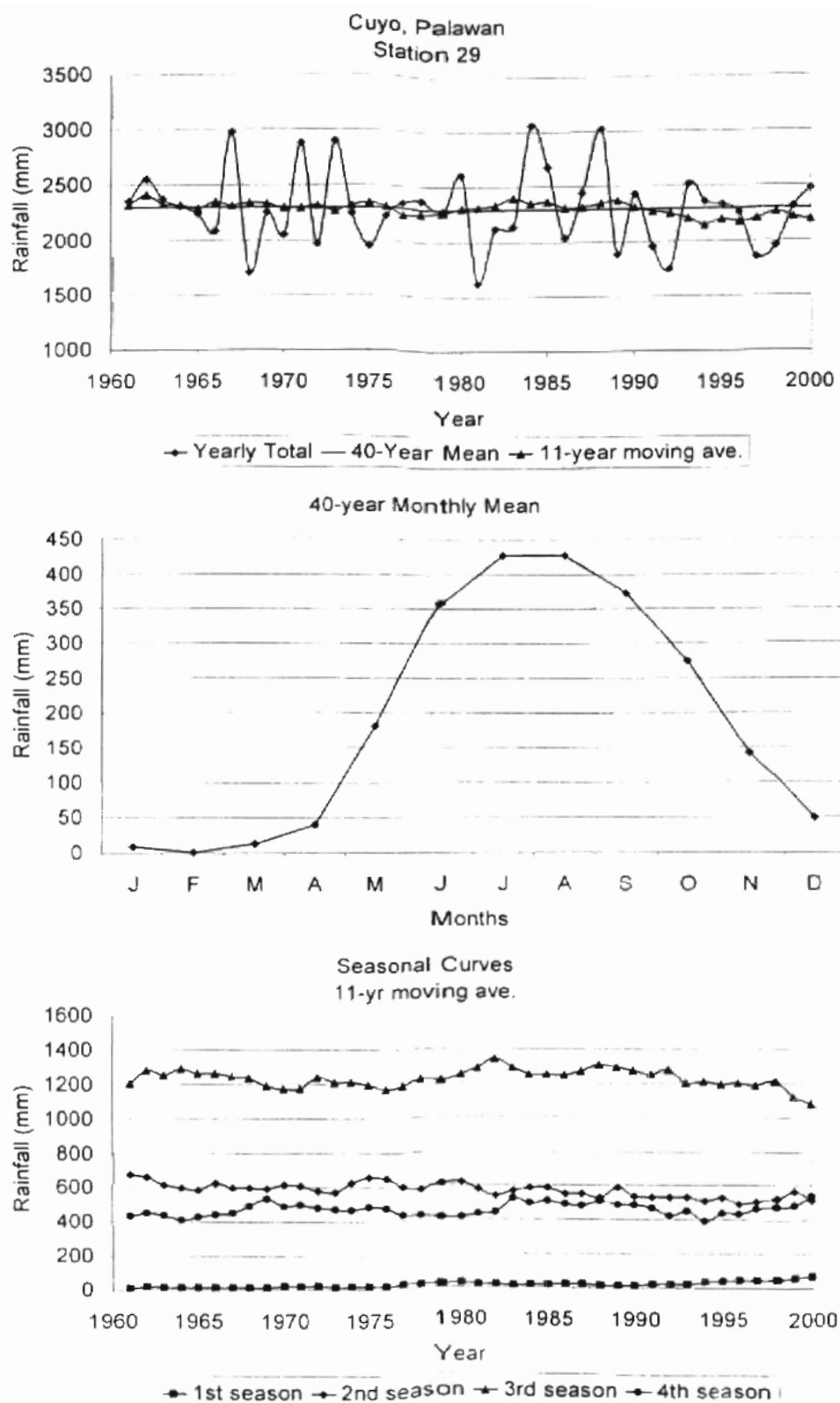


Figure A29. Station 29, Cuyo, Palawan.

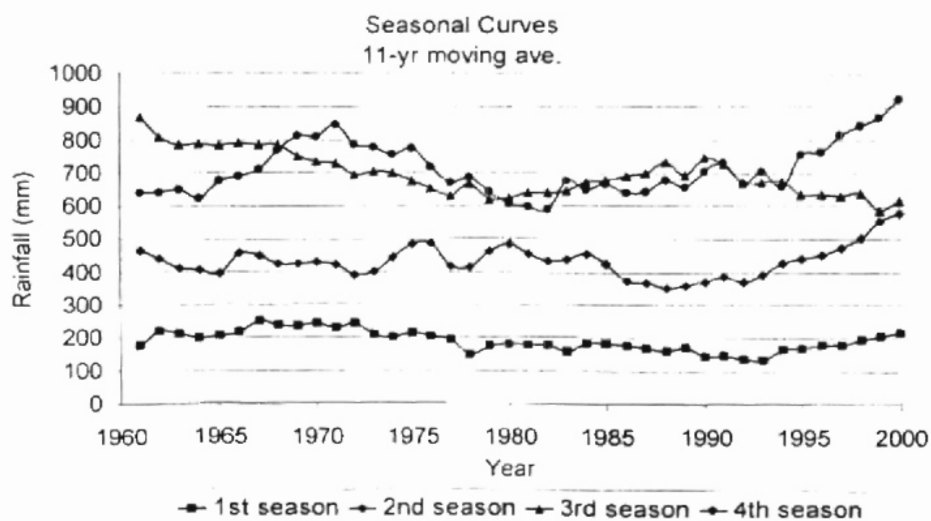
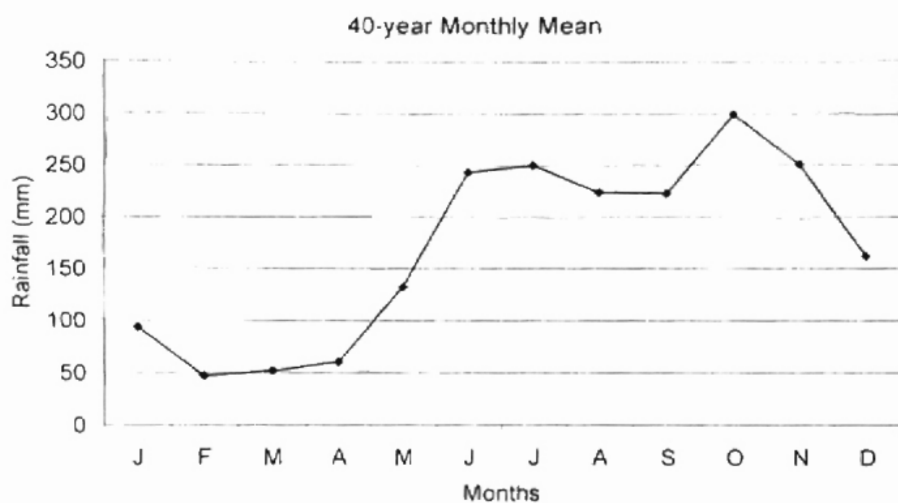
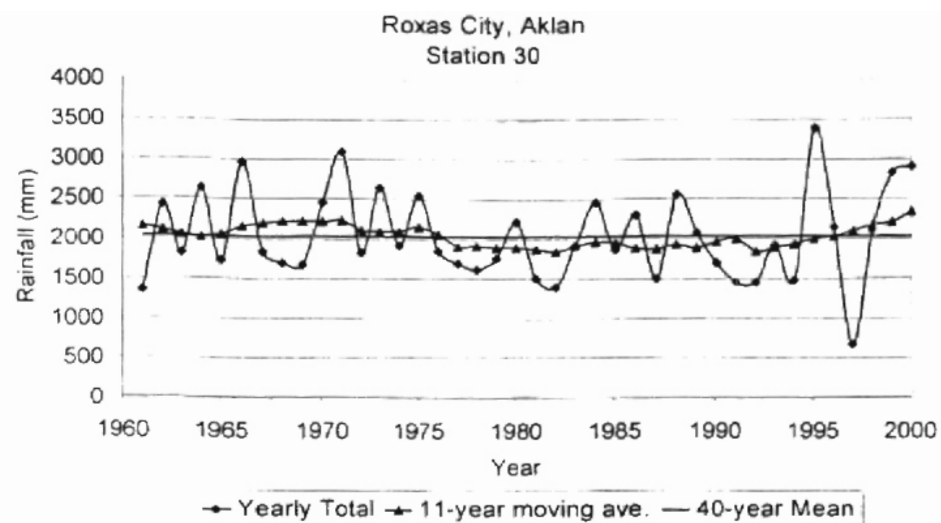


Figure A30. Station 30, Roxas City, Aklan.

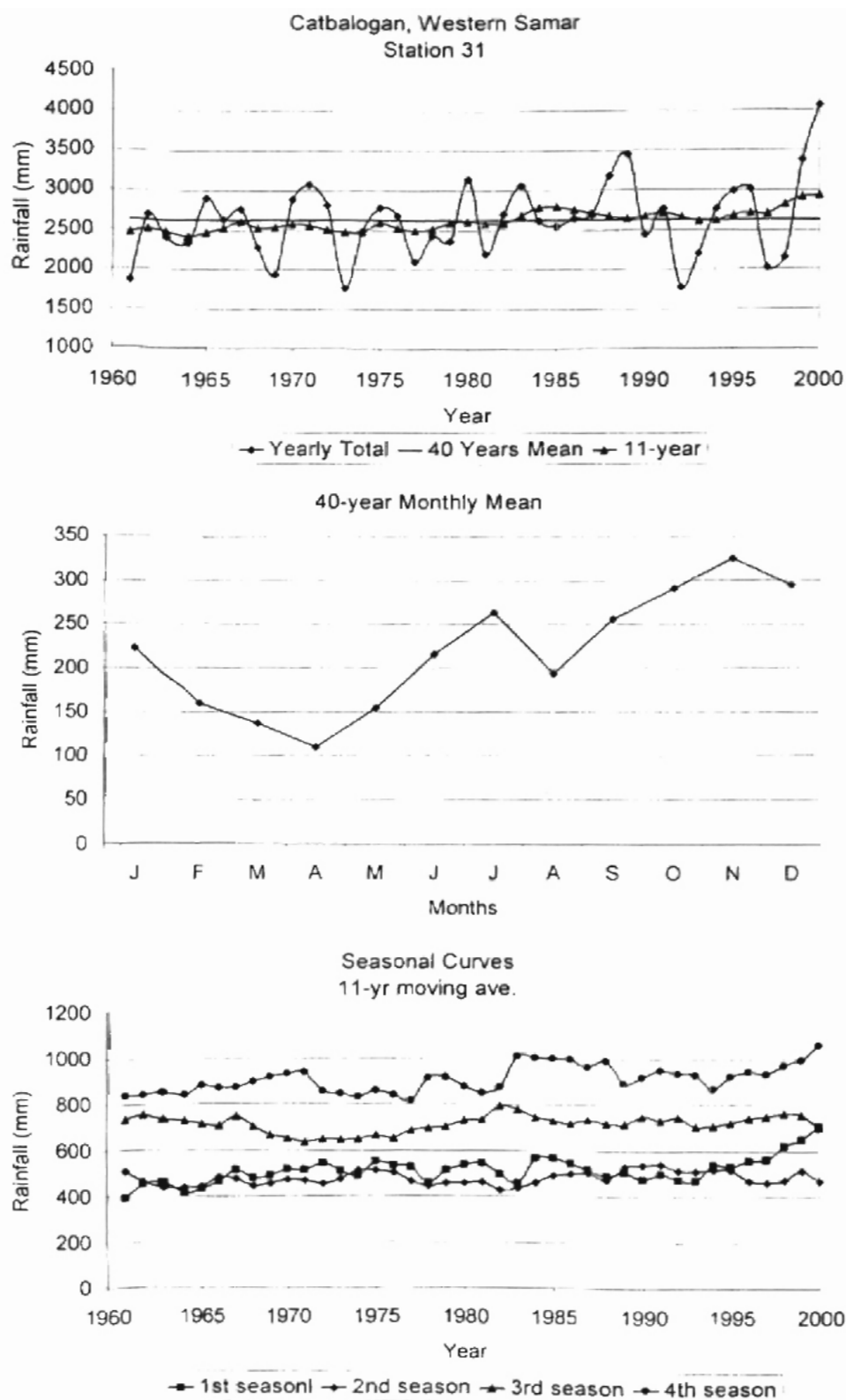


Figure A31. Station 31, Catbalogan, Western Samar.

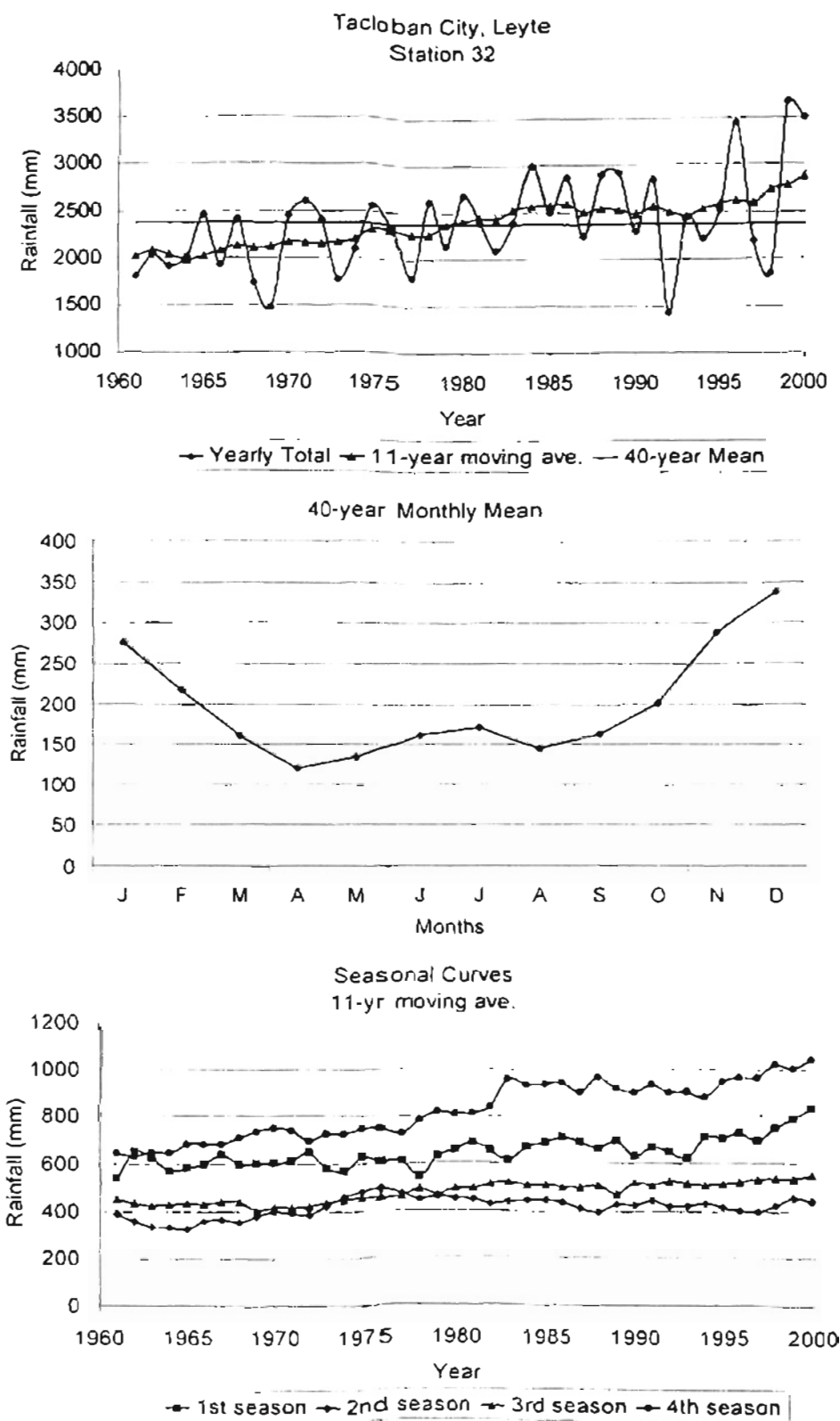


Figure A32. Station 32, Tacloban City, Leyte.

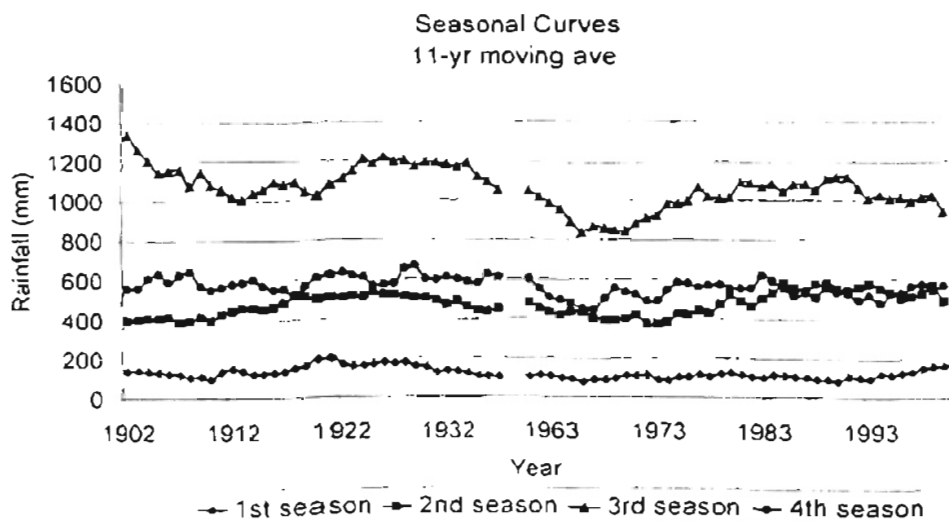
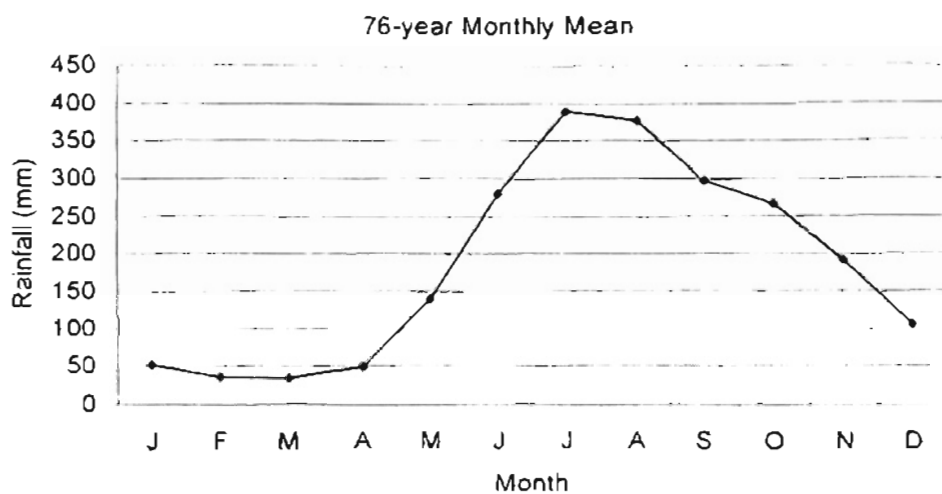
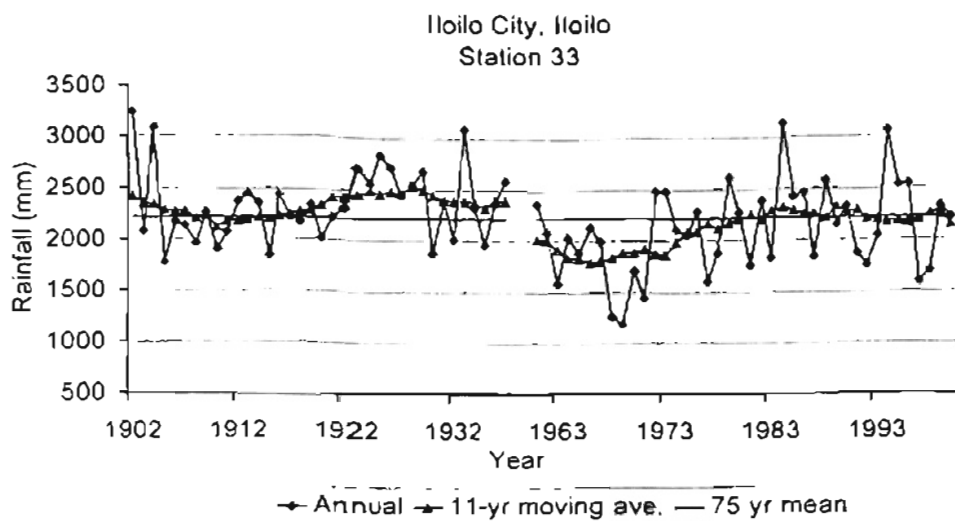


Figure A33. Station 33, Iloilo City, Iloilo.

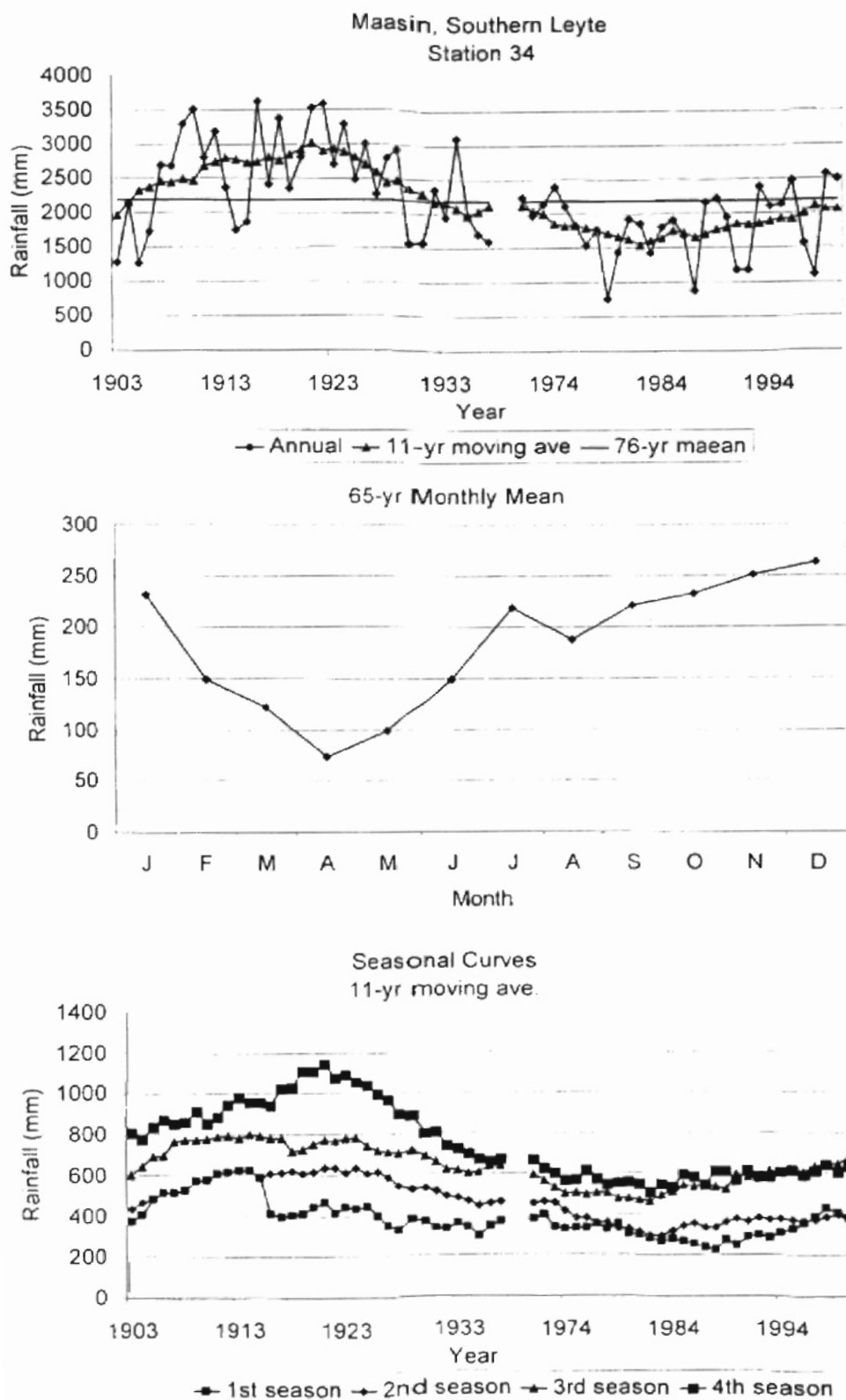


Figure A34. Station 34, Maasin, Southern Leyte.

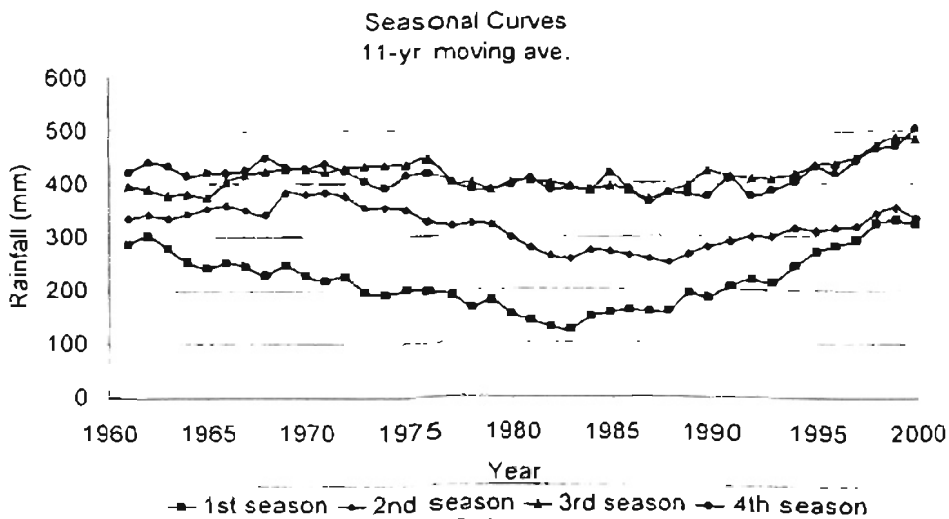
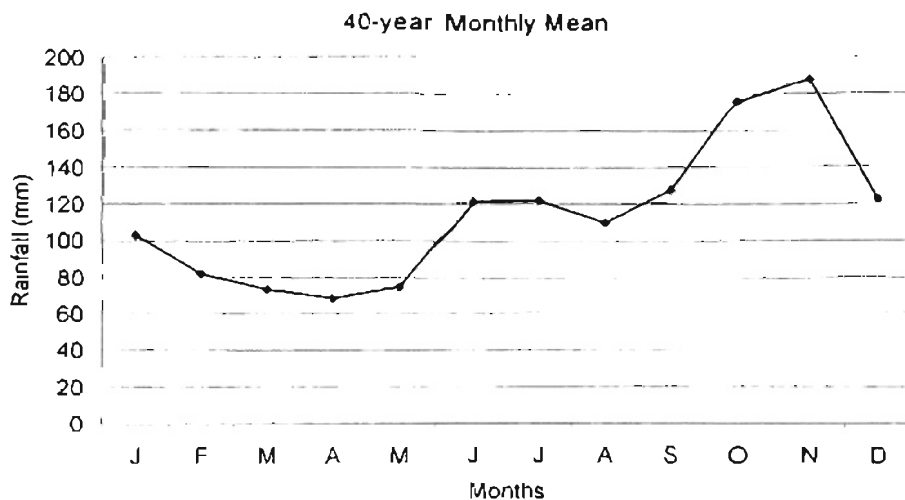
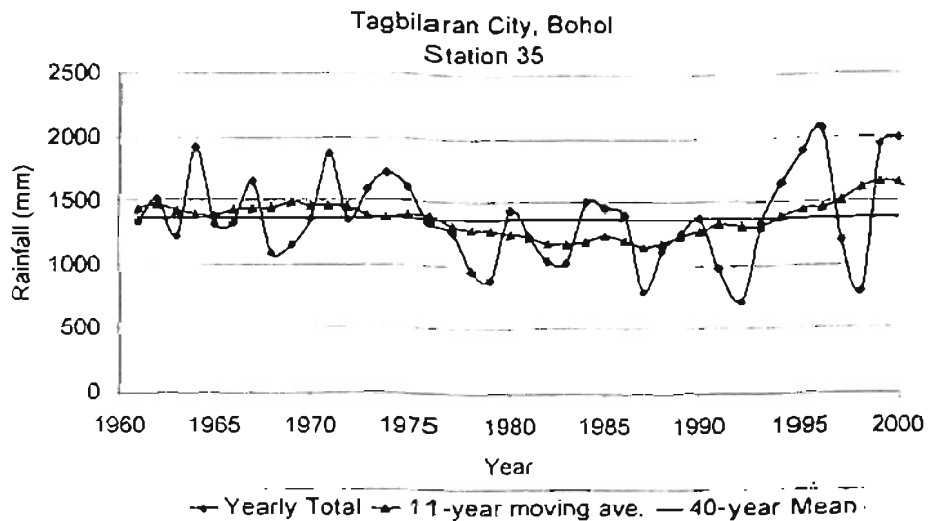


Figure A35. Station 35, Tagbilaran City, Bohol.

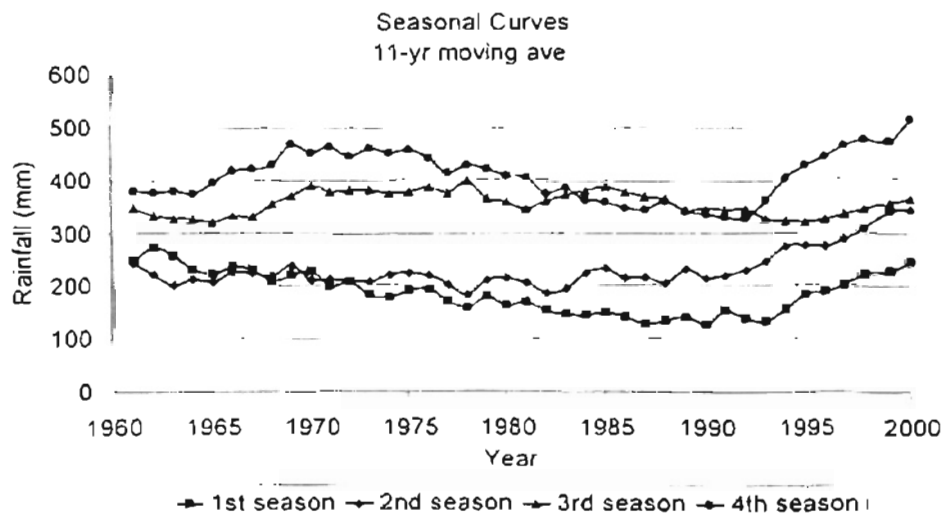
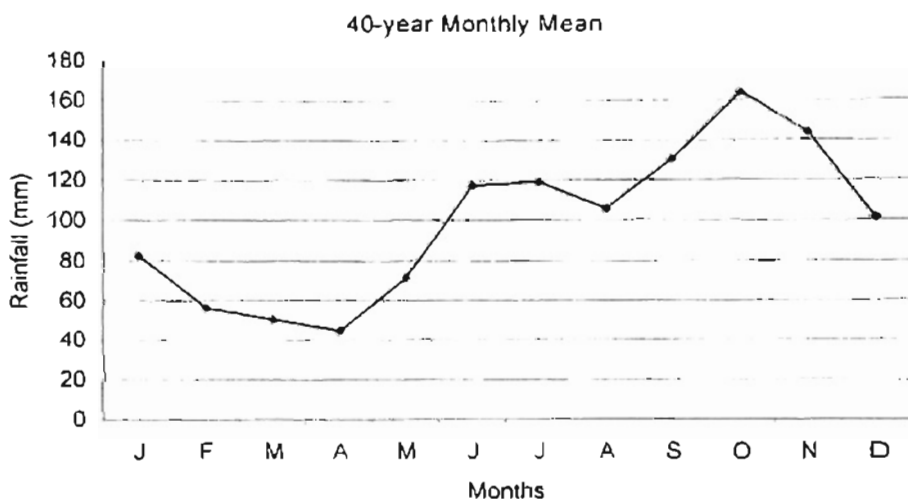
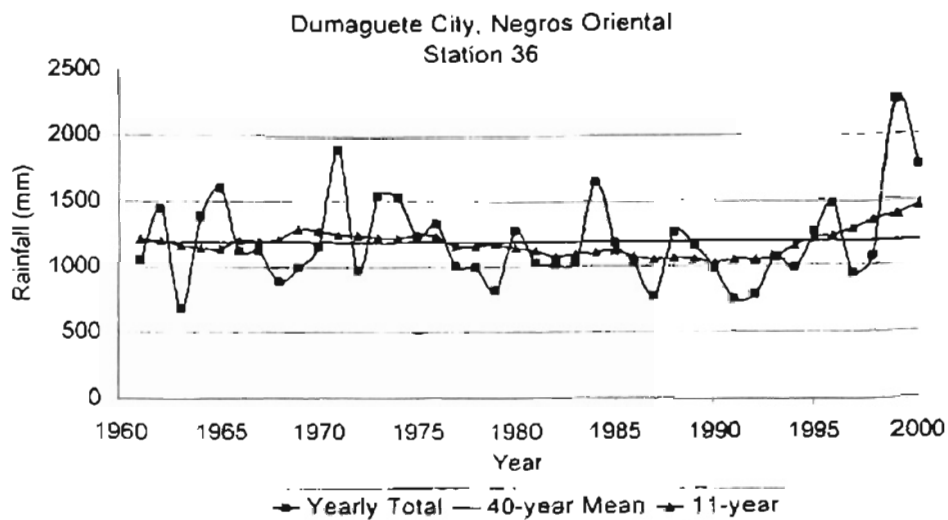


Figure A36. Station 36, Dumaguete City, Negros Oriental.

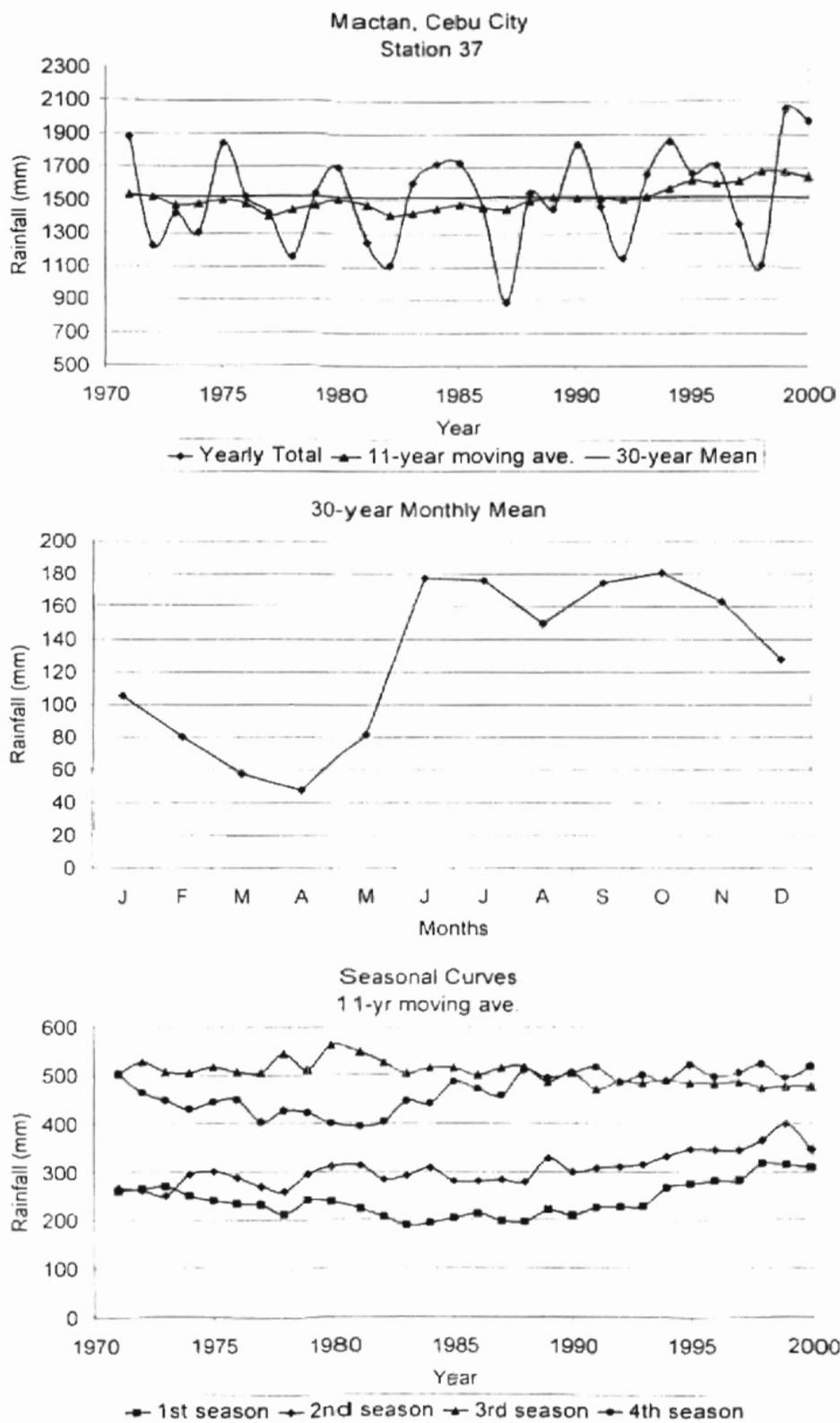


Figure A37. Station 37, Mactan, Cebu City.

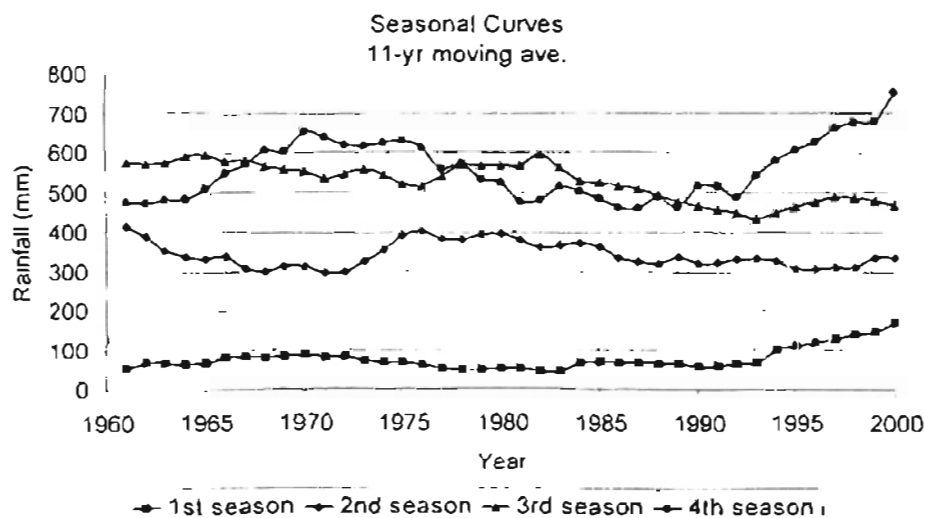
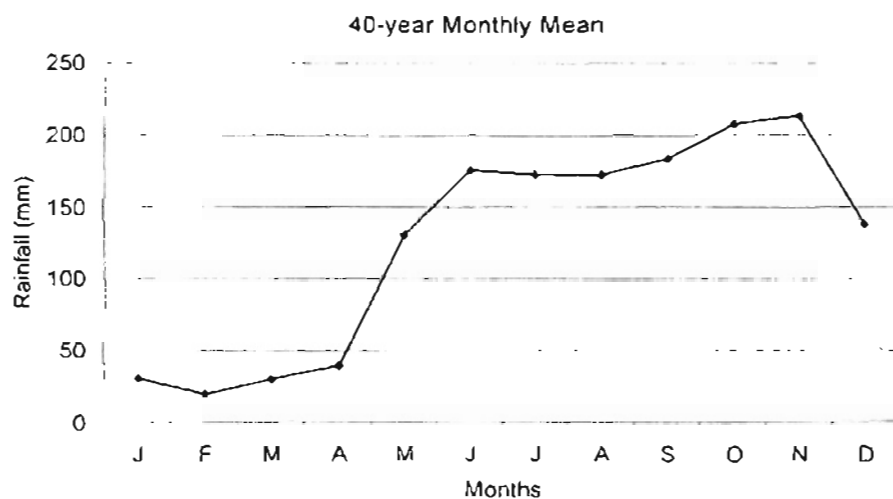
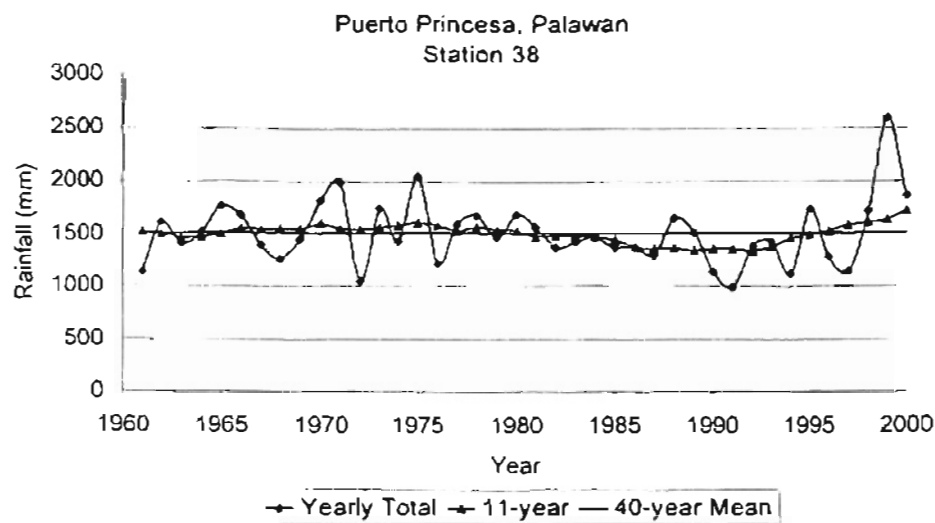


Figure A38. Station 38, Puerto Princesa, Palawan.

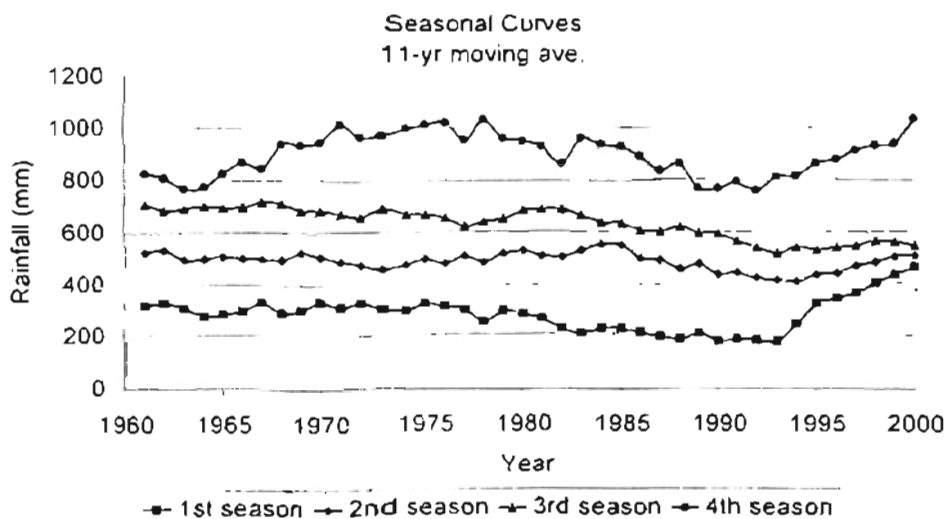
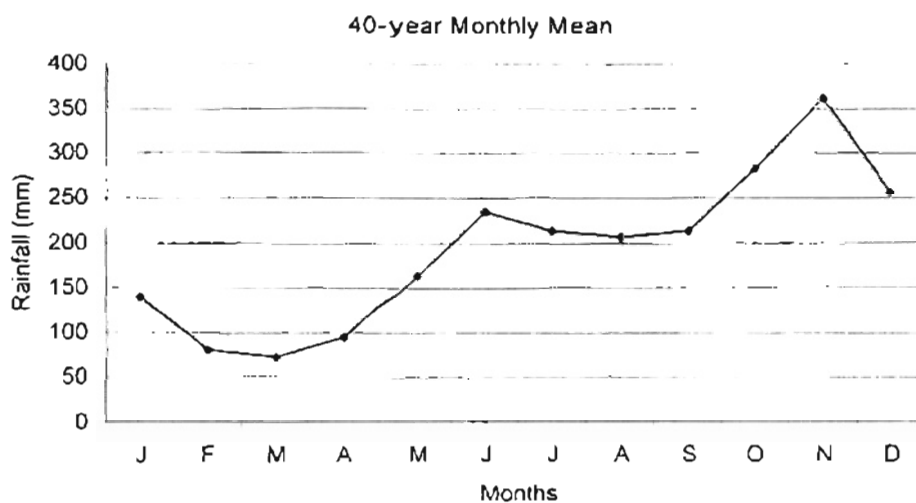
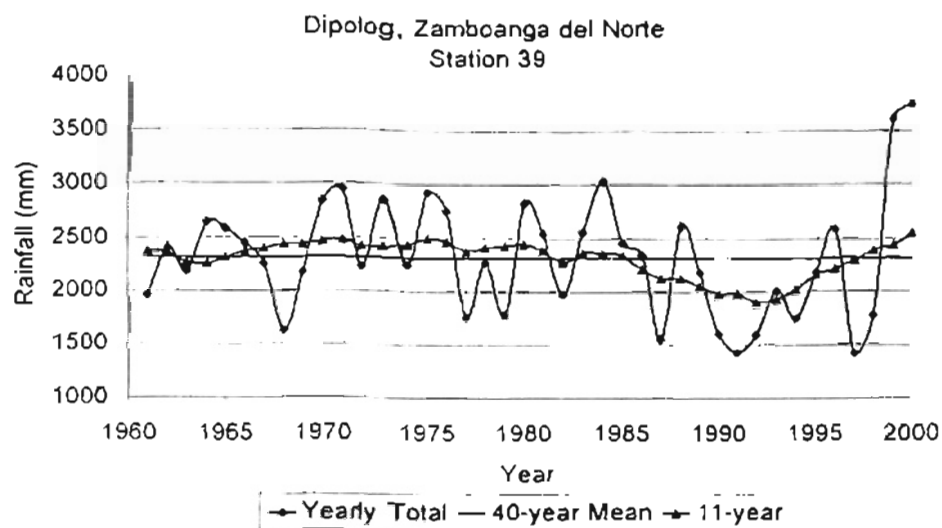


Figure A39. Station 39, Dipolog City, Zamboanga del Norte.

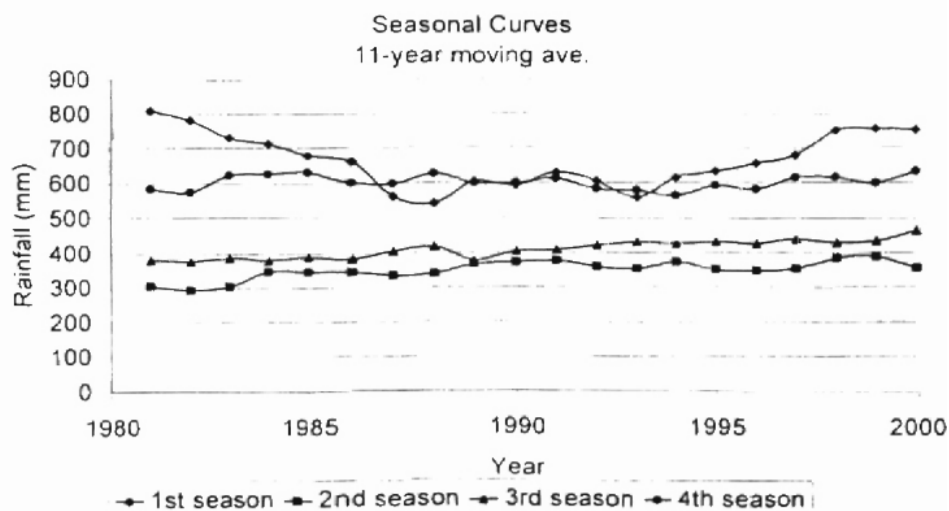
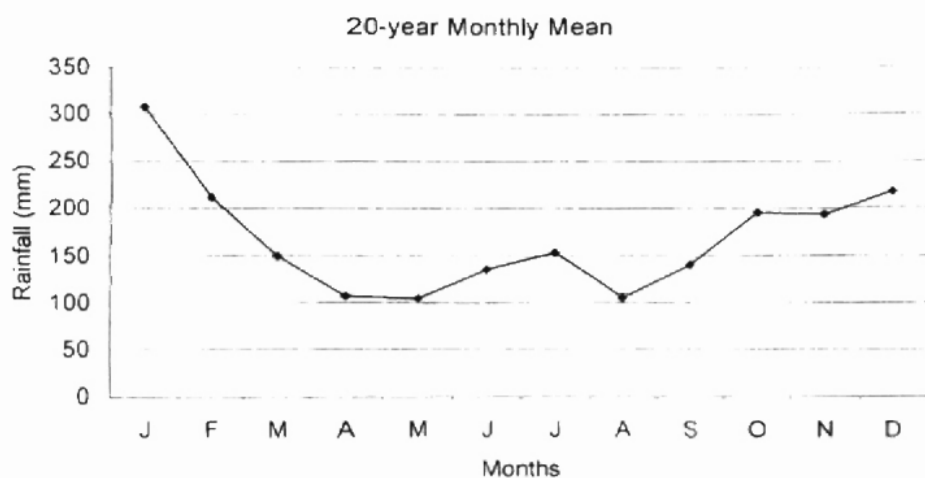
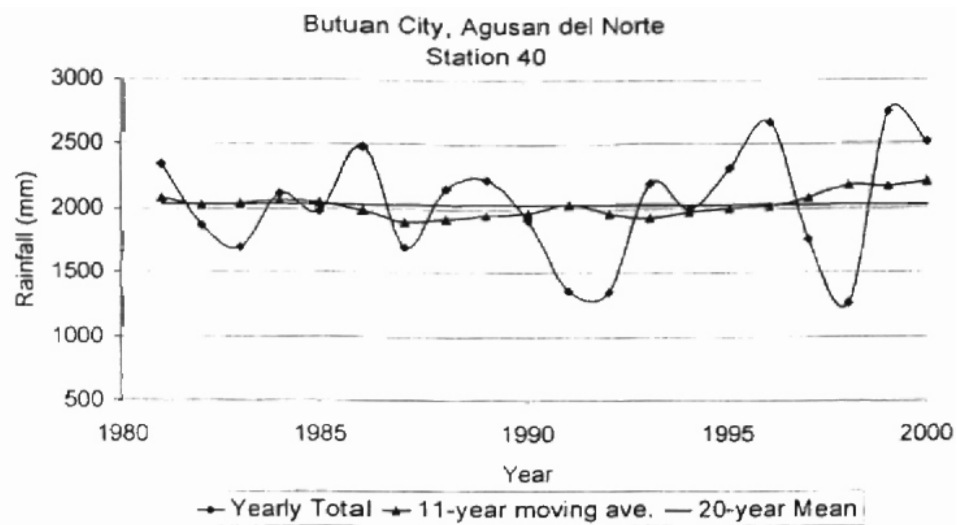


Figure A40. Station 40, Butuan City, Agusan del Norte.

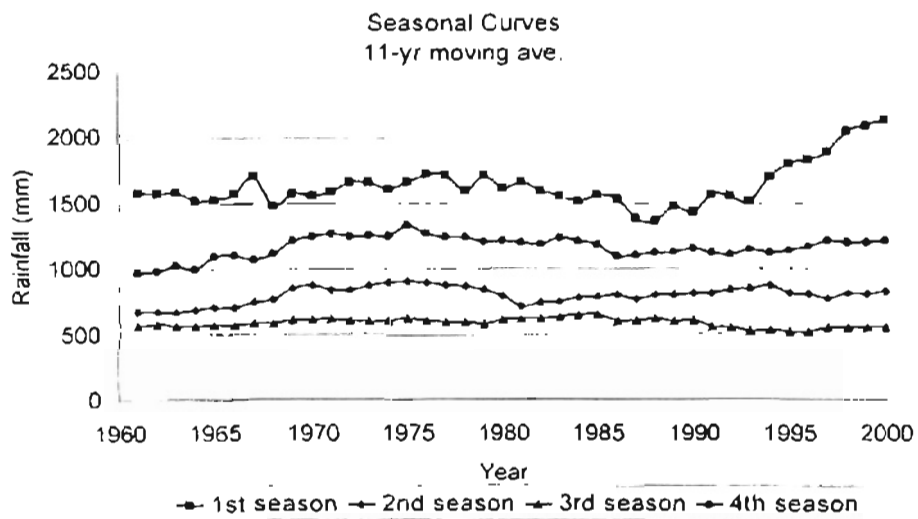
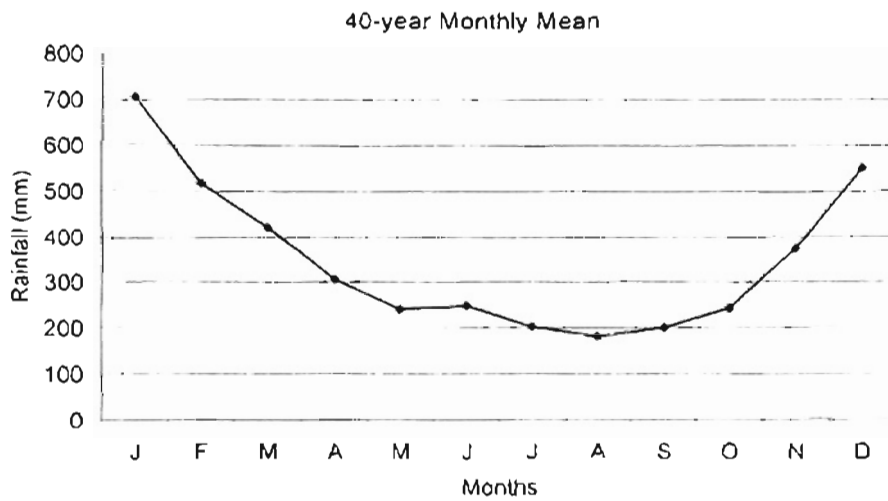
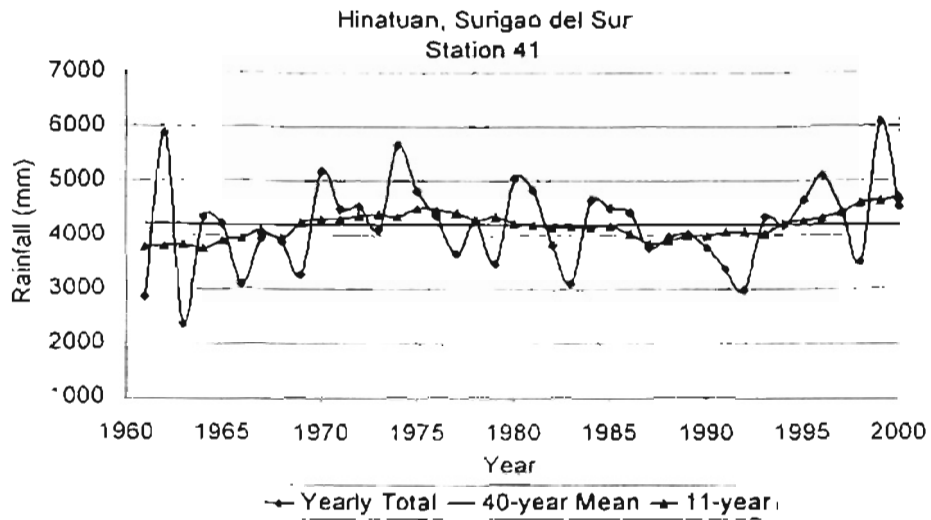


Figure A4). Station 41, Hinatuan, Surigao del Sur.

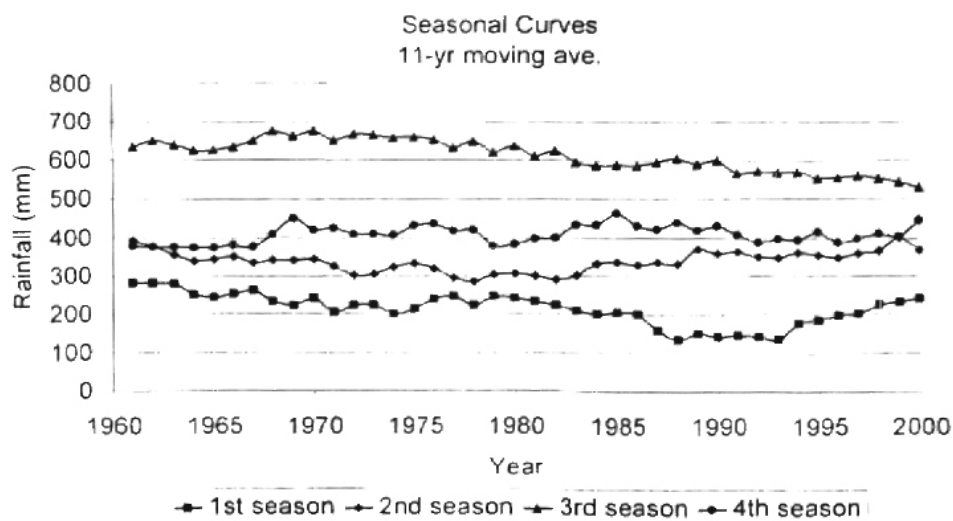
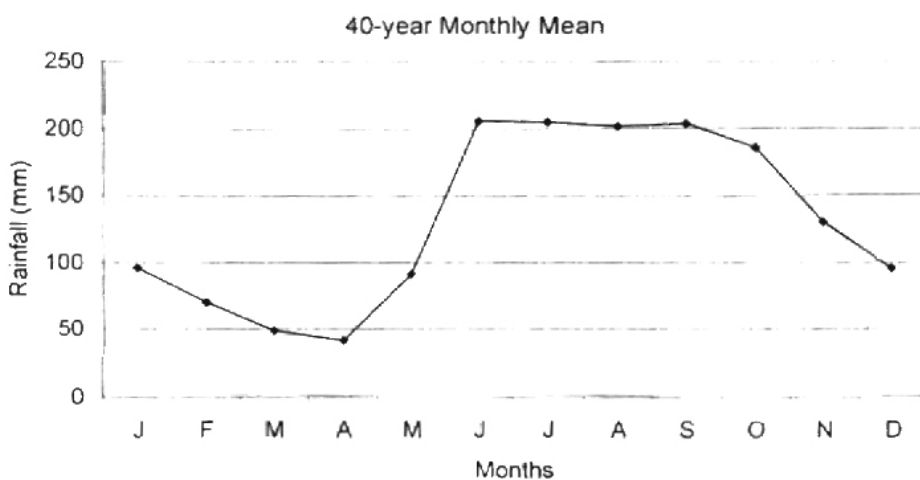
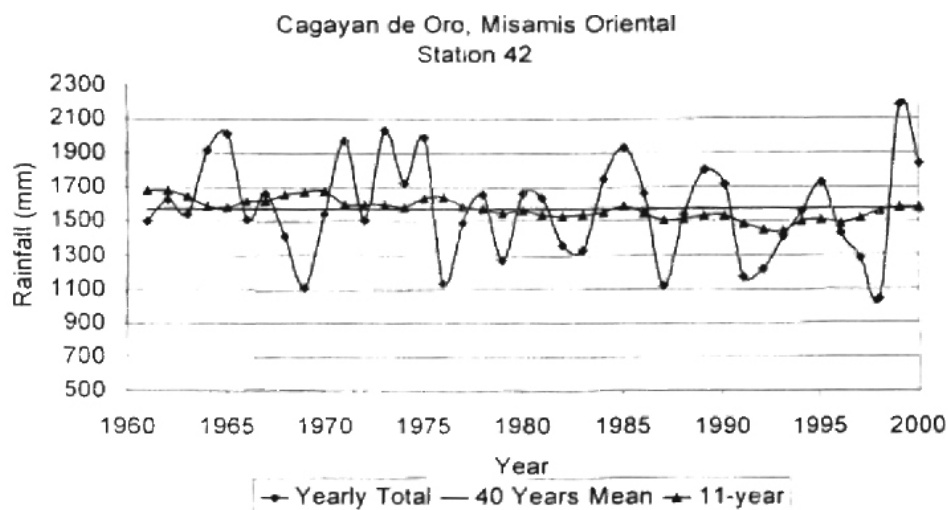


Figure A42. Station 42, Cagayan de Oro, Misamis Oriental.

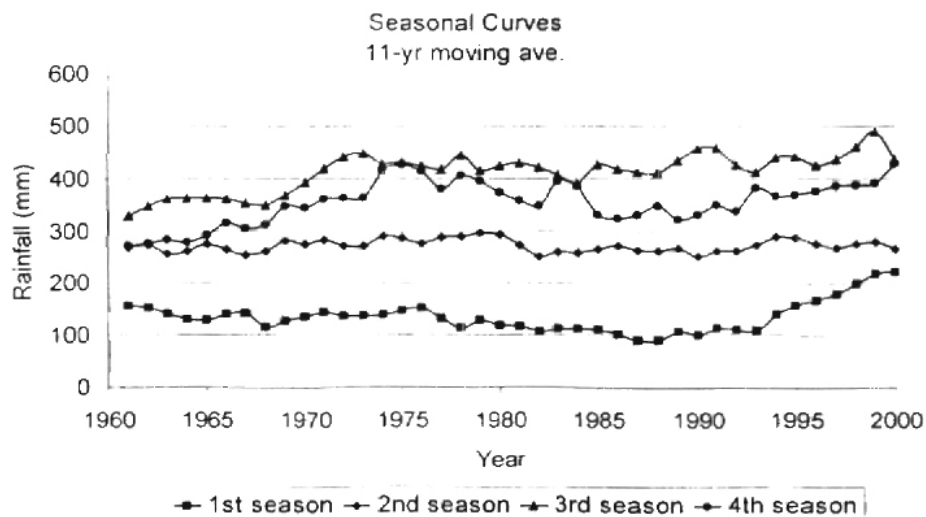
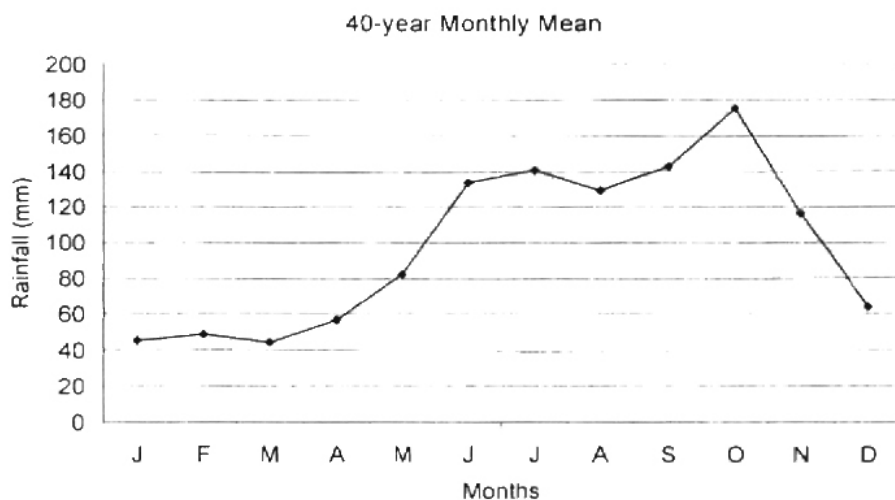
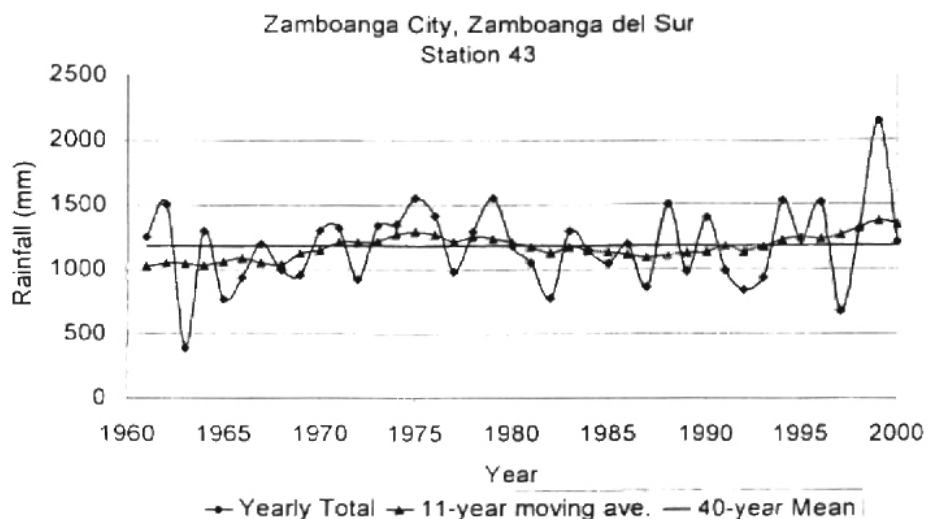


Figure A43. Station 43, Zamboanga City, Zamboanga del Sur.

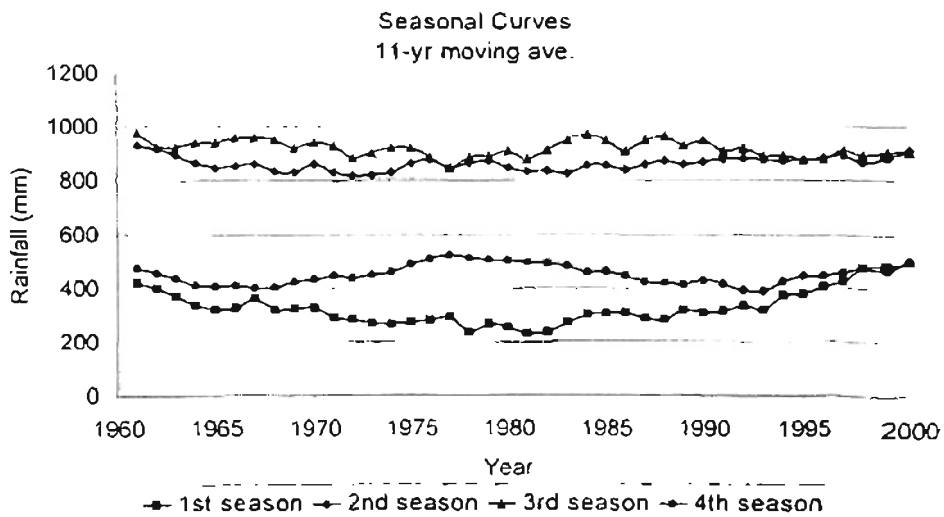
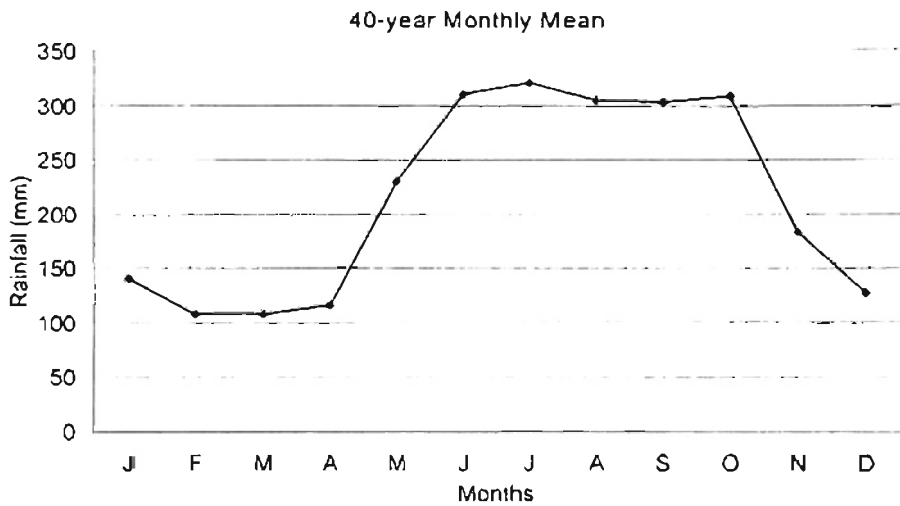
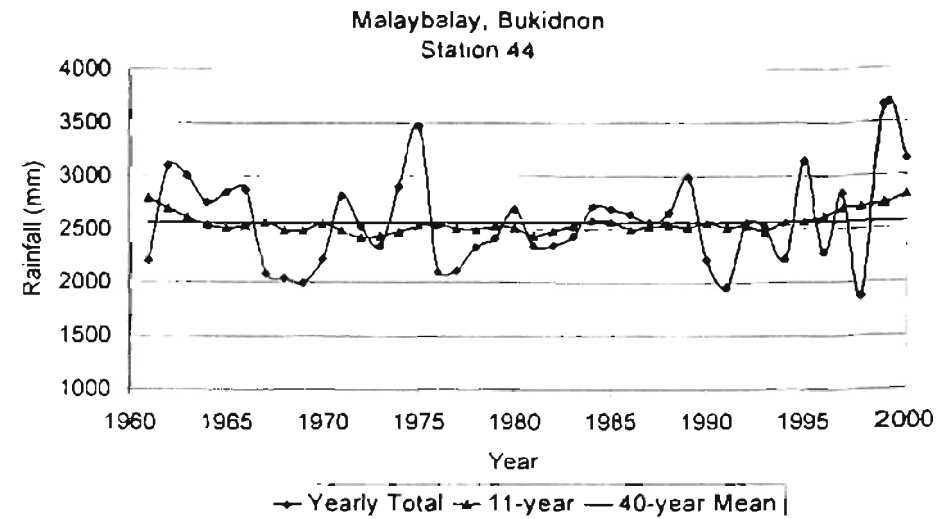


Figure A44. Station 44, Malaybalay, Bukidnon.

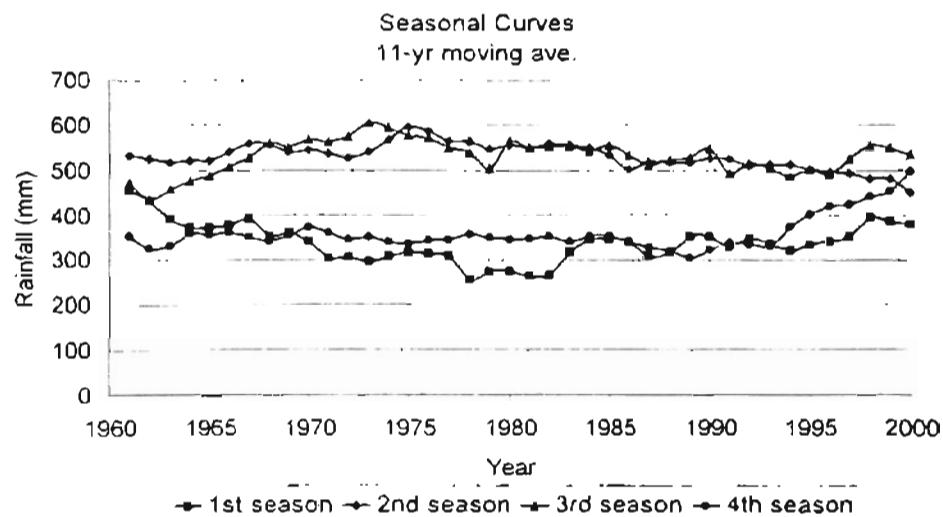
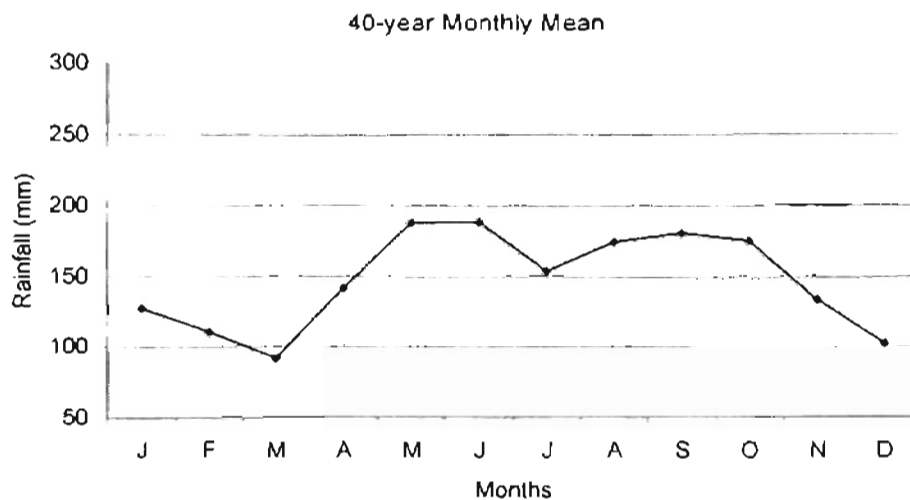
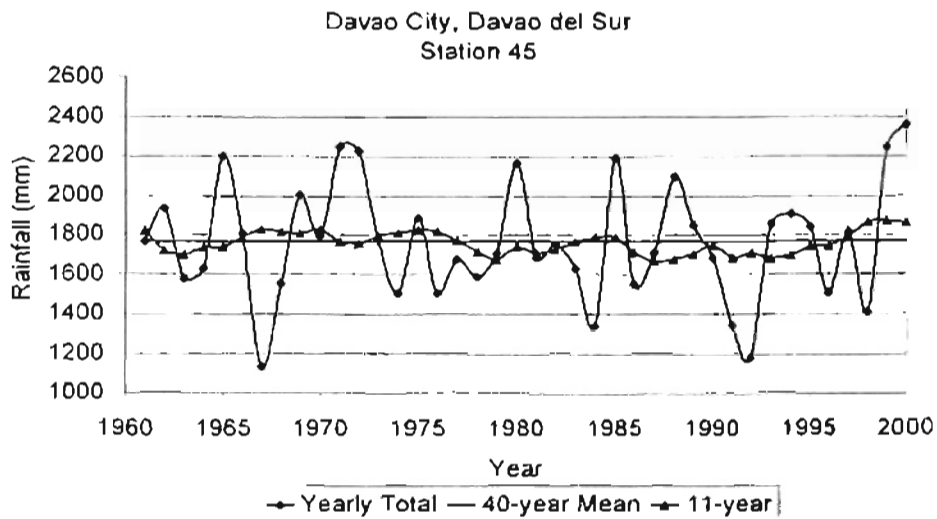


Figure A45. Station 45, Davao City, Davao del Sur.

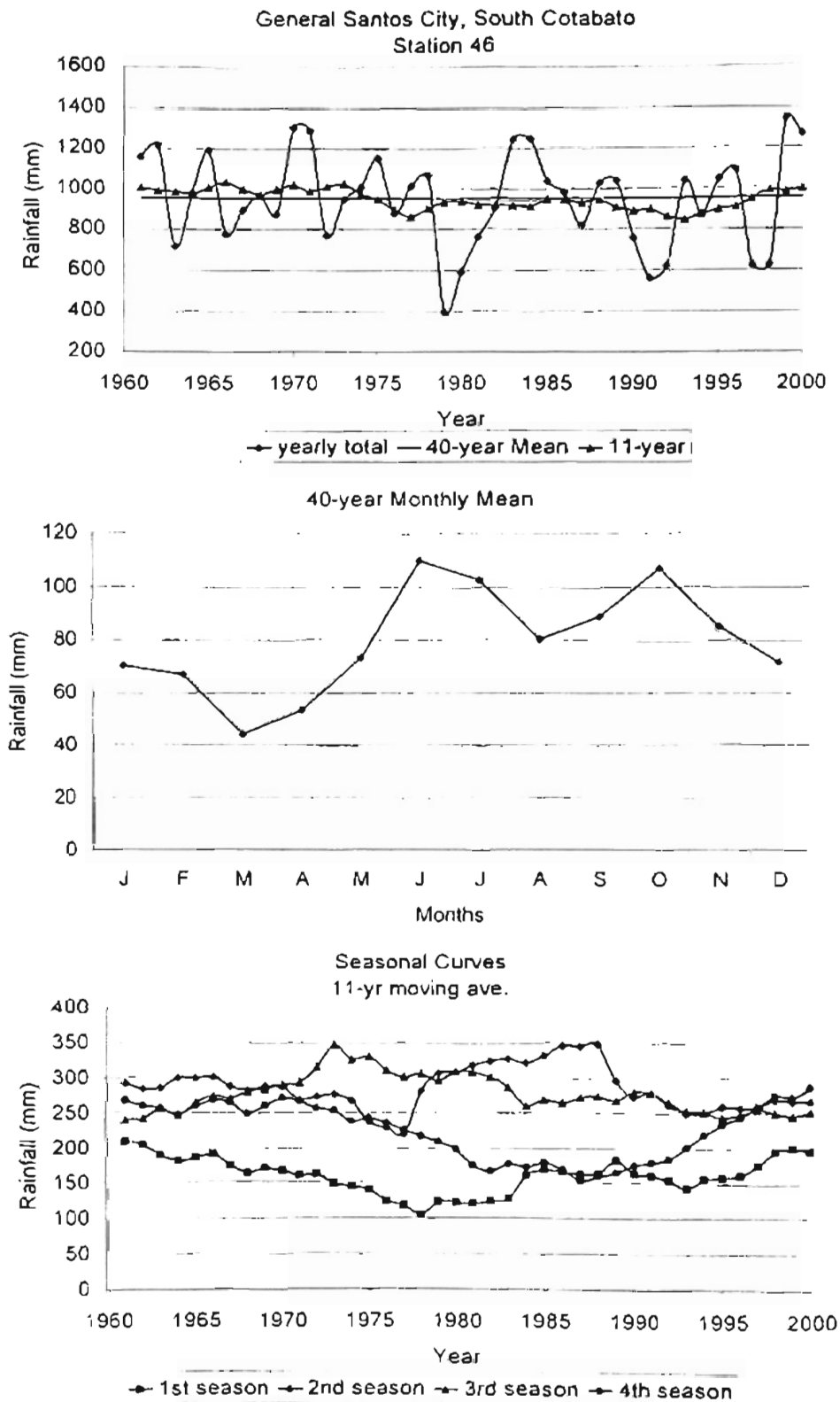


Figure A46. Station 46, General Santos City, South Cotabato.

VITA

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Master of Science

Thesis: RAINFALL TRENDS AND STREAMFLOW SENSITIVITY IN THE
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