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A STUDY ON THE IMPACT OF CLIMATE VARIABILITY/CHANGE ON WATER RESOURCES IN THE PHILIPPINES

*Aida M. Jose, Raquel V. Francisco and Nathaniel A. Cruz**

INTRODUCTION

Studies on hydrologic implications of global warming and climate change using precipitation run-off and temperature relationship in many regions of the world have been conducted. With reference to changes in extreme hydrologic characteristics, such studies indicated that with global warming, maximum floods might be found to increase on one hand, and on the other hand, severe drought might become frequent. Both could cause serious ecological and economic damage especially in the urban and rural areas with unstable moisture conditions.

In many regions of the world, global climate change is expected to bring about changes in the requirements for water resources. The quality and quantity of underground water resources and the structures and character of water consumption may also alter.

This paper presents an effort towards understanding the potential impact of climate variability and change on the hydrology and water resources in the Philippines. Because of uncertainties in detecting climate change based on observational data as well as in predicting climate change particularly in a tropical region like the Philippines using General Circulation Models, it is desirable that a study on climate variability should first be undertaken. There are also some emerging

* Dr. Jose is Weather Services Chief, Dr. Francisco is Assistant Weather Services Chief, and Mr. Cruz is Senior Weather Specialist from the Climate Change and Drought Early Warning and Monitoring Center. All three (3) are from the Climatology and Agrometeorology Branch of the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), DOST.

thoughts to propose that observed climate change may just be an inherent part of overall climate and constitutes part of climate variability. Occurrences of extreme climatic events recorded recently in many parts of the globe have also been experienced in the past. For example, W.J. Maunder noted that Professor Helmut Landsberg (1975), the most eminent climatologist of the 20th century, concluded that the Sahel Drought of the 1970s was not unprecedented, and expressed the view that such instances have to be accepted as part of the normal climate of that region. Due to the uncertainties in the aspect of climate change, it is, for practical purposes, quite reasonable to deal with a climate variability within the time scale of 100 years.

Based on the above context, this preliminary study on the variability of the important climatic elements which affect the hydrology and water resources in the Philippines, is presented. These elements considered in particular are temperature and rainfall. Parallel to this, a preliminary study on the variability of inflow in relation to rainfall at the major dams in Luzon Island and the natural water reservoir of Lake Lanao located in Mindanao Island was also undertaken. Hydrologic impacts of extreme events like drought experienced in the Philippines are further presented. Some areas for future study on the impact assessment of climate variability and change on hydrology and water resources in the Philippines are mentioned.

TEMPERATURE VARIABILITY

Generally, the Philippines has high temperature because of its tropical maritime setting and the warm air currents flowing over its land masses. The mean annual temperature is about 27.1°C. The hottest months are May with 28.4°C, June with 27.9°C and April with 27.8°C. The coldest months are January with 25.5°C, February with 25.8°C and December with 26.1°C. The seasonal variation of temperature is small, with an average annual range of 2.9°C. In general, the highest temperatures are observed in valleys and plains while the lowest occur at stations with high elevations.

The absolute maximum temperature recorded in the Philippines was 42.2°C at Tuguegarao, Cagayan Valley on April 29, 1912 and on May 11, 1969. The absolute minimum temperature of 3°C was recorded in Baguio, which has an elevation of 1,482 meters, in January of 1903.

Year-to-year variations of surface air temperature at the representative stations in the Philippines with long periods of observations (1920–1990) were examined. The stations are located in Baguio (16°25'N, 120°33' E with elevation of 1,500 of 4 meters), Manila (14°30' N, 121°00' E with elevation of 33 meters), and Cebu (10°20'N, 123°54' E with elevation of 4 meters.) These averages of the yearly temperature anomalies for the 3 stations were computed and plotted against time as indicated in Figure 1. The trend line is also drawn indicating an average increase of about 0.18°C per decade.

Surface air temperature data from other existing stations were also examined. Increasing trends of temperature were indicated in most of the stations. Although the average trend appears to be consistent with observations in many parts of the globe, still some degree of uncertainty could not be discounted. Such uncertainty could be traced to some problems that might have affected the observations, such as changes in the exposures of the thermometers, location of the stations and changes in the environment due to urbanization.

RAINFALL VARIABILITY

The single climatic element that primarily determines the climate variability in the Philippines is rainfall. Three rainfall periods defined as rain-year, first semester and second semester are adopted in discussing seasonal and annual rainfall variability in the Philippines. A rain-year rainfall is defined as 12–month rainfall starting April and ending in March of the following Julian calendar year. This is synchronized with the start of the general rainy season in the Philippines in April which terminates in the minimum rain month of March. The first semester rainfall covers the summer monsoon period from April to September, while the second semester rainfall covers the winter months from October to March.

The first and second semester rainfall distributions in the Philippines are shown in Figure 2. During the first semester, rainfall greater than 2,000 mm is found in the western sections of Luzon and Panay Island. The Cagayan Valley, the interior portion of the Visayas and the southern part of Mindanao have rainfall amounts of less than 1,000 mm. During the second semester, rainfall greater than 2,000 mm is found in the eastern section of the Philippines which is more exposed to the prevailing northeasterly. Rainfall less than 500 mm is experienced in the western part of Luzon.

The distribution of the year-rainfall and second semester rainfall in percent of the year-rainfall are shown in Figure 3. More than 50 percent

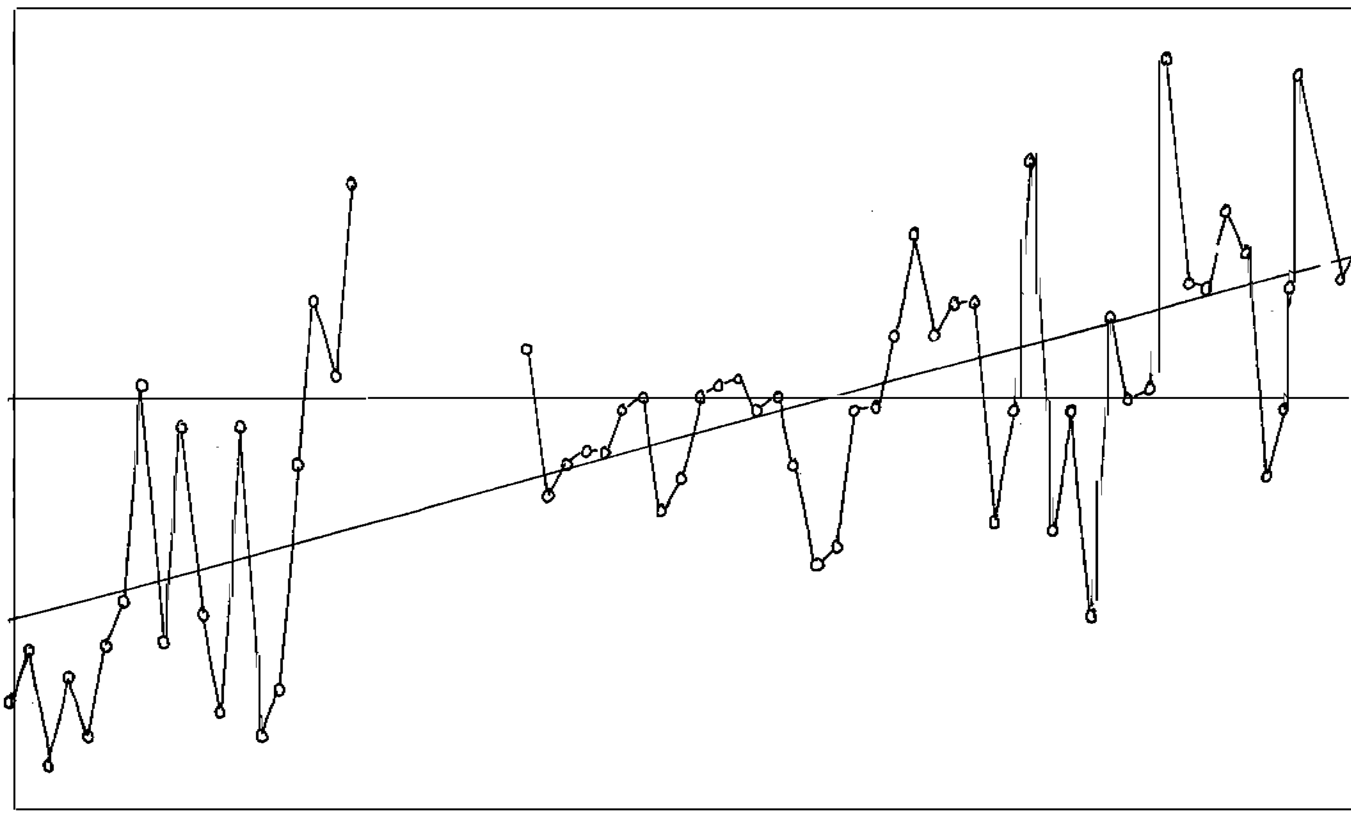

Figure 1. Average yearly temperature variation in the Philippines based on Baguio-Manila and Cebu observed data

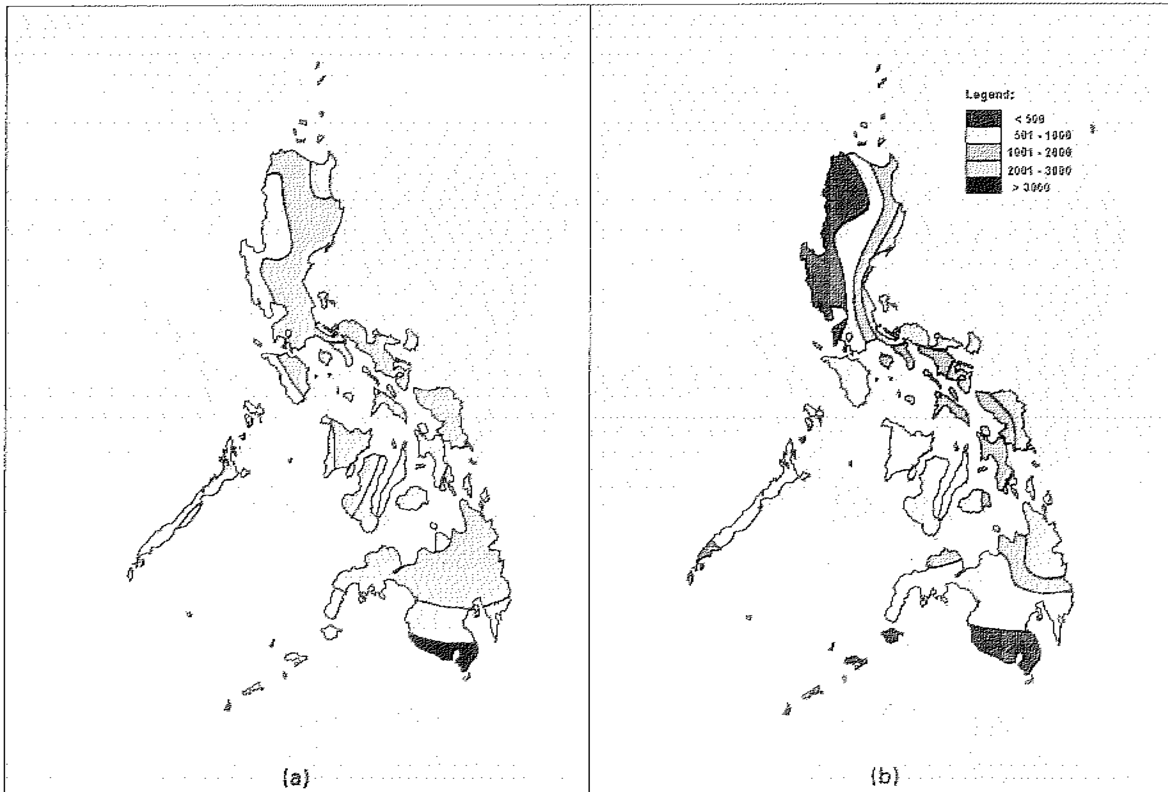

Figure 2. Rainfall distribution (in mm) in the Philippines during the (a) first and (b) second semester

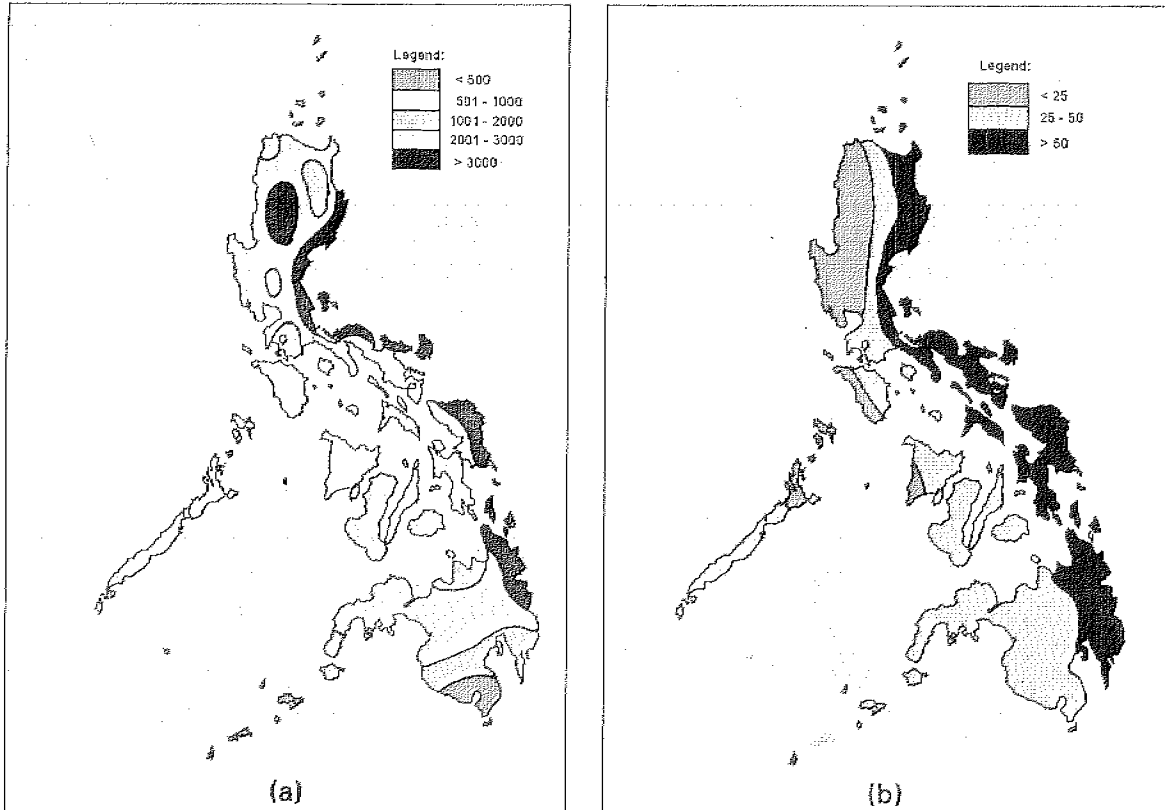

Figure 3. Distribution of (a) year rainfall and (b) the second semester rainfall in percent of the year rainfall (1951–92)

of the year-rainfall over the eastern sections of the country are observed during the second semester, while the western sections generally have less than 25 percent of the year-rainfall.

In a 1989 study made by A. M. Jose, spectral analysis of standardized seasonal and annual rainfall anomalies in the Philippines revealed 2 significant quasi-periodicities with a wavelength equivalent to 2–2.5 years and 4–5 years. These quasi-periodicities of rainfall variation represent certain pulsation in the general atmospheric circulation. The first quasi-periodicity may be referred to as the Quasi-Biennial Oscillation (QBO) and the 4 to 5 years quasi-periodicity can be attributed to the El Niño Southern Oscillation (ENSO) phenomenon. These kinds of periodicities are also found in many stations in the whole tropical and sub-tropical regions. Figure 4 shows an analysis of the spectral estimates of 4.5 years quasi-periodicity of seasonal rainfall anomalies in the Philippines.

For the first semester rainfall, a bigger area of significant spectral estimates of more than 10% can be found in Luzon (130°N to 21°) while for the second semester, it is most prominent in Mindanao (50°N to 9°N) covering about 85%.

Previous studies indicated the rainfall data of the countries near the equator and most of the Pacific Islands exhibited marked signals in the range of 5 years. This quasi-5-year oscillation is also observed in the atmospheric pressure. This is most particularly distinct in long period variations of the Southern Oscillation Index (Bauer, 1969, Troup, 1965 and others) which is related to the feedback mechanisms of the ENSO phenomenon.

Based on scientific assessment, it is believed that one of the manifestations in the global climate change which can be affected significantly by global warming or climate change is the ENSO. Climatological studies also indicated that extreme climatic events are associated with this phenomenon. It is expected that extreme events associated with the ENSO such as drought, floods and storminess will be more intense and frequent simply because of the increase in temperature.

To further investigate other aspects of rainfall variability, trend analysis of seasonal and annual rainfall was conducted. Annual rates of change of rainfall expressed in millimeters per year were computed for various stations in the Philippines during the period 1951 to 1992. These values were plotted, and analyzed and shown in Figure 5. It is

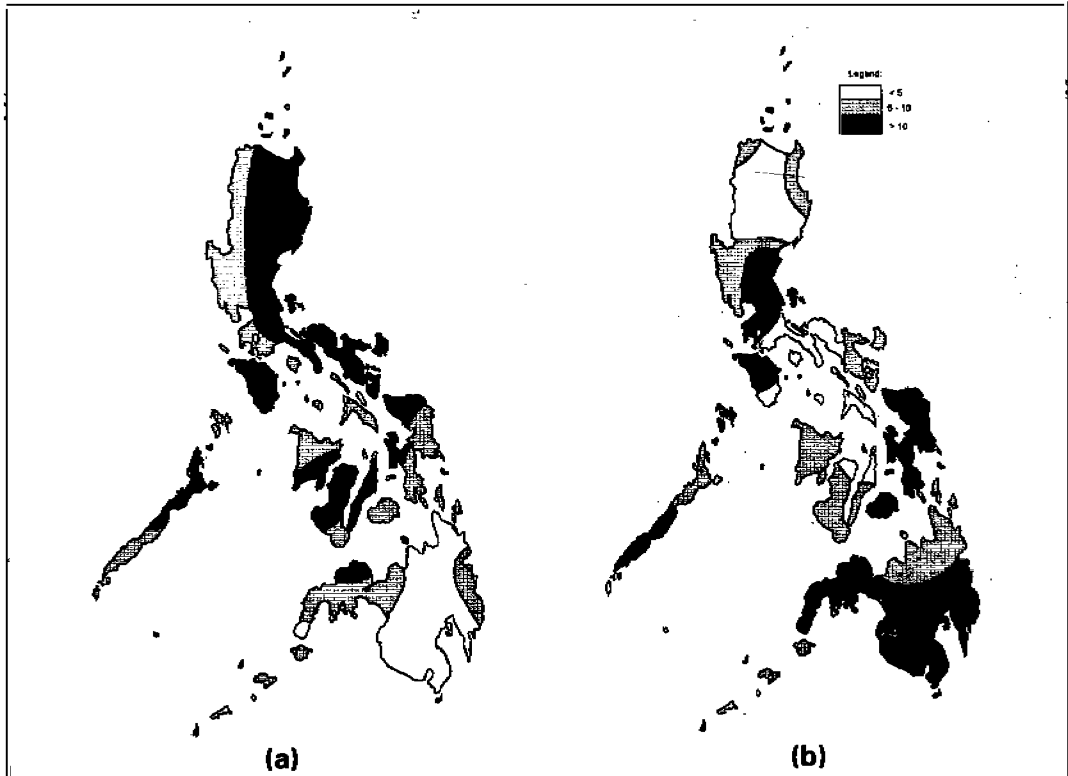

Figure 4. Analysis of spectral estimates of 4 to 5 years quasi-periodicities in the Philippines during (a) first semester and (b) second semester

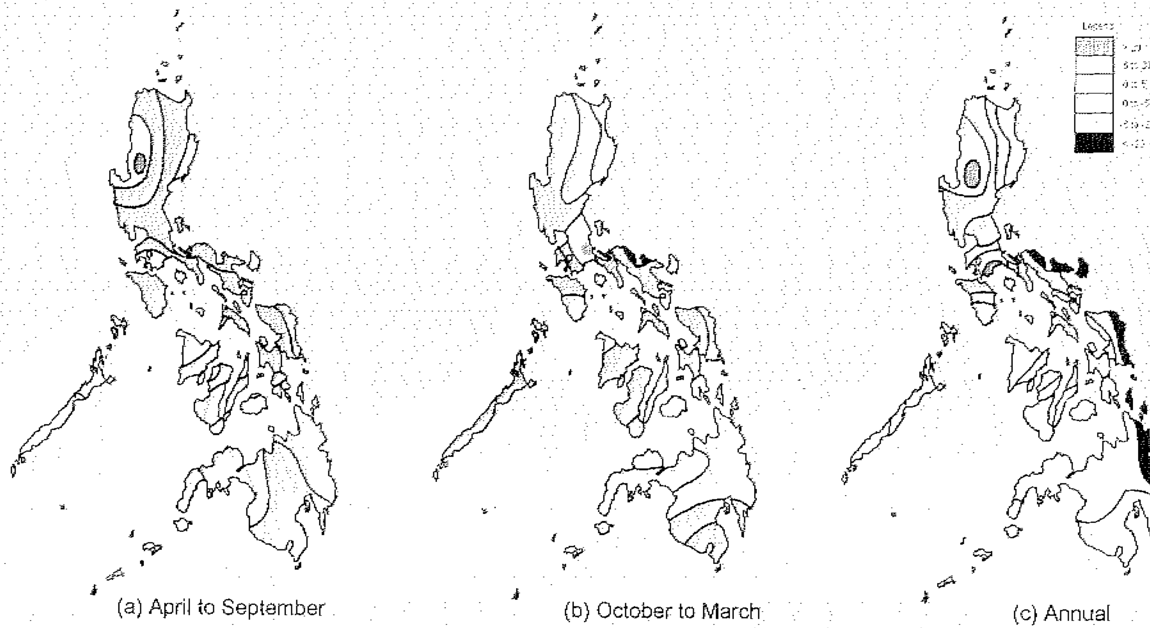

Figure 5. Seasonal and annual rainfall trends (mm/year) in the Philippines (based on 1951–92 records)

interesting to note the geographical distribution patterns of the annual rainfall trend (millimeters per year) exhibited. Positive rainfall trends are indicated mostly in the western sections of Luzon and negative rainfall trends are found in Mindanao, Visayas and Eastern Luzon . To find out a possible physical meaning of this distribution, seasonal rainfall trends were also computed, plotted and analyzed. Also in Figure 5, the April to September and the October to March seasonal rainfall trends are shown.

As mentioned earlier, rainfall in the Philippines during the April to September period is mainly attributed to the activity of the southwest (summer) monsoon while the October to March rainfall is due to the activity of the northeast (winter) monsoon. Following this basic information, it may be implied that the increasing rainfall trends in the western section of Luzon may have some relations with the possible changes in the southwest monsoon activity. Similarly, the decreasing rainfall trends in the eastern sections of Luzon, Visayas, and Mindanao may be attributed to possible changes in the northeast (winter) monsoon activity. Further, it is important to note that based on climatological studies, inter-annual climate variability in the Philippines and other areas in the tropics is attributed to a large extent to the activity of the ENSO phenomenon.

Because seasonal rainfall trends were based on the total rainfall for the six-month period, it is also important to investigate the characteristics of distribution and intensity of the rainfall occurrences during these periods. For example, in the area where there are increasing trends of rainfall particularly those associated with the southwest monsoon season (second semester) may imply increase in intensity, however, the rain period (rainy season) may be of short duration, thus rendering the dry season as abnormally much longer. This kind of situation will imply extreme rainfall events posing some problems on existing water system management.

INFLOW VARIABILITY IN MAJOR RESERVOIRS

Several factors and processes affect local or regional water resources. Human activities, in particular, influence hydrologic cycle through change, or water and land use. In recent years, the issue of climate change due to human activities posed a major concern to water resource managers, planners, and policy decision makers. The reason for this is, the present water management is mainly based on semistationary geophysical processes with some consideration on increasing demands due to population and land use changes. As an initial effort in understanding the impact of climate change and other human activities on water resources, variability and trends of inflow at various major reservoirs in the Philippines were examined. These multipurpose major reservoirs are mostly found in Luzon Island. These include Ambuklao, Magat, Pantabangan and Angat dams. Another water reservoir which is considered as multipurpose and natural is Lake Lanao in Mindanao Island. The geographical location of these reservoirs are indicated in Figure 6.

Just like rainfall, examination of the variations of seasonal and annual inflow were considered. Since inflow or availability of water in the reservoir depends largely on the precipitation over the watershed areas, the analysis of the variability of inflow in relation to rainfall was made for a particular reservoir.

Figure 7 shows the regressions of the annual and seasonal inflows of Angat Reservoir with the rainfall over Manila. The rainfall regime over Manila is believed to be representative of that of the Angat Reservoir watershed. Manila has a long period of rainfall observations which can later be subjected to variability analysis and be used in developing possible predictive hydrological models for Angat Reservoir.

Year-to-year variations of the annual and seasonal inflows (1968–93) at Angat water reservoir as compared to that of Manila rainfall are shown in Figure 8. The trends are similarly decreasing for both the inflow and the rainfall time series although the trends are not statistically significant. It is interesting to note that the minimal amounts of inflows and rainfall are associated with the ENSO-related drought event particularly in 1968, 1969, 1973, 1977, 1983, 1987 and 1991. During the most recent drought of 1991–92, Angat recorded its historical lowest water level of 150 meters (normal is 180 meters). The Angat water reservoir was constructed for various purposes such as domestic water supply, irrigation and hydropower. However, because of the recurrence of drought during the past few years, the reservoir is now basically reserved as a priority for the domestic water supply for Metro Manila.

Similar decreasing trends of inflow are also indicated in the other water reservoirs of Magat, Ambuklao, Pantabangan and Lake Lanao. These are indicated in Figure 9.1 and 9.2. In the case of Magat, the decreasing trend of SW inflows is significant at 5% level. The same is true in the seasonal inflow trends of Lake Lanao. The NE inflow in

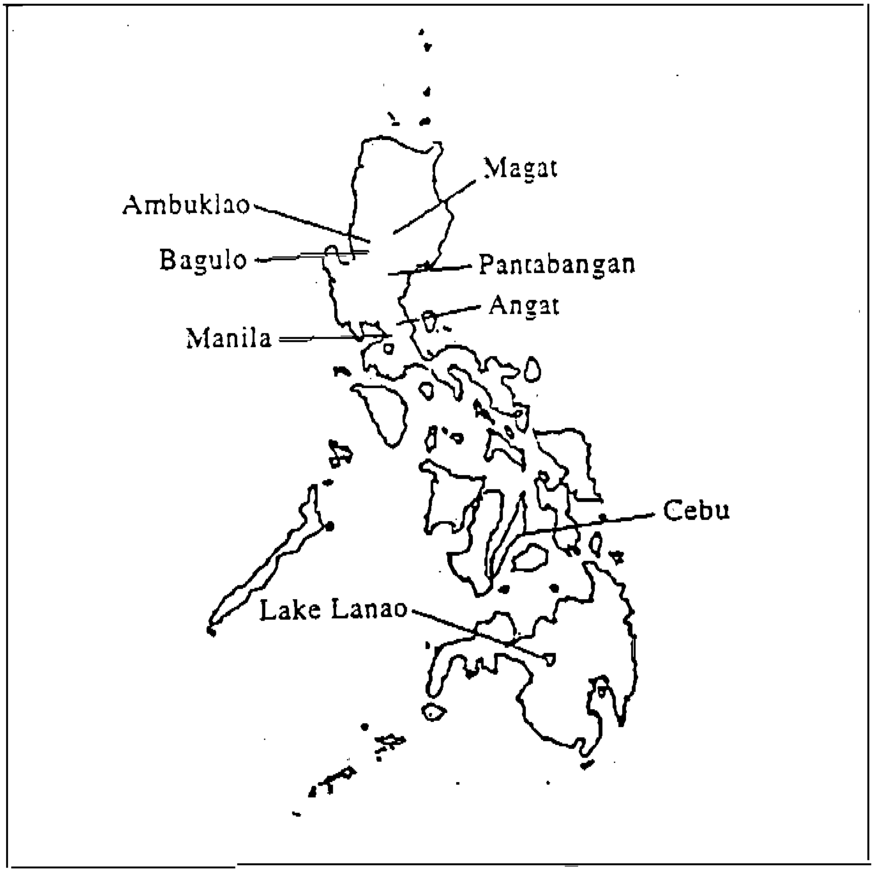

Figure 6. Geographical location of major water reservoirs including climatological stations of Baguio, Manila and Cebu in the Philippines

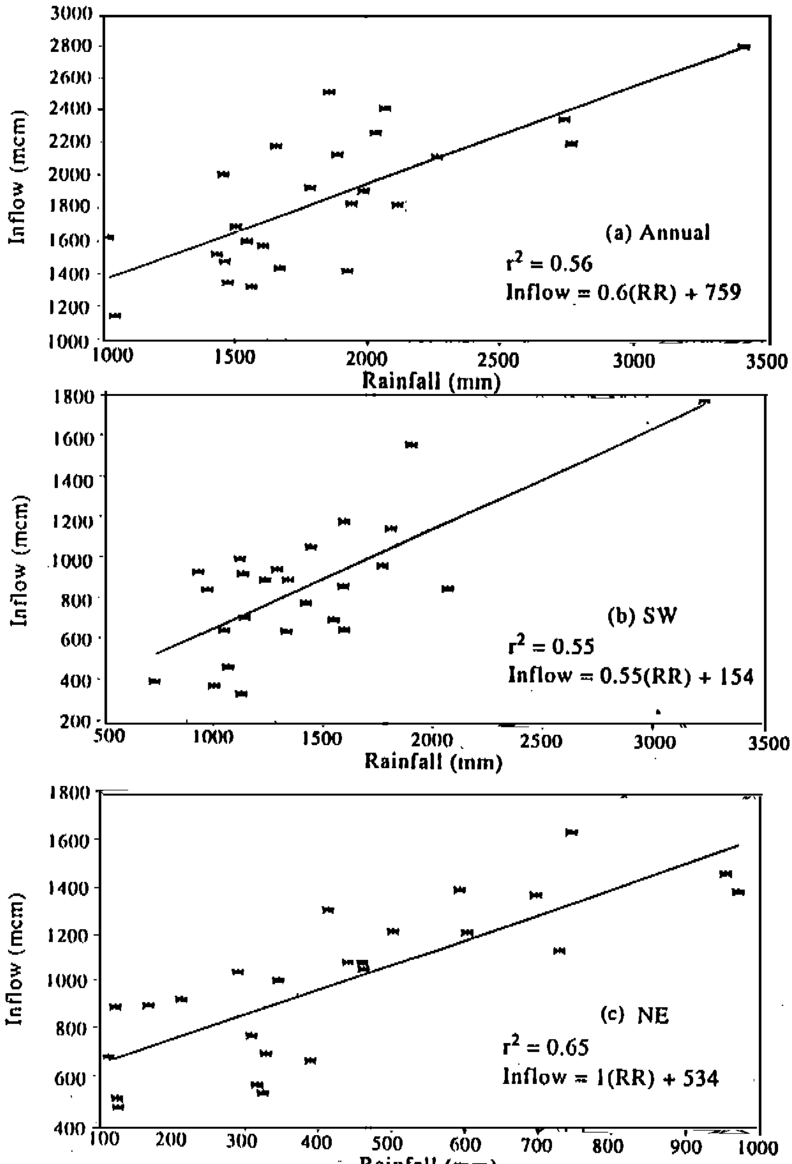

Figure 7. Regression of the annual and seasonal inflows of Angat reservoir with that of Manila rainfall

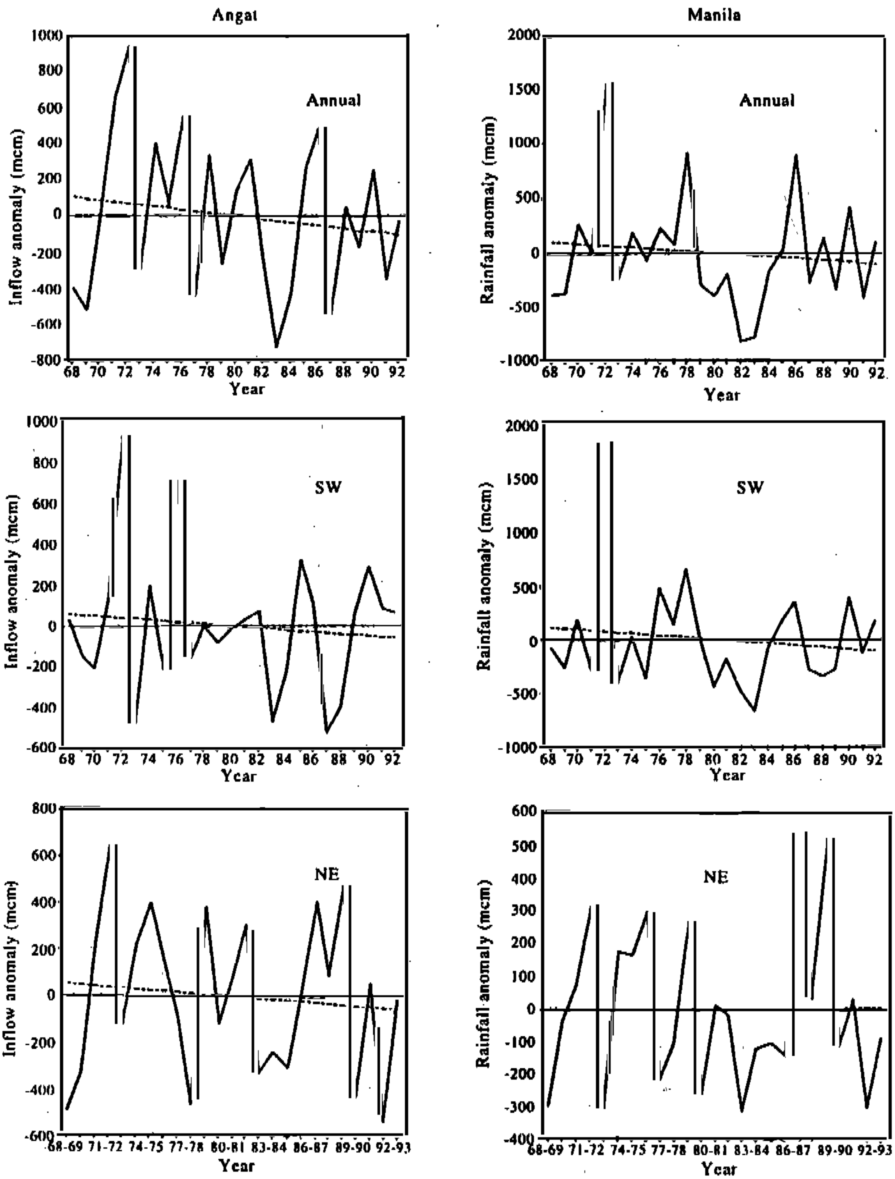

Figure 8. Year-to-year variations of the annual and seasonal inflows (1968–93) of Angat reservoir and Manila rainfall

Figure 9.1
Annual and seasonal inflow variations in Ambuklao and Magat reservoirs

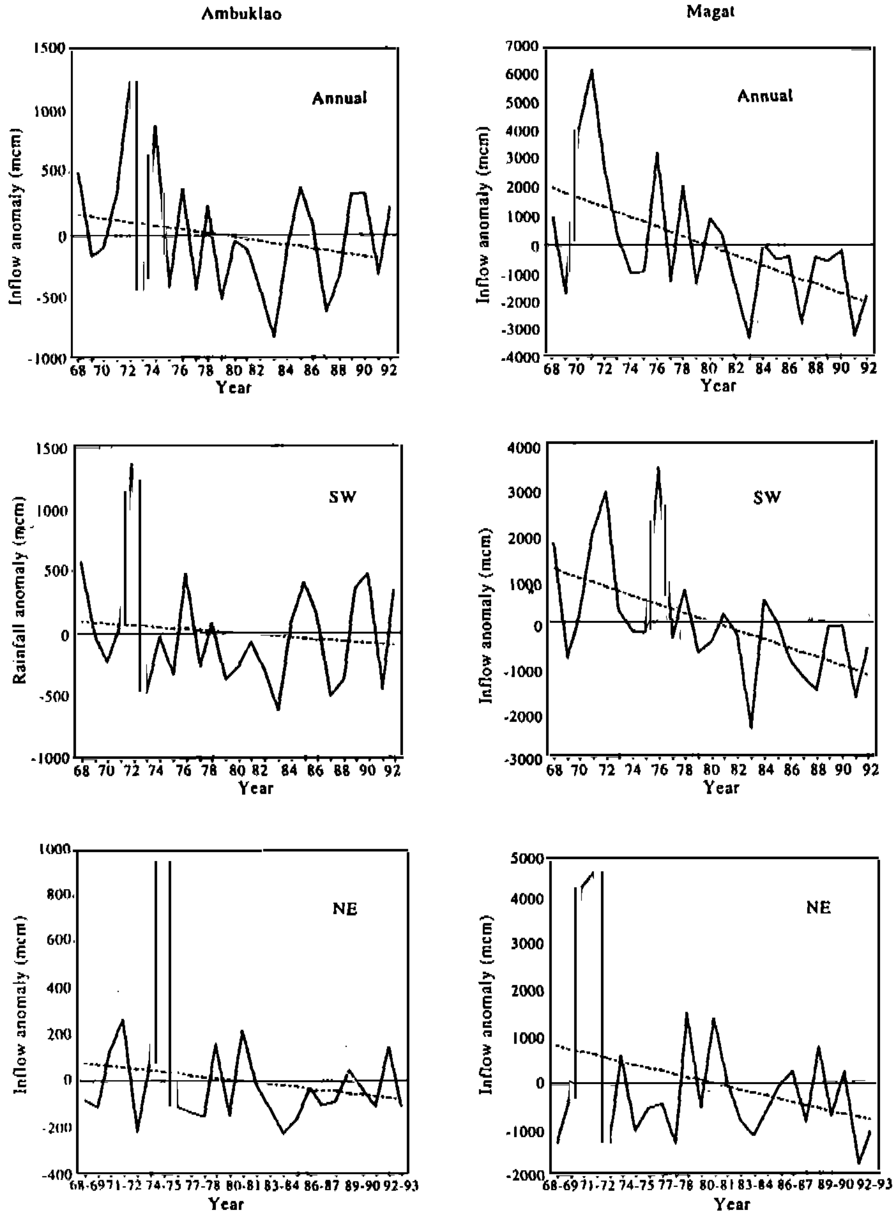

Figure 9.1. Annual and seasonal inflow variations in Ambuklao and Magat reservoirs

Figure 9.2
Annual and seasonal inflow variations in Pantabangan reservoir and Lake Lanao

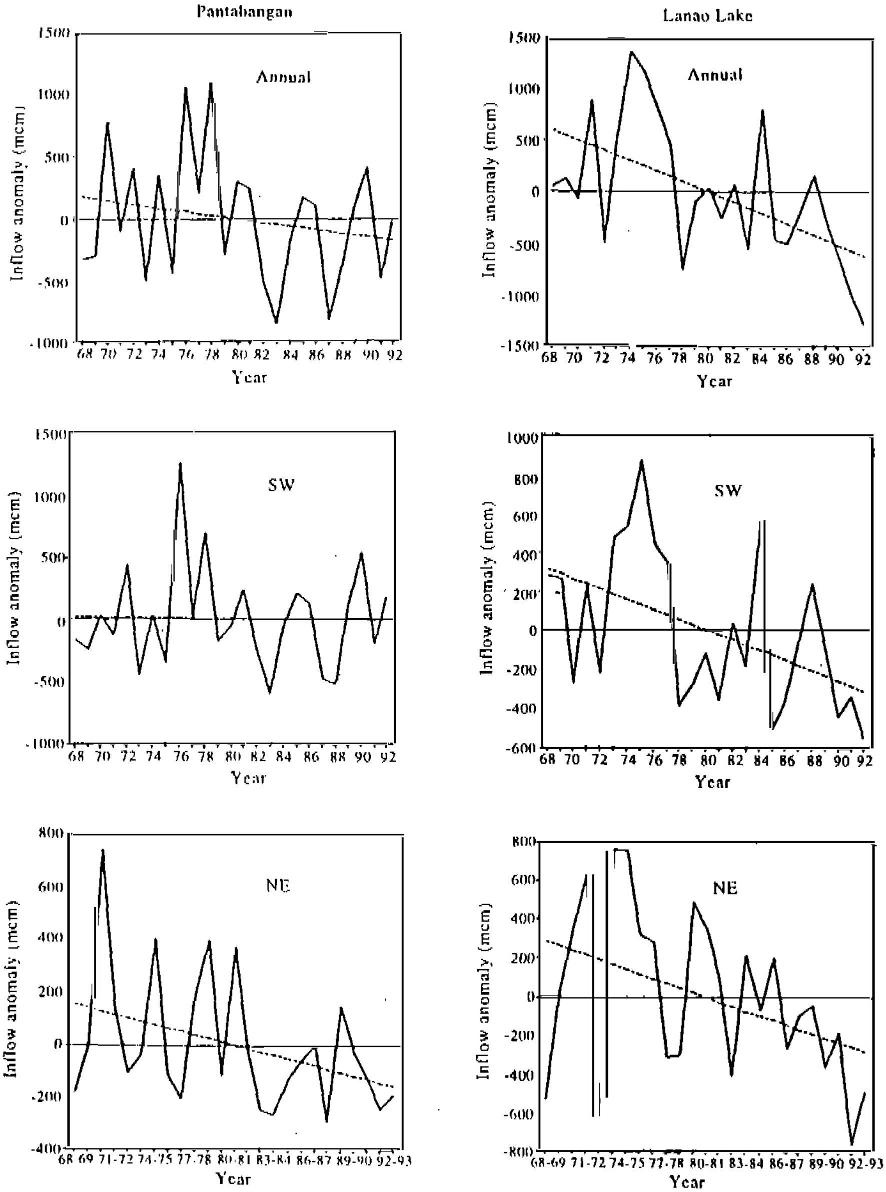

Figure 9.2. Annual and seasonal inflow variations in Pantabangan reservoir and Lake Lanao

Pantabangan exhibits a decreasing trend which is significant at 10% level. ENSO-related four to five years quasi-periodicity of the inflows are also evident. Since rainfall and inflow in the reservoir are closely related based on figures, it is implied that the percentage of variance of inflow that can be attributed to ENSO/SOI would be in the range of 10 to 20%. The decreasing trends of inflow and rainfall pose problems in water resource management. The impact of water shortages is wide-spread affecting various sectors.

In agriculture for example, Table 1 shows that the production damages at various regions caused by the ENSO-related drought event of 1991–92 amounted to more than 4 billion pesos.

The domestic water supply for Metro Manila and its contiguous areas mainly comes from Angat watershed (70%). During the same drought event, the Metropolitan Water Sewerage System reported an equivalent of 20% shortfall of water production. This condition caused water rationing in many low water pressure areas of Metro Manila.

Reports from the National Power Corporation for the same drought event which resulted in the rapid lowering of the major reservoir elevations, drastic curtailment of the generating capacity of the various hydropower plants particularly in Luzon and Mindanao occurred. In Luzon alone, the three major multipurpose dams of Angat, Magat and Pantabangan experienced power generation losses of about 31% of the expected power generation for October 1991 to March 1992 (Table 2). With the decrease of hydro-energy due to low water elevations, there was an increase in the load of the thermal plants to cover the deficiencies which was costly.

About 73% of the power generation in Mindanao is derived from hydro-plant operations and about 90% of the hydropower is generated from Lake Lanao. The persistently low water elevation of Lake Lanao during the past few years including the drought event of 1991–92 caused major socio-economic and environmental concerns not only to the populace of Mindanao but also to the whole country, although indirectly.

Table 1. Summary of agricultural production damages at various regions caused by the 1991-92 El Niño-related drought event

	Area Affected (hectares)						
Region	**Rice**	**Corn**	**Vegetables**	**Fruit Trees**	**Other Crops**	**Total**	**Estimated Damages (P)**
1	2851	679	527			4057	34362920
2	2285	6950				9235	92589760
CAR	429	4049	262	132		4872	45059033
5	4099	456	43			4598	30609764
6	70990	454	368		28	71840	856743835
7	35	187	87	1767		2076	5426660
8	7591	1177	1353	38	28	10187	86298944
9	7974	8689	2564			19227	227601981
10	2387	28552	1381	13640	130	46090	232649997
11	21156	56589	1265	90987	1684	171681	1304986686
12	38263	74763	2390	1320	1183	117919	1178603224
Grand Total	**158058**	**182543**	**10240**	**107884**	**3053**	**461782**	**4094932804**

Table 2. Actual monthly flows compared with the normal values for three major reservoirs in Luzon (million cu. m.)

	Angat			Magat			Pantabangan		
	Actual	**Normal**	**% of Normal**	**Actual**	**Normal**	**% of Normal**	**Actual**	**Normal**	**% of Normal**
Month									
1991 Oct	68	318	21.4	362	1046	34.6	98	193	50.8
Nov	101	308	58.8	294	641	45.9	50	149	33.6
Dec	113	204	55.4	226	313	72.2	14	30	46.7
1992 Jan	62	102	60.8	132	215	61.4	9	13	68.24
Feb	29	59	49.2	38	149	25.5	5	8	62.5
Mar	15	51	29.4	38	134	28.3	4	7	57.1
Total	**468**	**1042**	**44.9**	**1090**	**2498**	**43.6**	**180**	**400**	**45.0**

CONCLUDING REMARKS

It is important to remember that with or without climate change or global warming, climate variations will still be present in the global system that will affect a wide range of human activities. In relation to impacts of climate variations on hydrology and water resources, future repetition of extreme climate events that affect rainfall and inflow can be expected. These events should be planned for. Some considerations should be given to the fact that the effects of these extreme events are now compounded with the impacts of population growth and accompanying changes in land and water use. Along this line, more research activities are needed. The critical role of ENSO in a year-to-year variability and extreme events has been documented. This highlights the need to understand how ENSO will be affected by global warming.

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