

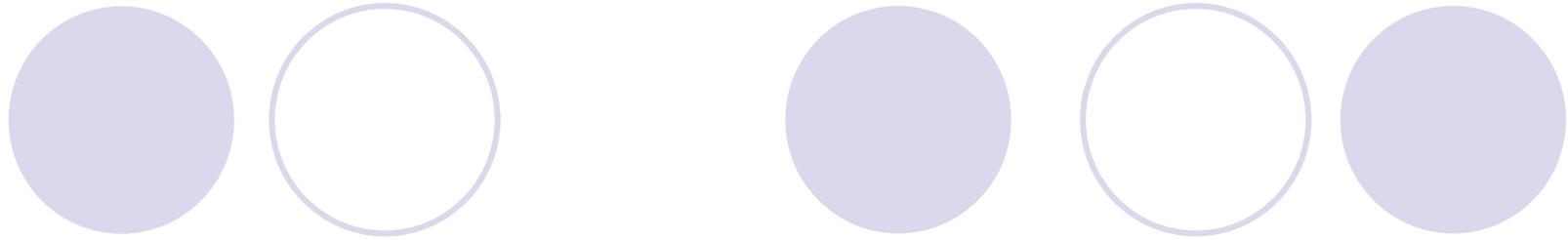
Climate Changes and Water Resources in Taiwan History

PNC2011

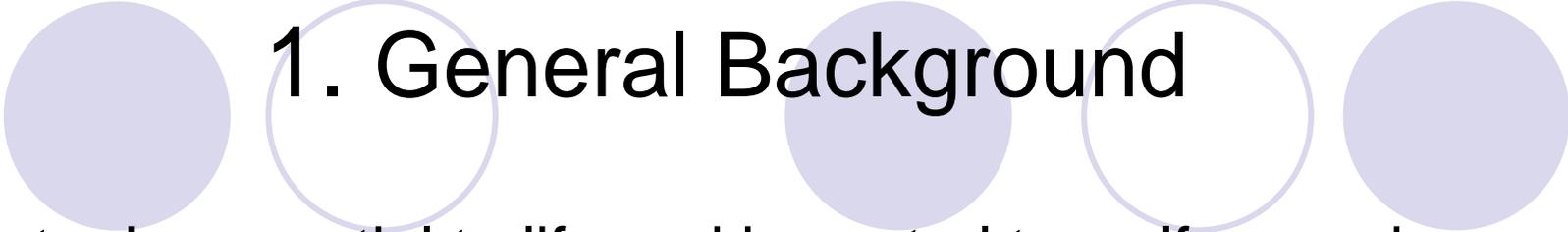
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- General Background
- Climatic Disasters
- Water Resources and Utilization



1. General Background

- Water is essential to life and is central to welfare and sustainable development of the society.
- The movement of water cycle, also known as hydraulic cycle, is sensitively related to climate change.
- Of the total amount of water on the earth, more than 97% is too salty to drink or grow food and freshwater is estimated to be less than 3%. In practice, most freshwater are kept as ice in Antarctica and Greenland, or as groundwater, or runoff to the ocean, only about 0.3% retained in rivers and lakes become a major source for human daily use; but the distribution of this water resource varies among regions.

- Taiwan and its offshore islands, located in subtropical region along southeast coast of Asian Continent, have the climate affected by both the oceanic and continental climatic patterns as well as by the island's topography of central mountain range.
- The annual average air temperature in Taiwan is 23°C, but there are seasonal and regional variations.
- The annual precipitation in Taiwan is around 2,500 millimeters (mm), which is about 3 times of the world average; but the distribution of rainfall is uneven in season and in region.

- The precipitation in Taiwan comes mainly from the Mei-yu (plum-rain, May-June) and the typhoon-rain (July-October). In terms of proportion, the spring-rain (February-April) shares 16%, the Mei-yu 22%, the typhoon-rain 43%, and the winter-rain (November-January) 19%.
- Taiwan has 151 major and minor rivers with a total length of 3,717 kilometers, but most of them run from high mountains in short and steep courses. The river flows can not be retained easily and fluctuate greatly in wet and dry seasons. Thus only about 25% of the total rainfalls can be utilized.
- Regional and seasonal variations of precipitation have important impacts on water resource utilization in Taiwan.

- In addition to surface water, the use of groundwater by bamboo wells in Taiwan could be traced back to the seventeenth century.
- In the 1920s, groundwater corridors were developed and since the 1940s, deep wells were developed. Until the 1990s, there were more than 200,000 deep wells in Taiwan.
- A survey in 1958 found that at nine areas of groundwater storages in Taiwan, the annual safe yield was estimated to be 24.64 billion m³.
- In the 1990s, the annual groundwater withdrawal reached 71 billion m³, while the annual natural recharge was only 40 billion m³. As a result, over withdrawal of groundwater had induced serious land subsidence along Taiwan's west coast.

- As for changes in temperature, using data collected by meteorological stations during 1897-1997, scholars created an “All-Taiwan Temperature Series” and found that there was a strong and significant temperature increase of 1.14°C in Taiwan, whereas the global temperature showed an increase of only 0.6°C over the same period.
- The largest temperature increase in Taiwan was observed in summer, while global observations identify winter warming as the main cause of annual temperature increase.

- It was also found that Diurnal Temperature Range (DTR) in Taiwan had decreased 0.4°C in 1930-1970 and 0.8°C in 1970-1984, while global average was 0.43°C in 1950-1993. This difference is probably due to land-use changes or air pollutants emitted locally in Taiwan.
- As for precipitation, it is found that beginning from the twentieth century, the amount of rainfall was decreasing, the curve reached a trough in 1910 and recovered after 1930 until reached a peak in 1960 and then declined again, signaling a trend of precipitation decrease.

- A recent study confirmed that the increase in temperature and the decrease in rainy days had become more apparent in the past 30 years in Taiwan.
- Another study on Taiwan's climate changes in the past 100 years suggested that in 2100, in northern Taiwan the average temperature would be 1-1.5°C higher than the present and the annual precipitation would increase 400-600 mm; while in southern Taiwan, the temperature would rise in the same level, but the precipitation would decrease 500-700 mm. Thus, the problem of water resource shortage will become more serious in the near future.

- In 1990, the amount of rainfalls in Taiwan was estimated to be 901 billion m³, of which 79% was runoff to the ocean and only 21% was utilized for water supply. Taking Taiwan's population as a denominator, the per capita amount of freshwater was 930 m³, which was only 27% of the amount estimated for Asia (3,400 m³) in 1990.
- This demonstrates that Taiwan is, in fact, a place of poor water resources regardless of abundant rainfalls.



2. Climatic Disasters

2.1 Disaster of Typhoon

- It is possible to use historical records with precise dates to identify typhoons in Taiwan history. Figure 1 shows 112 typhoons attacked Taiwan during 1721-1898. Apparently, the number of typhoons was under-recorded as compared with that of modern meteorological records.
- During 1897-2010, there were 405 typhoons attacked Taiwan with different intensities as illustrated in Figure 2.

Figure 1: Typhoons Recorded with dates in Taiwan History, 1721-1898

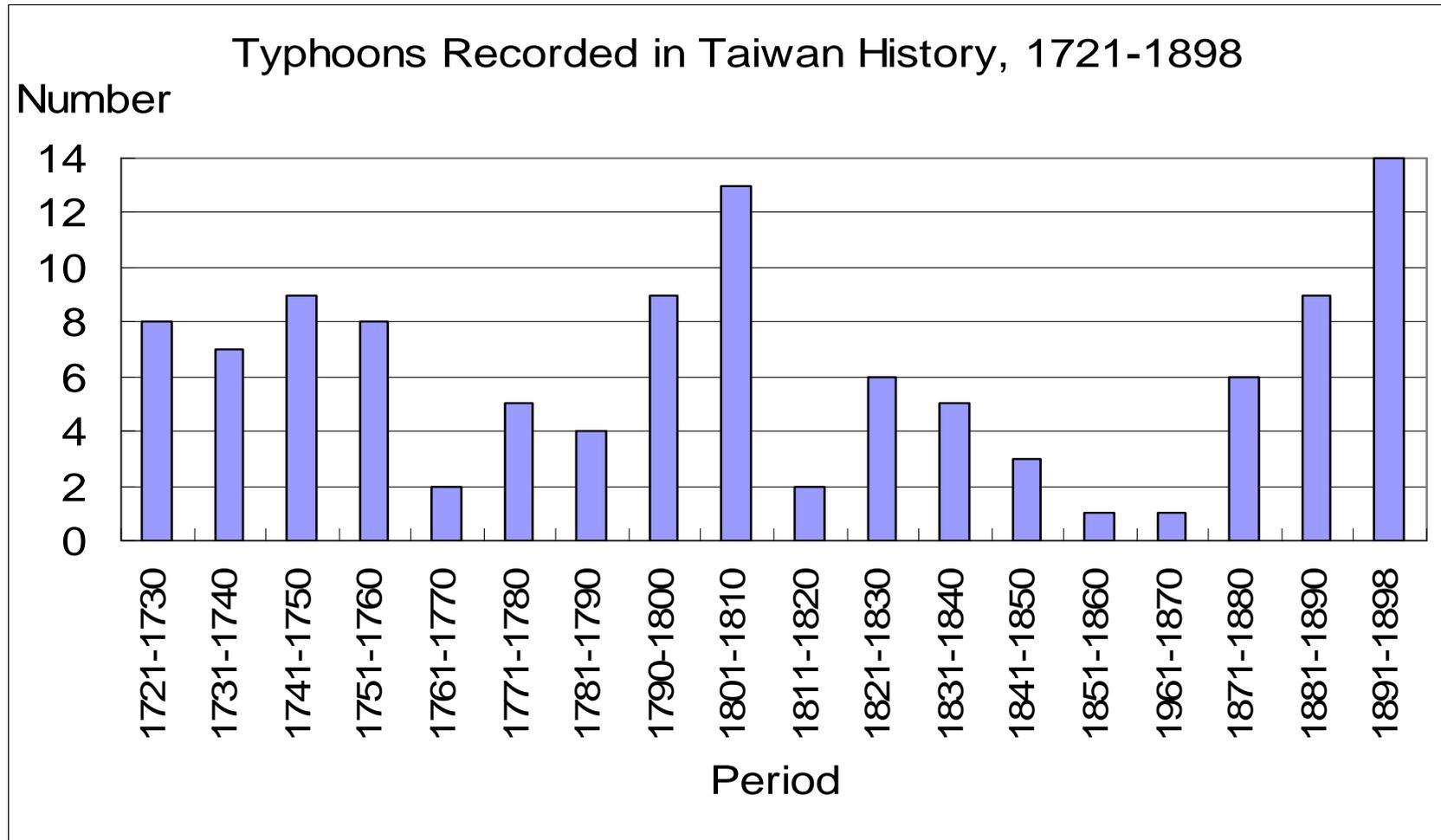
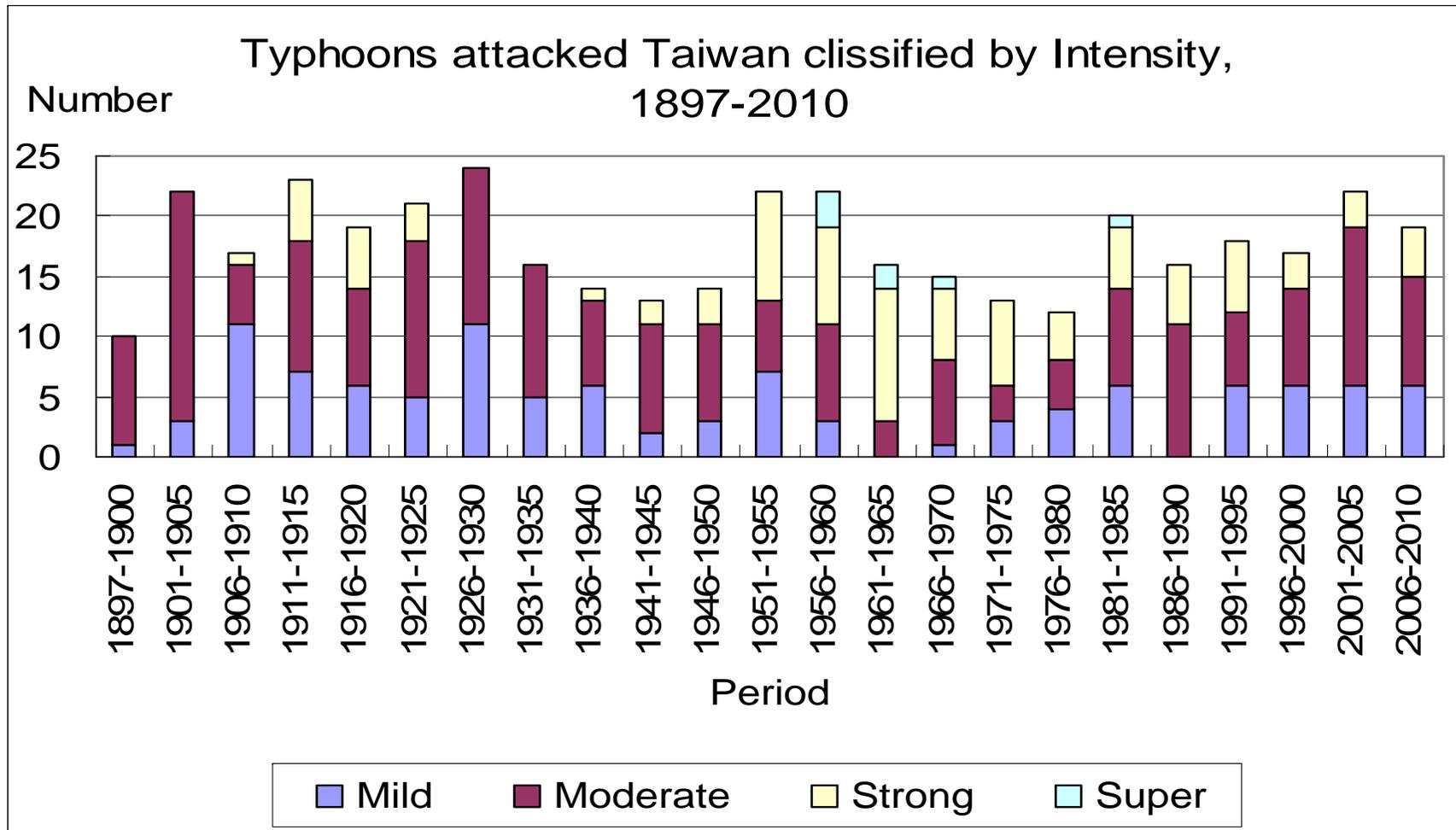


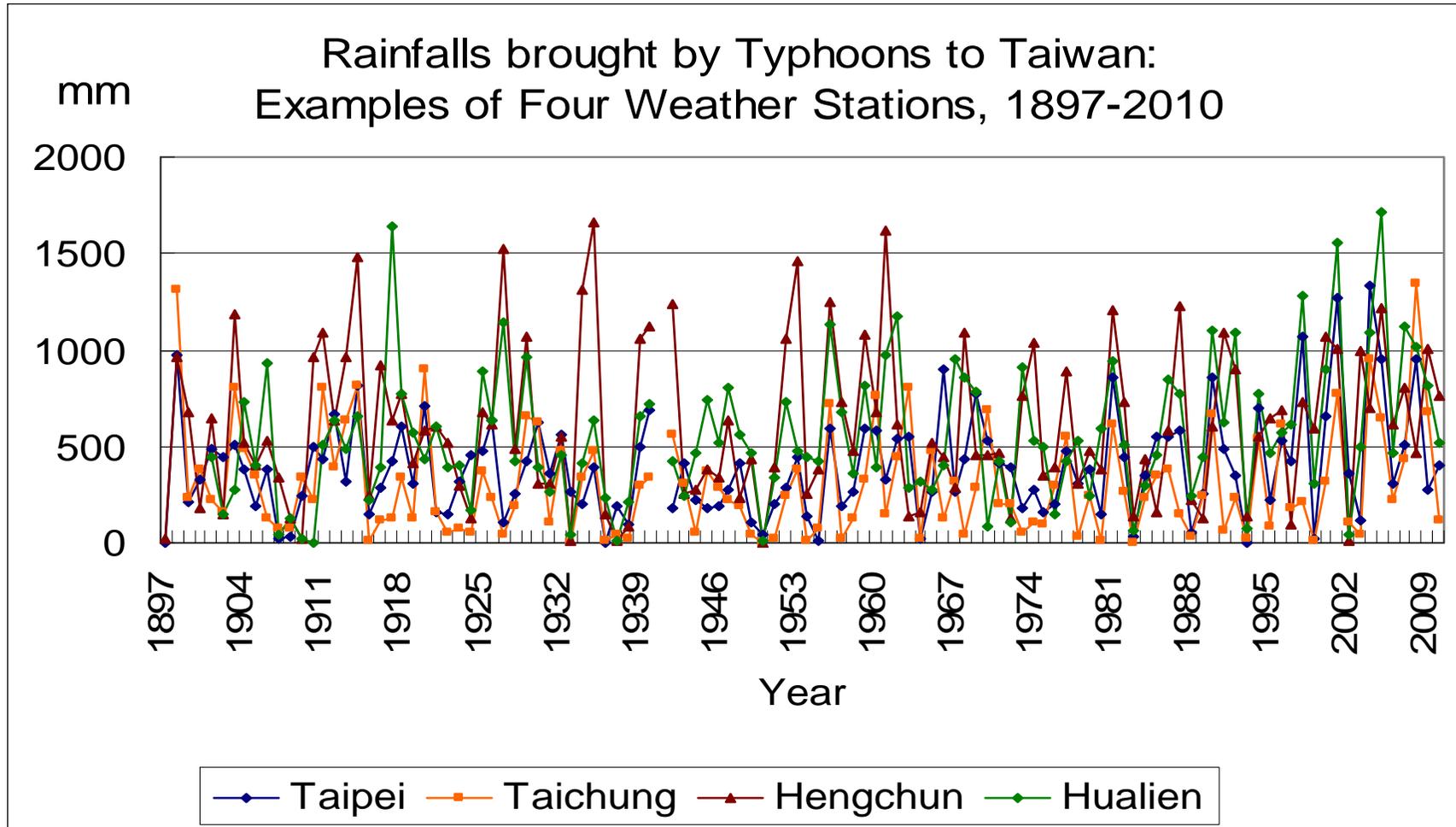
Figure 2: Typhoons attacked Taiwan classified by Intensity, 1897-2010



- Of these 405 typhoons attacked Taiwan during 1897-2010, the mild ones shared 26.7%, the moderate ones 49.1%, the strong ones 22.5%, and the super strong ones 1.7%.
- On average, there were 3.6 typhoons attacked Taiwan per year.
- If classified by month, August shared 30.4%, July 25.2%, September 21.5%, June 7.9%, October 7.7%, May 3.9%, November 2.5%, and both April and December 0.5%.

- During 1897-2010, the record of rainfall brought by typhoon was available for 472 cases, including those not attacked Taiwan directly. But both the number of typhoons and the number of weather stations varied year by year.
- For examples, annual records of four weather stations in Taipei 臺北 (north, from 1897), Taichung 臺中 (central, from 1898), Hengchun 恆春 (south, from 1897) and Hualien 花蓮 (east, from 1901) are illustrated in Figure 3.
- As can be seen, yearly rainfalls brought by typhoons fluctuated greatly with more peaks above 1,000 mm appeared in Hengchun and Hualien, but it is difficult to perceive a trend of increasing typhoon rainfalls through time.

Figure 3: Rainfalls brought by Typhoons to Taiwan:
Examples of Four Weather Stations, 1897-2010



- Some examples can be cited to show the disaster of typhoon.
- Table 1 shows disasters of a typhoon attacked Taiwan on October 3, 1721. There were 10,688 houses destroyed, 75 persons dead, and 22,491 persons stricken. They received 10,820.50 taels of silver and 3,790.4 shih (1 shih = 133.3 pounds) of grain for relief.
- Table 2 shows disasters of a typhoon attacked Taiwan on October 17-18, 1797. There were 83,982 households with 178,132 adults and 144,182 children stricken. These people received 18,766.725 shih of grain and 37,533.45 taels of silver for relief.

Table 1: Disasters of a Typhoon attacked Taiwan on October 3, 1721

County	No. of Houses Destroyed	No. of Persons Dead	Relief Funds (tael)	No. of People Affected	Relief Grain (shih)
Taiwan	5,881	38	5,944.50	5,058	937.5
Fengshan	3,365	29	3,419.25	8,867	1,487.6
Chulo	1,442	8	1,456.75	8,566	1,365.3
Total	10,688	75	10,820.50	22,491	3,790.4

Table 2: The People Stricken by a Typhoon attacked Taiwan on October 17-18, 1797

Location	No. of Households	No. of Adults	No. of Children
Tamshui Ting	9,888	22,400	18,082
Taiwan County	15,359	34,252	25,000
Fengshan County	17,634	36,689	29,000
Chiayi County	21,981	43,090	39,000
Changhua County	19,120	41,701	33,100
Total	83,982	178,132	144,182

- A third example took place on July 10-16, 1845 when heavy rains with a typhoon and high tides attacked Taiwan.
- In the Taiwan County City (i.e., today's Tainan 臺南), the flooding water accumulated to several feet; there were 1,256 households with 3,416 people stricken and 342 corpses of fishermen were found around Luermen (鹿耳門). Moreover, 11 mercantile marines were stricken with 40 sailors drowned. Out of Anping (安平) harbor, a ship from the Philippines was broken and 26 sailors were rescued and settled by the County Office with food and clothing.

- In Chiayi (嘉義) County, at nine villages near the coast, more than 2,300 corpses were found, 875 households were inundated with 1,157 people escaped; at 15 villages further away from the coast, there were 79 households with 131 people stricken.
- In Fengshan (鳳山) County, the disaster was lighter as most houses along the streets were built with bricks, but straw huts along the coast could not stand the rain and wind, and 232 corpses of fishermen were found.

- In addition to typhoons, heavy rains also brought disasters. For examples, continuous heavy rains during March 31-June 6, 1721 caused landslides and floods with farms and fields buried by sands in many places; continuous rains in Changhua (彰化) County during September 12-October 10, 1787, brought the flood water up to one meter; heavy rains during July 29-August 27, 1802, brought turbid flows in the Choshui (濁水) River with woods and houses driven down and corpses were found along the river banks; heavy rains on July 16-19, 1893, in Yunlin (雲林) and Chiayi Counties forced river flows to rise suddenly and destroyed many houses and dry fields, and thus, the year witnessed serious famine.

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- During the Japanese Colonial Period in Taiwan (1895-1945), reports on typhoon calamities by the *Taiwan Daily* can be collected as listed in Table 3.
 - These records are, of course, incomplete; but still they reveal some serious disasters particularly those brought by two typhoons in August 1898.

Table 3: Typhoon Disasters in Taiwan in 1898-1934

Year	Persons		Houses		
	Dead	Wounded	Collapsed	Damaged	Broken
1898	388	63	9,763	13,131	27,156
1899	5	1	518	737	918
1900			278		579
1904	2	20	182	8,307	
1911	58	52	1,315	635	641
1912	112	25	4,483	3,954	4,759
1913	3		8	15	
1924	36	2	1,588	291	5,006
1934	1	5	436	889	65

- As before, the official relief was indispensable. For instance, in 1898 in Taipei County, 2,022 households received 19,881 yen for relief. The Japanese Emperor bestowed 4,000 yen in 1899, and again bestowed one yen for each household for the relief in 1900, thus, Taipei County received 760 yen, Taichung County 294 yen, Tainan County 23 yen, and Yilan Ting (宜蘭廳) 123 yen.
- Moreover, in 1898 the *Taiwan Daily* initiated to raise a relief fund and similar actions were taken later, such as to collect relief funds for the 1931 flood in Mainland China, the 1932 flood in Manchuria, and for typhoon disasters in Taiwan in 1943.

- Based on meteorological records, the disasters of typhoons during 1958-2010 are illustrated in Figures 4 and 5.
- The largest number of disasters was recorded in 1961-1965 as there were 601 dead, 250 missing, and 4,894 persons wounded as well as 45,163 houses entirely collapsed and 60,713 damaged (half collapsed). The second largest numbers were found in 1958-1960 and 1966-1970.
- In comparison with Figure 2 above, it is notable that there were more strong and super strong typhoons attacked Taiwan during 1956-1970 and thus more disastrous.

Figure 4: Number of Persons Stricken by Typhoons in Taiwan, 1958-2010

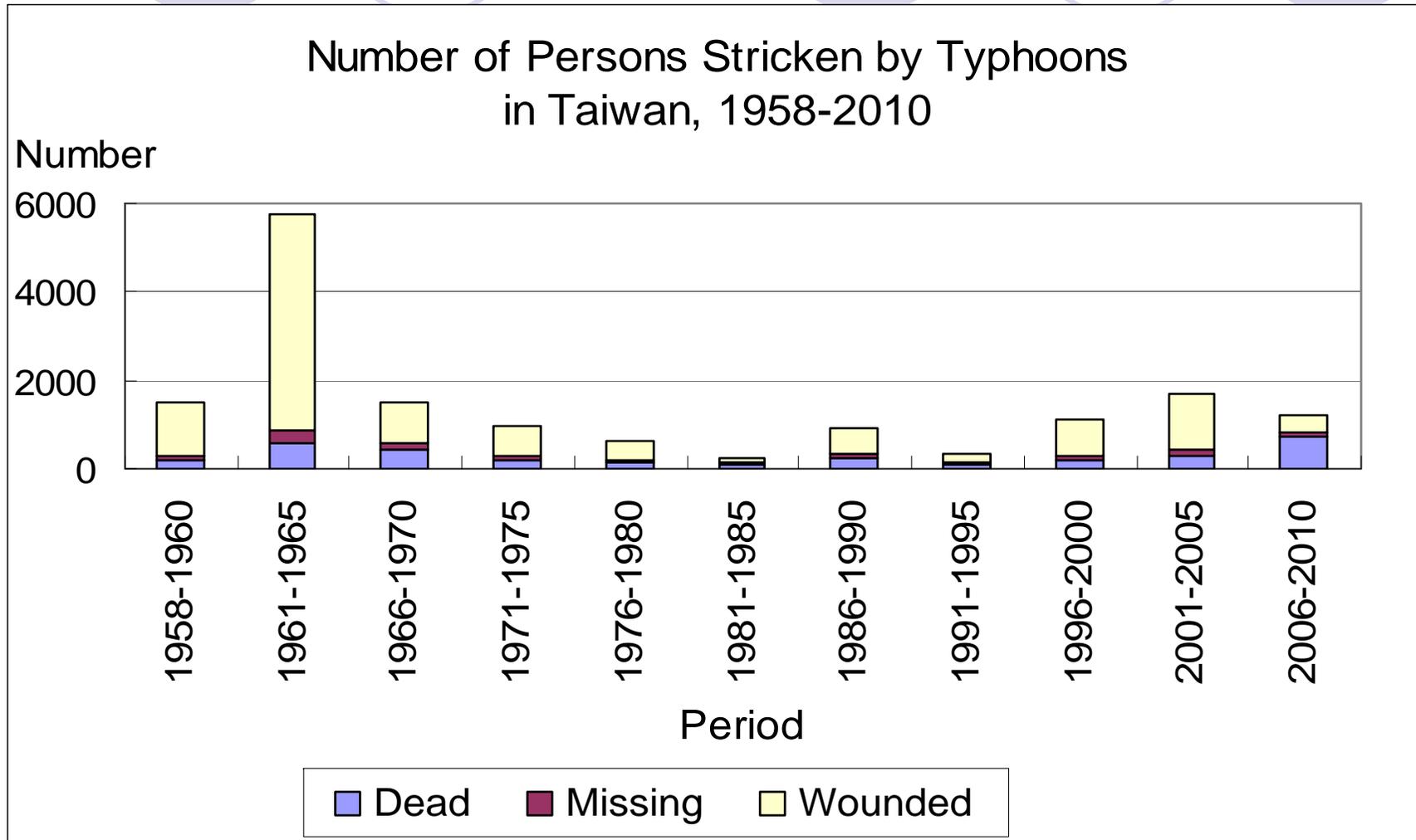
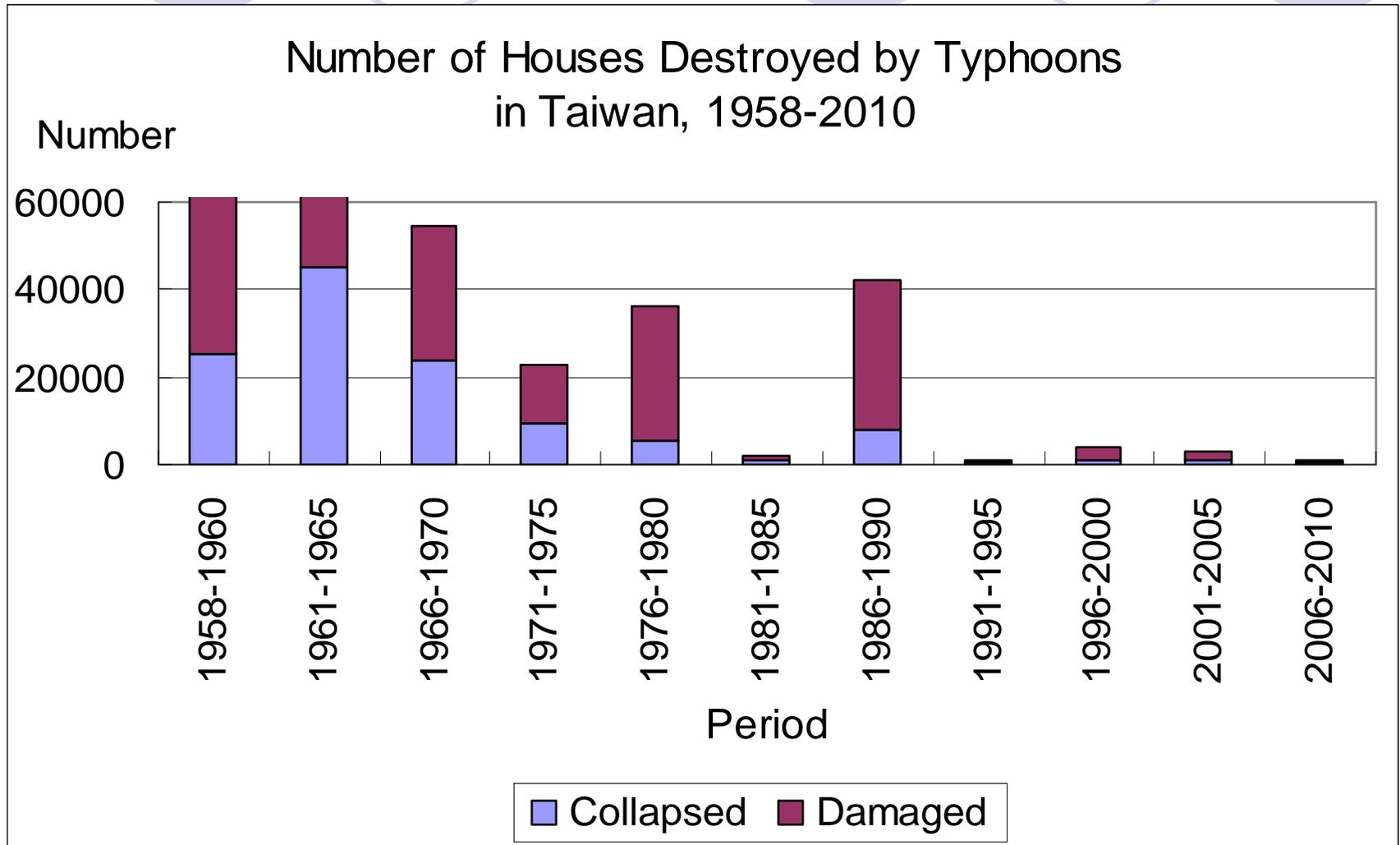


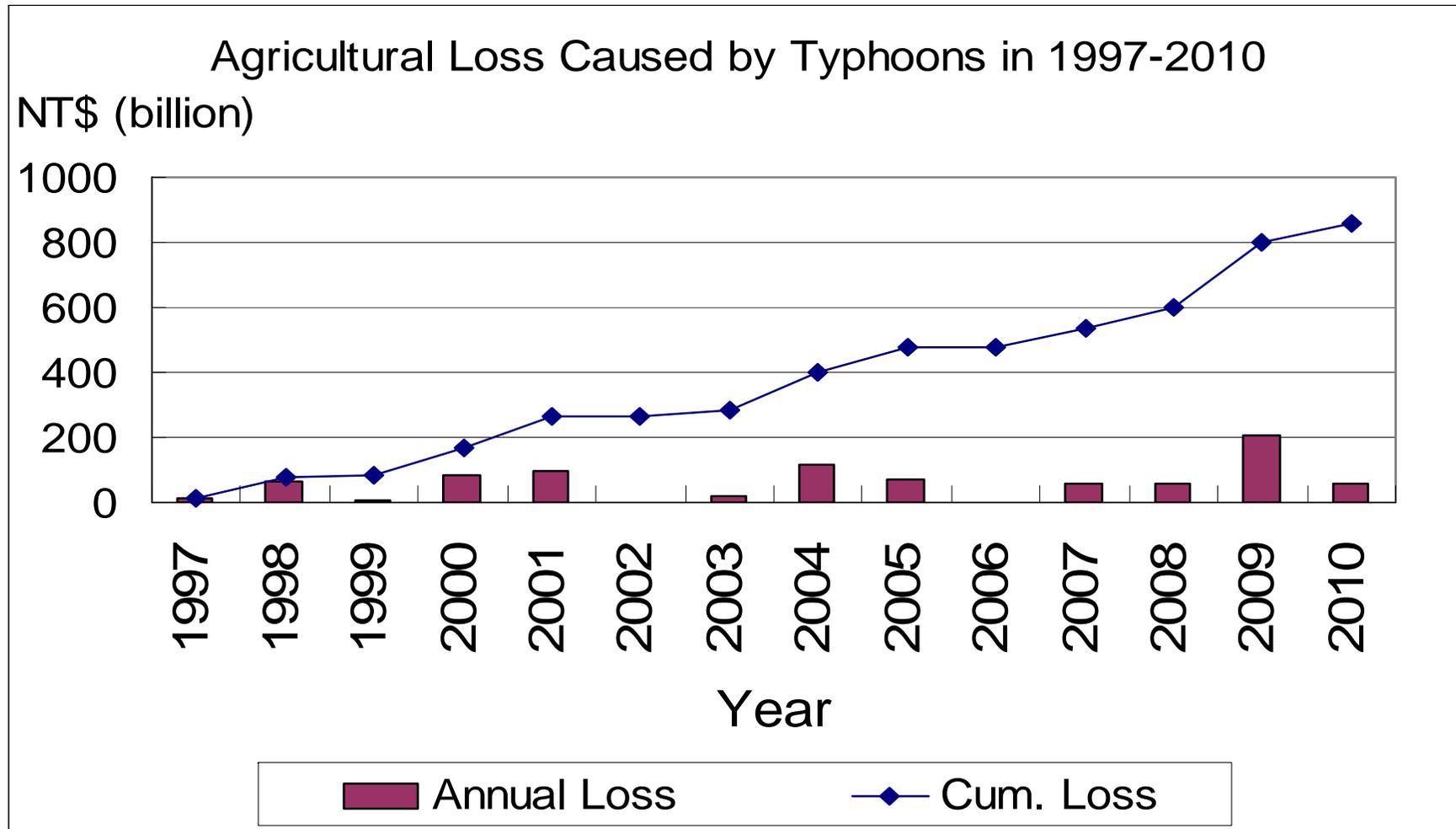
Figure 5: Number of Houses Destroyed by Typhoons in Taiwan, 1958-2010



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- The second largest number of dead and missing persons (813 together) was recorded in 2006-2010, as Morakot Typhoon brought 15,138 mm of rainfalls on August 5-10, 2009. Comparatively, houses collapsed and damaged were small in number, however, a village of aboriginal people was completely destroyed.

- Typhoon also brought agricultural loss as shown in Figure 6.
- Available data revealed that in 1997-2010, there were 41 typhoons which caused a total agricultural loss of NT\$ 859.12 billion.
- In terms of year, the largest agricultural loss was NT\$ 203.70 billion incurred by three typhoons in 2009. This amount accounted for 5% of the 2009 annual agricultural production (NT\$ 4,071.69 billion); and Morakot Typhoon alone caused a loss of NT\$ 195 billion (or 4.8%).

Figure 6: Agricultural Loss Caused by Typhoons in 1997-2010



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- In addition to typhoons, there were 48 cases of flood during 1959-2010 with the total disasters as follows: 994 persons dead, 493 missing and 1,066 wounded as well as 29,800 houses collapsed and 19,705 damaged.
 - Of these 48 cases, the flood on August 7, 1959 was so far the most serious one as it caused 667 dead (67% of the total), 408 missing (83%), and 942 wounded (88%) as well as 27,466 houses collapsed (92%) and 18,303 damaged (93%).

2.2 Disaster of Drought

- There were 50 droughts recorded in historical documents. Most of these cases were limited to certain locality and year as shown in Table 4.
- Penghu (澎湖) had 12 drought years; Taiwan Prefecture had 11; Taiwan (Tainan) County had 6; Chiayi had 5; Changhua had 4; Taiwan and Fengshan together had 3; Yunlin had 3; Shuchilin had 2; Miaoli and Tatupao each had 1.
- Droughts usually followed by famines and thus exemption of taxes and official relief were necessary.
- A study on the price of rice in the Qing dynasty pointed out that some cases of extremely high prices in 1754-55, 1758-59, 1811, 1815-16, and 1826-27 were related to droughts and floods.

Table 4: Droughts recorded in Taiwan History during 1683-1895

Locality	Year of Drought
Taiwan, Fengshan, Chulo (i.e. Taiwan Prefecture)	1683, 1705, 1707, 1717, 1718, 1726, 1728, 1731, 1743, 1746, 1747
Taiwan, Fengshan	1714, 1738, 1753
Taiwan, Fengshan, Changhua	1748,
Taiwan (Tainan)	1757, 1836, 1872, 1890, 1893, 1894
Fengshan, Changhua	1758
Changhua	1789, 1811, 1820, 1831,
Penghu	1811, 1831, 1851-52, 1855, 1860, 1870, 1872, 1873, 1879, 1881, 1882, 1885
Chiayi	1834, 1886, 1887-88, 1893, 1895
Yunlin	1851, 1888-89, 1893
Shuchilin	1894, 1895
Miaoli	1889
Tatupao	1894

- In early twentieth century, Penghu still suffered from wind and drought calamities in most years.
- In 1910, saving associations were organized for the purpose of relief at 74 towns and villages with a total fund of 6,000 yen and from which 1,400 yen were spent for the relief of drought in 1911.
- The drought in 1916 and the frost in early 1917 destroyed sweet potato, the staple crop of Penghu; fortunately, a new strain was transported from Taiwan for planting in the fields.
- In 1933, the drought in Penghu was ever more serious than before, as it did not rain for more than two months. At a local meeting in September, the village head urged the young people to pursue sidelines in order to tide over the difficult time.

- Based on rainfall records of 22 weather stations during 1971-2006, it is found that the absolute low rainfall was recorded at different stations in five years, 2003, 2002, 1993, 1983, and 1980.
- The next lowest rainfall records appeared in ten years, 2002, 1999, 1991, 1980, 2003, 1984, 1983, 1971, 2004 and 1993. In most of these years, the spatial distribution was irregular, except for the north.
- There was a continuity of drought, particularly in 1979-1980, 1993-1997, and 2002-2004, of which the droughts in 1980, 1993, and 2003 were more widespread.

- Comparatively, the agricultural loss of drought was smaller than that of typhoon and flood.
- Statistics during 1945-1993 showed that the cumulative agricultural loss due to natural calamities was NT\$ 902.0 billion (in current value), of which NT\$ 877.2 billion (97%) was due to meteorological disasters.
- The share of each category of disaster was in the order of typhoon 60.7%, flood 21.7%, drought 5.3%, frost and hail 2.2%, tornado and föhn 0.70%, and others 9.3%.

- The statistics of 1991-2010 showed that the agricultural loss due to meteorological disasters was NT\$ 1,106 billion, of which typhoon shared 79.5%, flood 10.2%, frost damage 6.4%, hailstorm 3.2%, and drought 0.6%.
- In comparison, shares of typhoon, frost damage and hailstorm increased, while those of flood and drought decreased.
- In terms of annual average, it was NT\$ 17.9 billion in 1945-1993 and NT\$ 55.3 billion in 1991-2010, indicating an increase of 3 times in recent 20 years.

3. Water Resources and Utilization

3.1 Water Supply and Demand in Taiwan

- Figure 7 illustrate the yearly total amount of water supply during 1971-2009. The amount fluctuated between 15,072 million m³ and 19,061 million m³ with a peak of 19,537 million m³ reached in 1990.
- Figure 8 shows the shares of water supply from three sources: rivers, reservoirs, and groundwater.

Figure 7: The Amount of Water Supply in Taiwan, 1971-2009

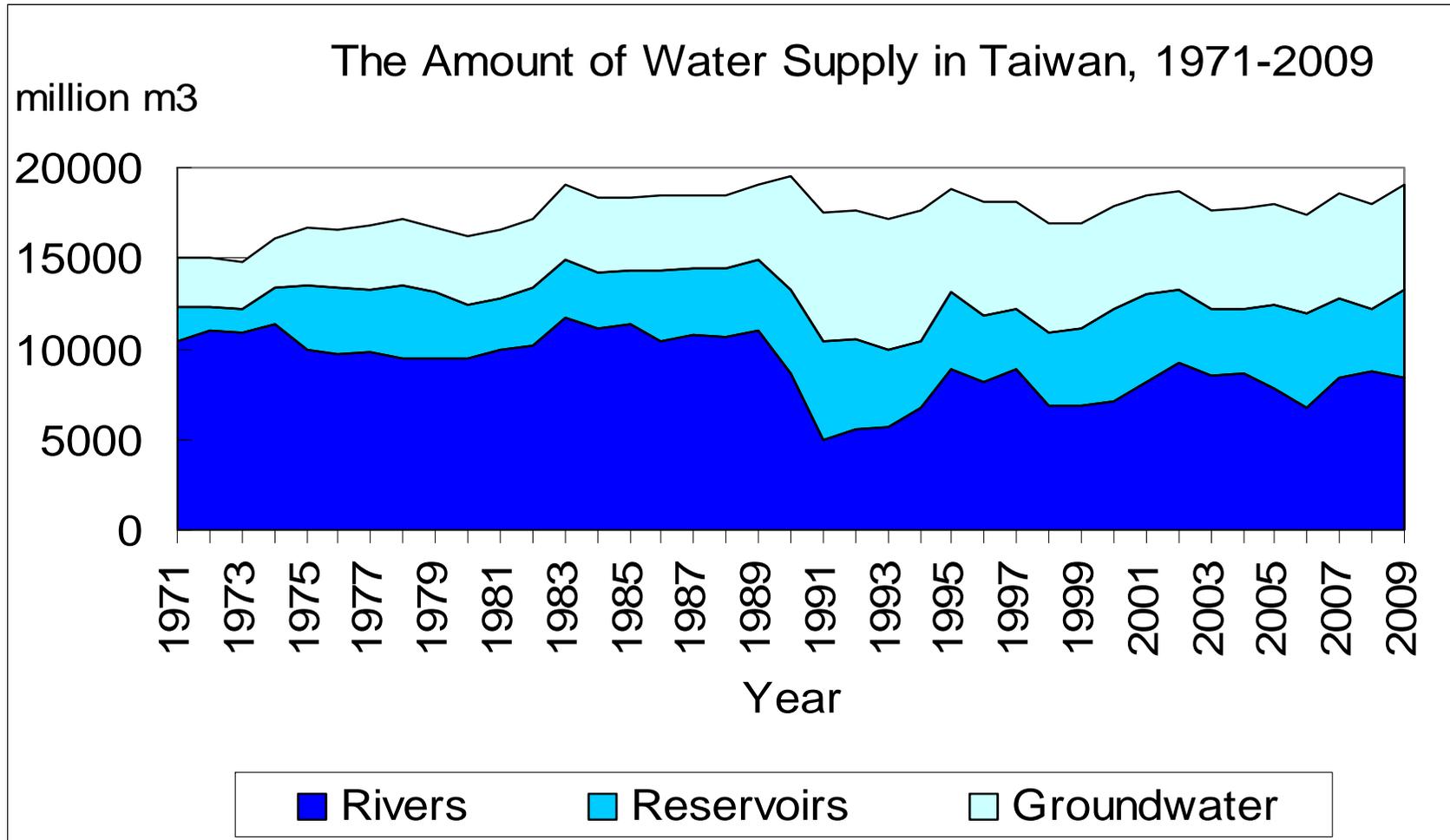
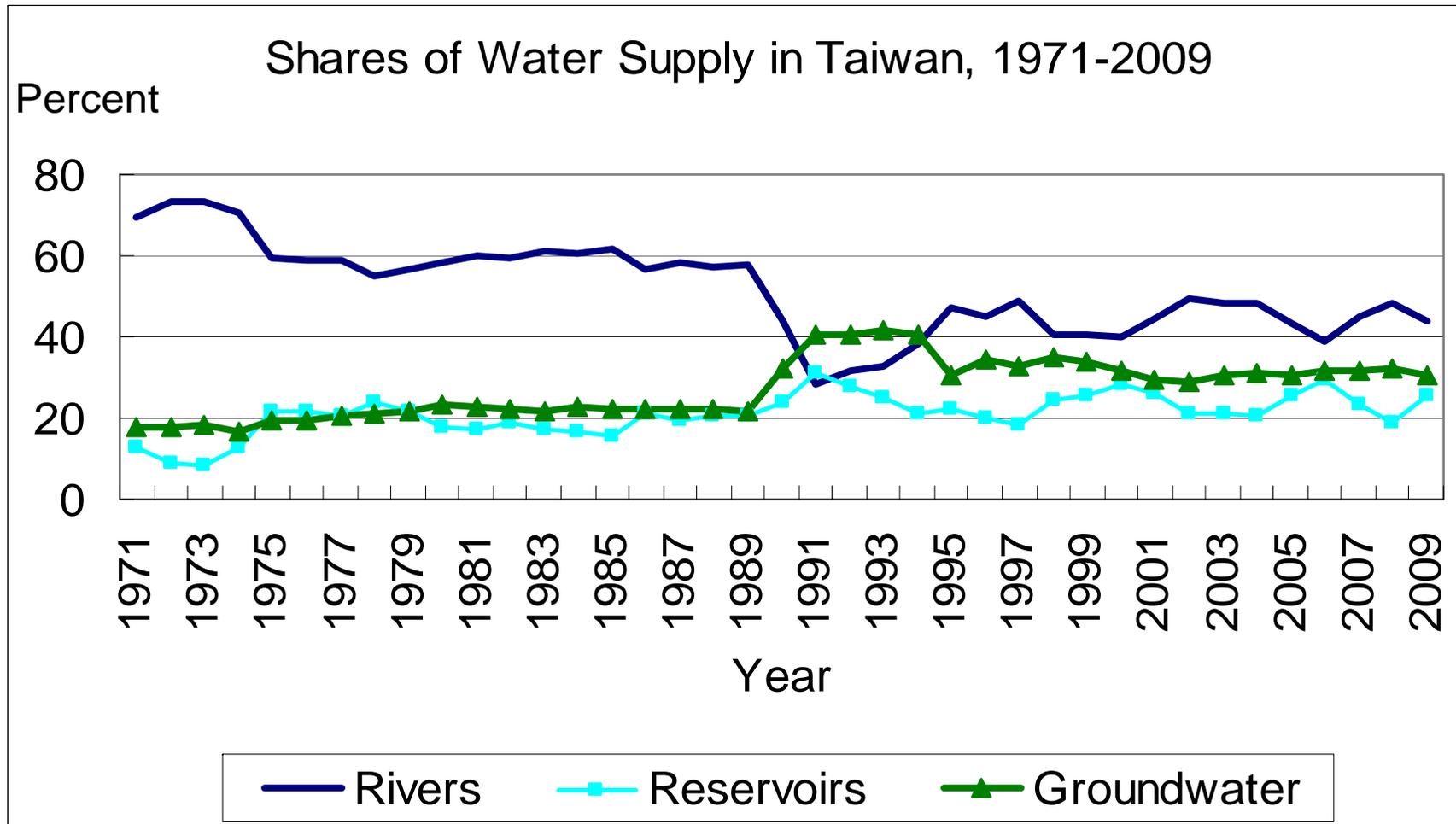


Figure 8: Shares of Water Supply in Taiwan, 1971-2009



- The shares of water supply from rivers fluctuated between 69.4% and 48.5%, with a peak of 73.5% in 1973 and a trough of 28.5% in 1991.
- The shares of water supply from reservoirs fluctuated between 12.6% and 19.1% with a trough of 8.3% in 1973 and a peak of 30.9% in 1991.
- The shares of water supply from groundwater fluctuated between 18.0% and 30.5% with a trough of 16.8% in 1974 and a peak of 41.7% in 1993.

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- With the available amount of water supply, Figure 9 shows the water consumed by agricultural, domestic and industrial sectors.
 - The shares of water consumed by agricultural sector decreased from 91.1% to a trough of 69.1% in 2000 and then slightly increased to 74.2% in 2009.
 - The shares of water consumed by domestic sector increased from 3.1% to a peak of 20.7% in 2006 and then decreased to 17.6% in 2009.
 - The shares of water consumed by industrial sector increased from 5.7% to a peak of 10.5% in 2000 and then decreased to 8.1% in 2009.

Figure 9: Shares of Water Consumption in Taiwan, 1971-2009

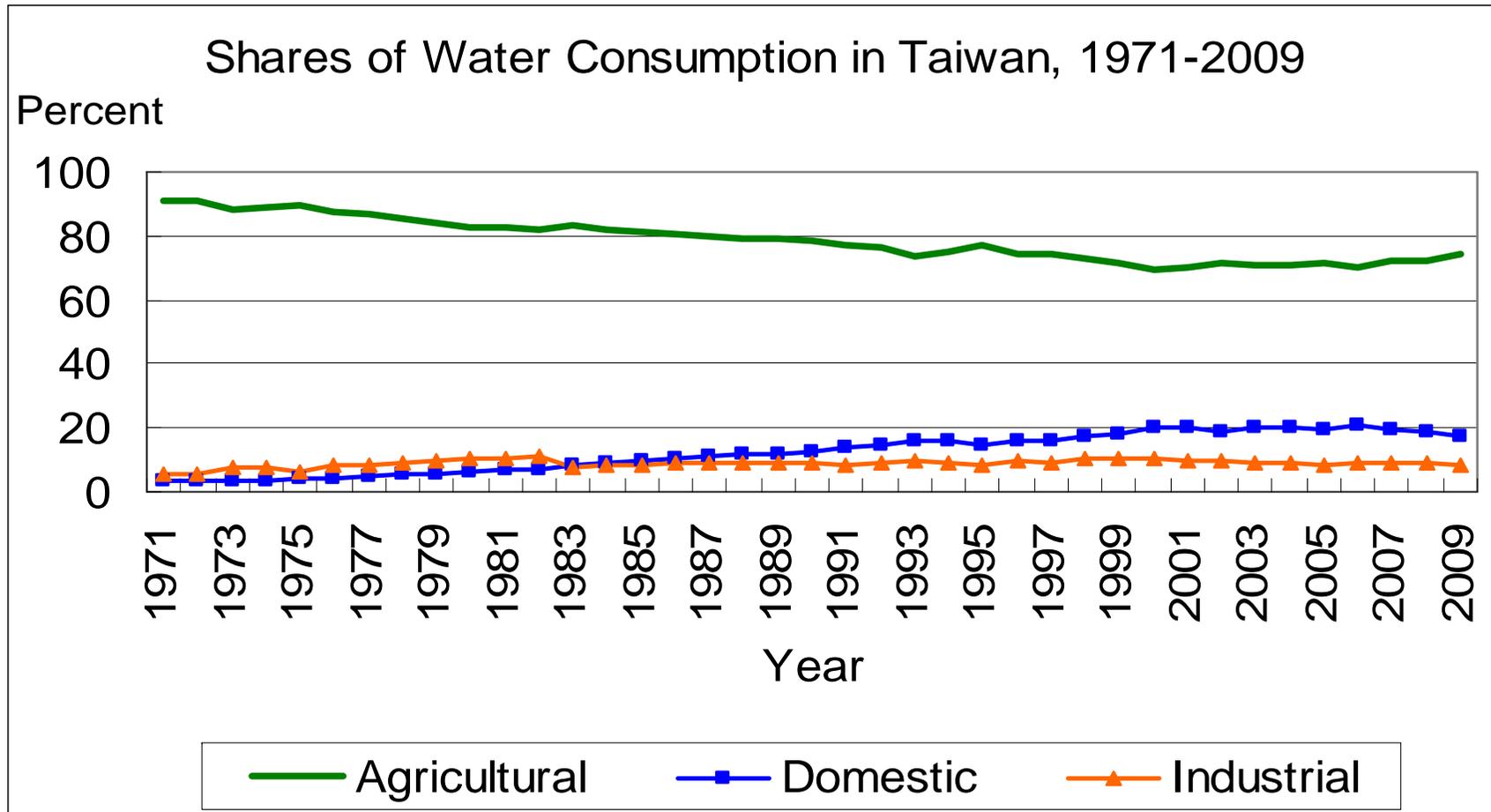
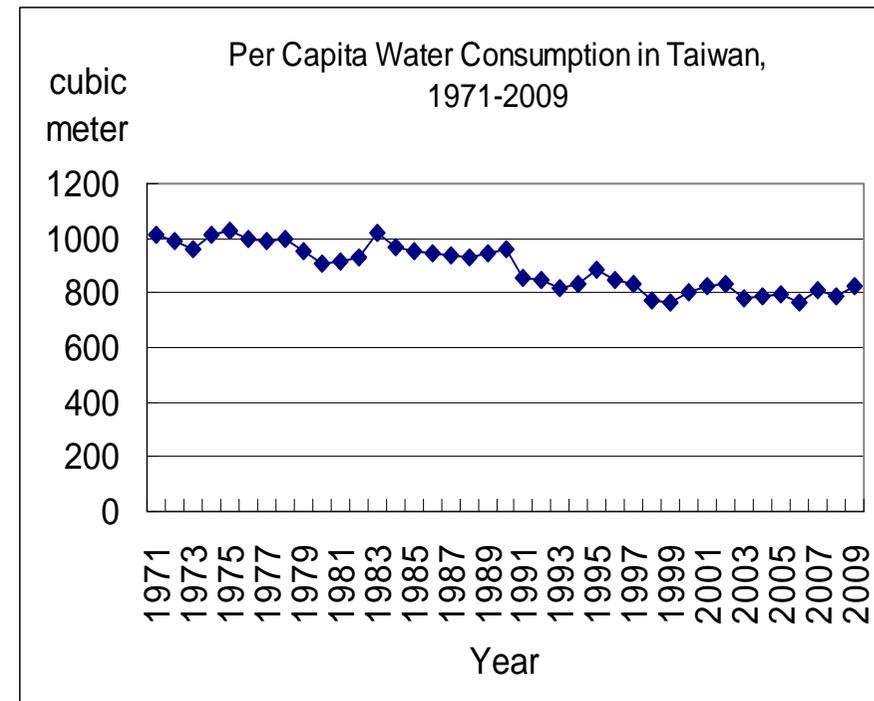


Figure 10: Per Capita Water Consumption in Taiwan, 1971-2009

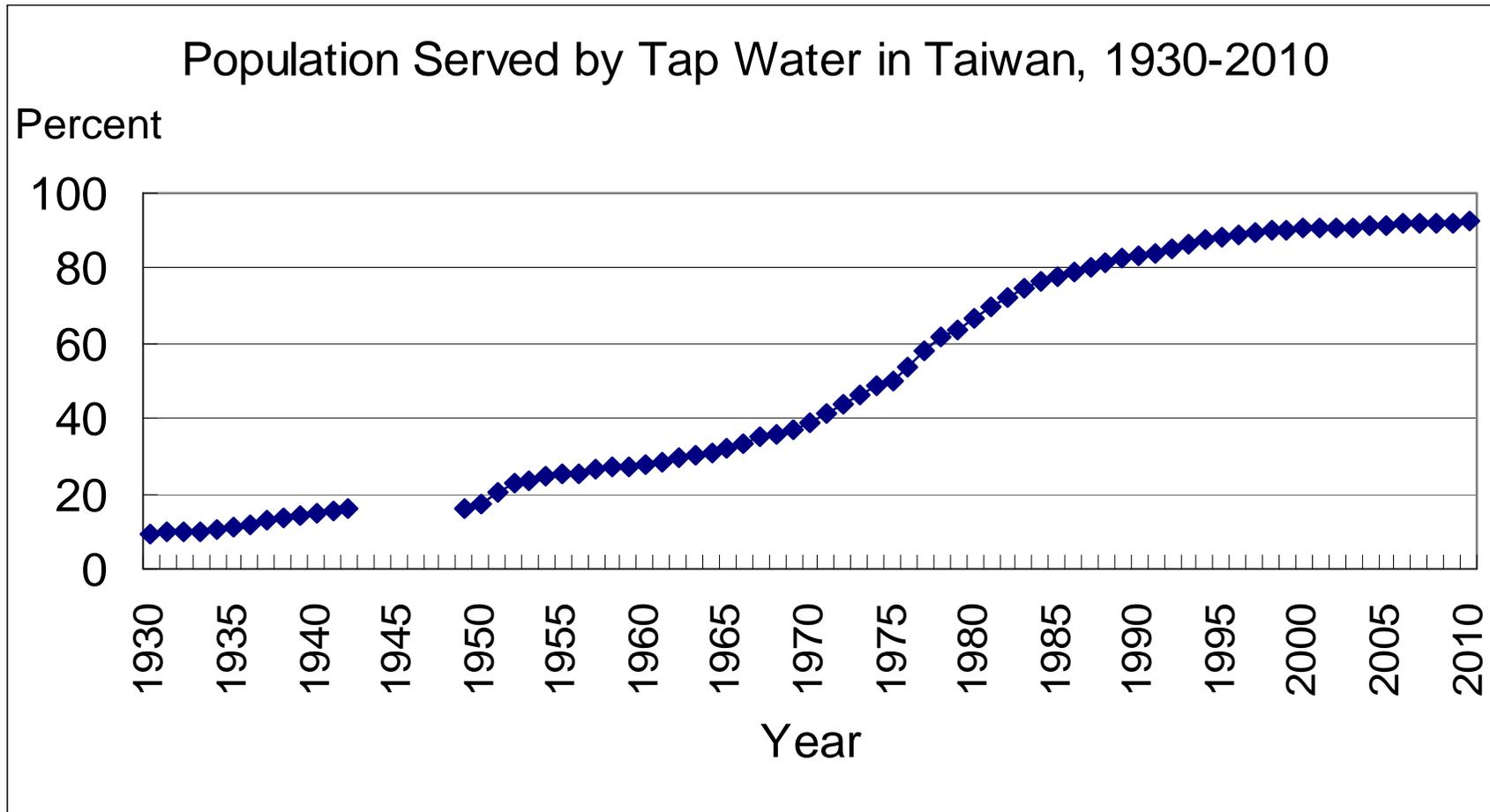
- Taking annual population as a denominator, the per capita annual amount of water consumption is illustrated in Figure 10.
- The per capita annual amount of water consumption in Taiwan fluctuated around 1,000 m³ by 1990 and then around 800 m³. A peak of 1,029 m³ was reached in 1975 and a trough of 764 m³ in 2006.



3.2 Supply of Clean Water in Taiwan

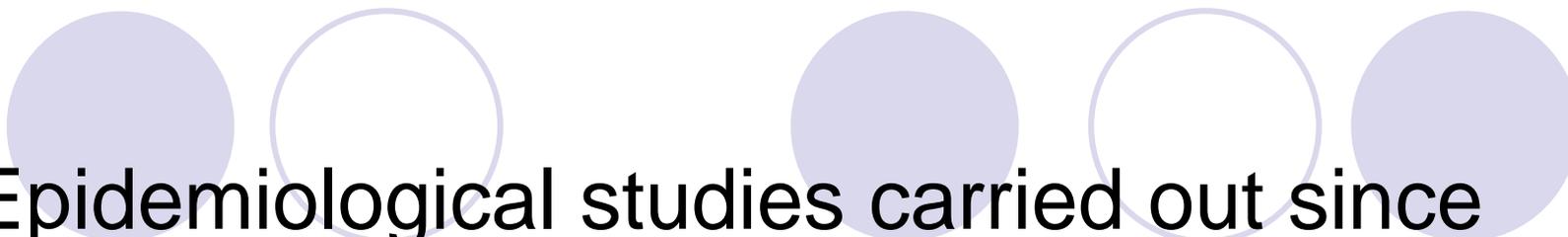
- Taiwan had its first tap water plant built in 1896. Available statistics of the population served by tap water in 1930-2010 is shown in Figure 11.
- The rate of population served by tap water was 9.2% in 1930 and 16.1% in 1942. During the period of World War II, some tap water supply facilities were destroyed but the rate of population served recovered to 16.3% in 1949, reached 30% in 1963, 50.3% in 1975, 90.9% in 2003, and 92.3% in 2010.
- In other words, nearly 8% of the population in Taiwan is still not served by tap water, but served by non-tap small water treatment facilities.

Figure 11: Population Served by Tap Water in Taiwan, 1930-2010



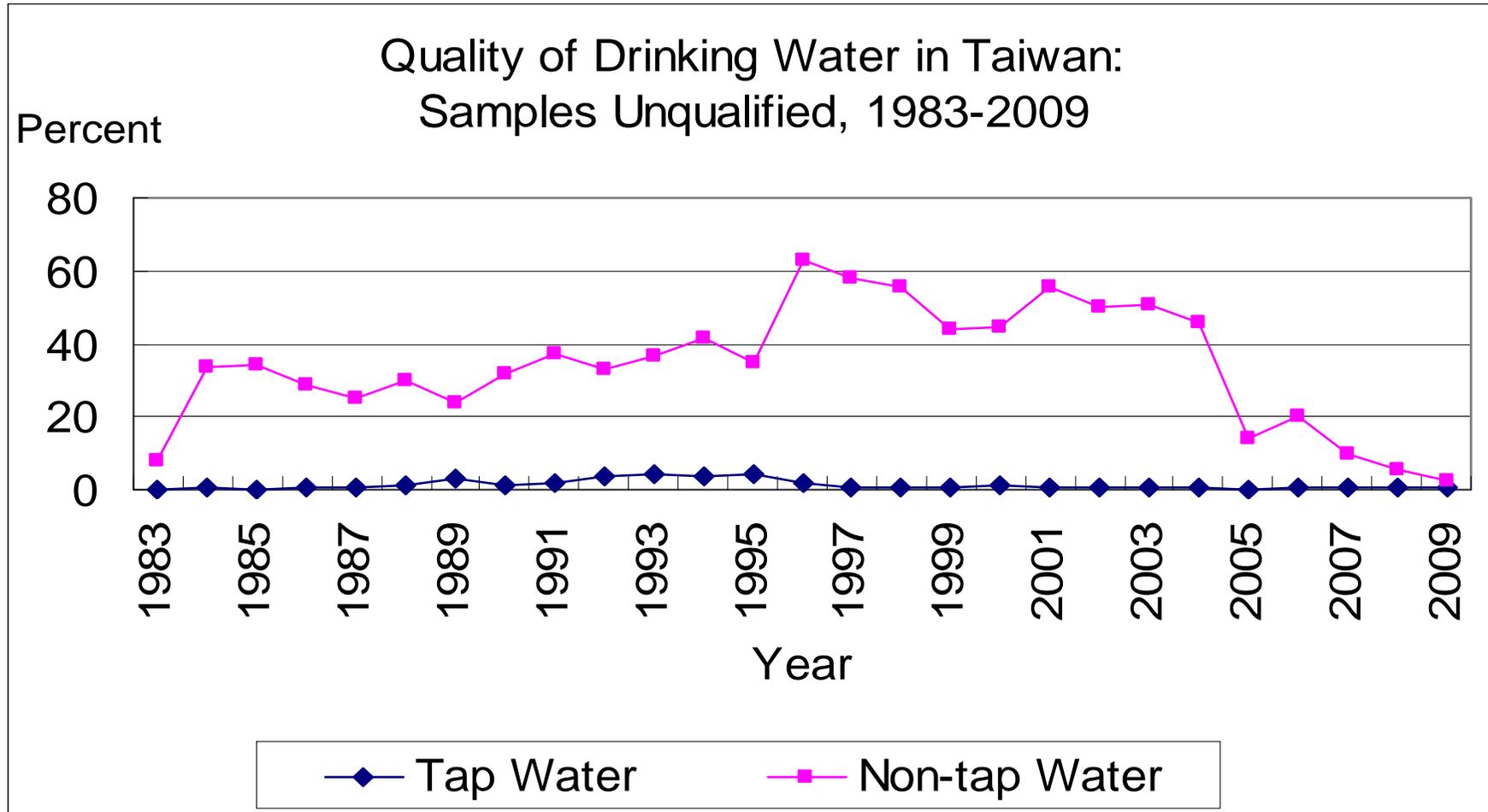
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- The development of tap water is closely related to the improvement of public health. In the early twentieth century, water-related diseases such as cholera, malaria, certain kind of parasitic diseases, skin diseases, and trachoma were quite prevalent in Taiwan, but the improvement in tap water supply had helped in reducing mortality of the population in Taiwan.
 - In the 1940-1950s, infectious diseases of digestive organs ranked on the top among causes of death in Taiwan; in 1962 this category still ranked the third, but in 1972 it was out of the top ten.

- It is notable that in southwestern Taiwan, particularly in Chiayi and Tainan Counties, an endemic disease of blood vessels known as “black foot disease” was induced by exposure to arsenic via drinking-water. This disease has not been observed in other parts of the world.
- In Taiwan, sporadic cases of “black foot disease” occurred in the early twentieth century, and a peak incidence was noted between 1956 and 1960, with prevalence rates ranging from 6.51‰ to 18.85‰ in different villages.

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- Epidemiological studies carried out since the mid-twentieth century revealed that “black foot disease” was associated with the consumption of inorganic arsenic from the artesian wells.
 - The incidence of this disease decreased dramatically after the implementation of tap water in these villages since the 1970s.

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- As for the quality of drinking water, available statistics of sample examinations during 1983-2009 are illustrated in Figure 12.
 - The results showed that the unqualified samples of tap water increased from 0.3% in 1983 to 4.8% in 1995 and then decreased to 0.4% in 2009.
 - The unqualified non-tap water increased from 8.2% in 1983, reached a peak of 62.8% in 1996 and then declined to 2.2% in 2009.
 - In other words, in Taiwan today, about 3% of drinking water still falls below the standard of quality.

Figure 12: Quality of Drinking Water in Taiwan, 1993-2009



3.3 Treatment of Waste Water in Taiwan

- In the late eighteenth and early nineteenth centuries, some cities in Taiwan, such as Tainan, Changhua, and Hsinchu (新竹), constructed drainage ditches and water gates when the city walls were renovated.
- In 1896, the Japanese colonial government in Taiwan started to plan the sewerage system in Taipei City and the regulation was announced in 1899.

- Up to 1915, some sewerage systems had been built in urban areas of Taipei, Yilan, Taoyuan (桃園), Hsinchu, Taichung (臺東), Nantou (南投), Chiayi, Tainan, Pingtung (屏東), Hualien, and Penghu. The total completed length was 357,154 meters, of which Taipei shared 32%.
- After WWII, the government revised the urban planning and identified the sewerage system as one of the major public works.
- However, most sewers collected rainwater as well as domestic and industrial wastewater and thus, rivers were easily contaminated.

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- As for the wastewater sewerage system, the plan in Taipei City started in 1962 but the construction began only in 1973. The construction of wastewater sewerage system was relatively late and slow in other places.
 - Figures 13 and 14 illustrate respectively the completed rates of rainwater and wastewater sewerage systems in 1998-2010.

Figure 13: Completed Rate of Rainwater Sewerage System in Taiwan, 1998-2010

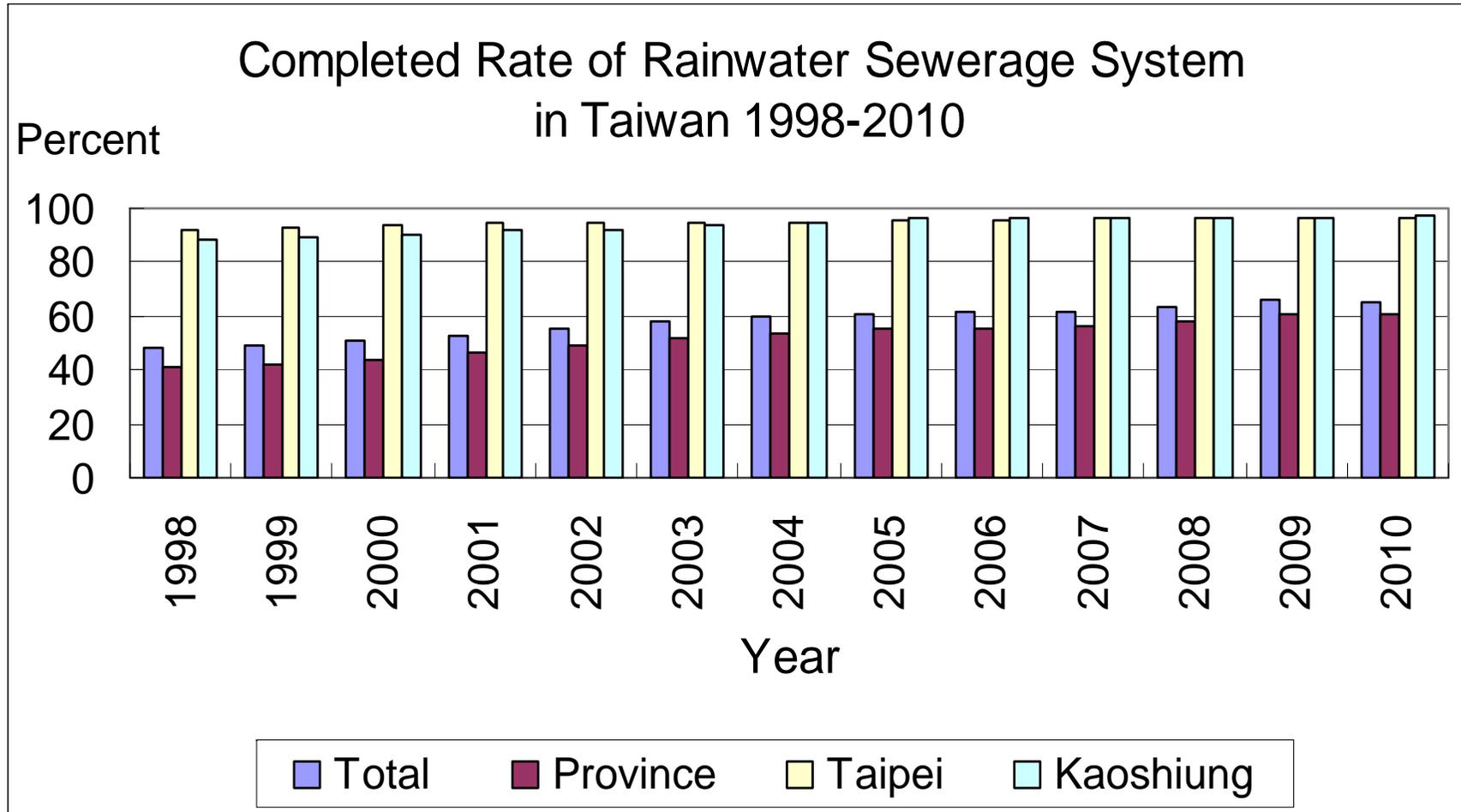
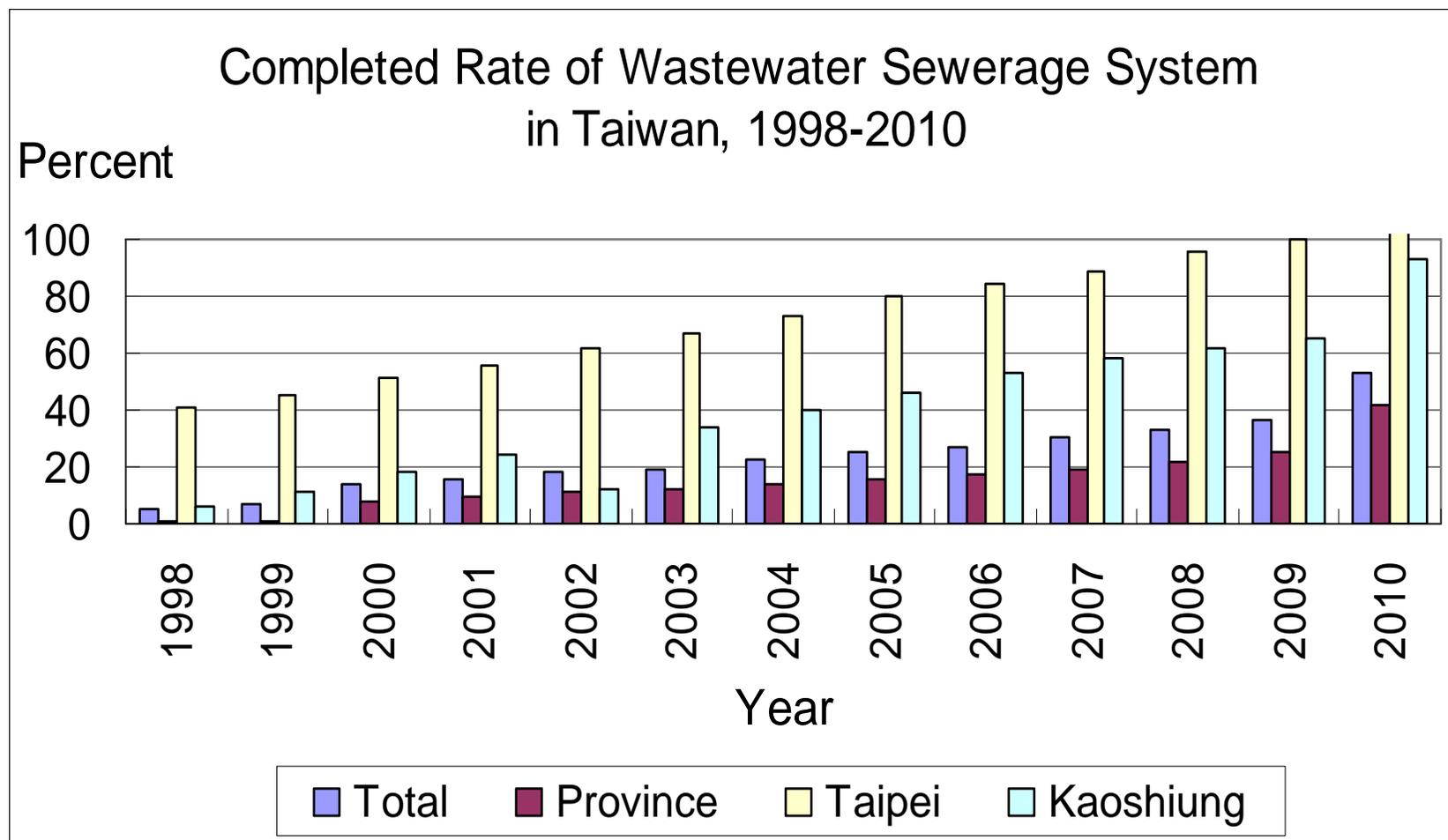


Figure 14: Completed Rate of Wastewater Sewerage System in Taiwan, 1998-2010



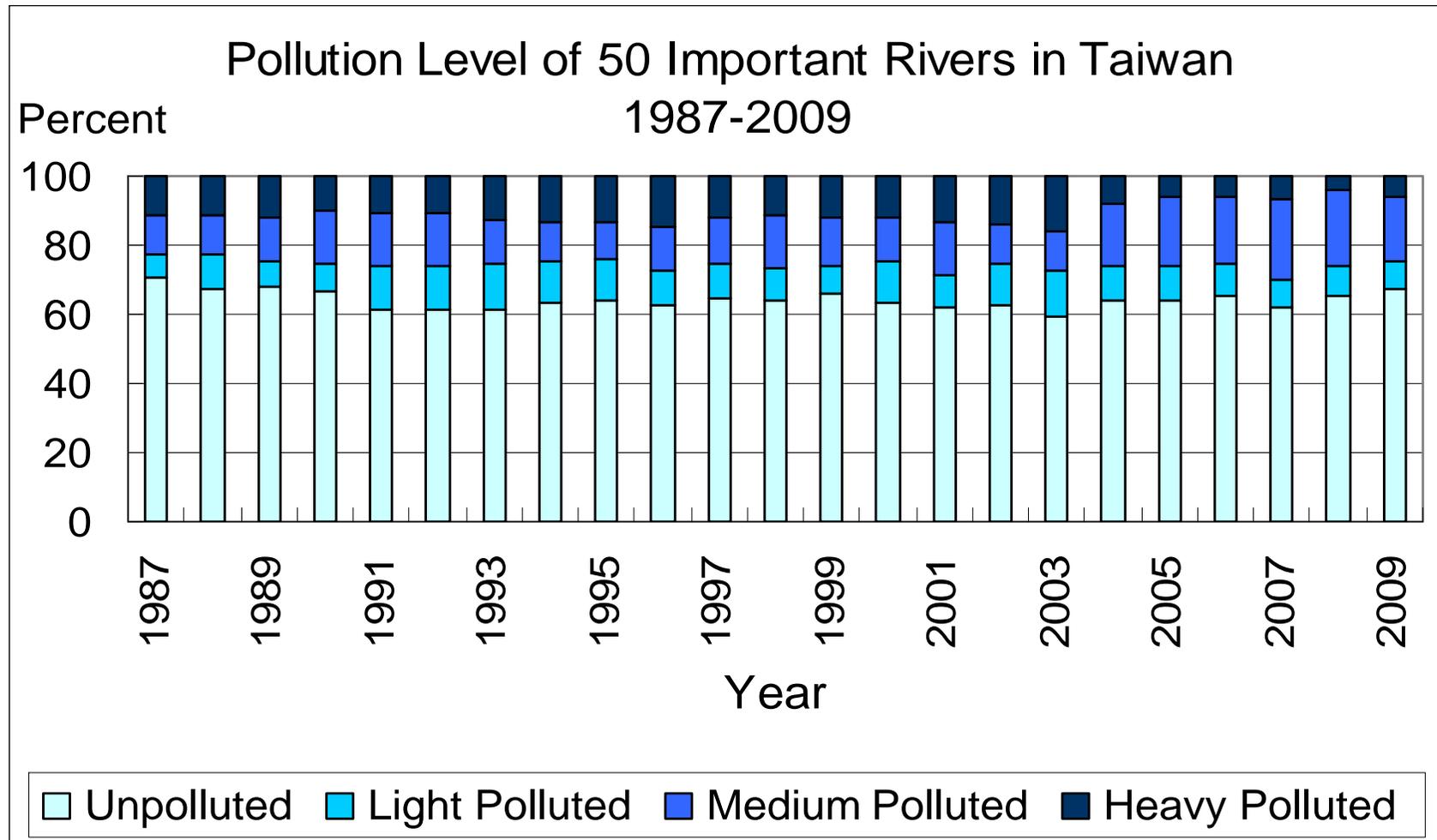
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- In 1998-2010, the population in Taiwan served by the rainwater sewerage system increased from 48.2% to 65.6% and by the wastewater sewerage system from 5.6% to 53.0%.
 - In both cases, the rates of Taiwan Province lagged far behind those of Taipei and Kaohsiung Cities. In 2010, in the case of rainwater sewerage system, Taipei had completed 96.7%, Kaohsiung 96.9% and Taiwan province only 60.6%; and in the case of wastewater sewerage, Taipei had completed 109.6%, Kaohsiung 92.7%, and Taiwan Province only 42.1%.

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- It should be noted that Construction and Planning Agency of Ministry of the Interior is well aware of the 2010 IMD report of national competitiveness, which showed that in 2007 Taiwan's rate of wastewater sewerage system was only 17.5%, which was far behind Hong Kong (93.0%), Korea (87.1%), and Japan (71.7%).

3.4 Water Pollution in Taiwan

- In the 1970s, most countries in the world started to draw up laws for pollution control and Taiwan had its law of water pollution control announced in July 1974. However, this law had not been rigorously executed until the mid 1980s when many incidents of collective dead fish and shell occurred at the estuaries of rivers. The fact was that many rivers in Taiwan were already quite seriously polluted.
- Figure 15 illustrates the pollution level of 50 important rivers in Taiwan during 1987-2009.

Figure 15: Pollution of 50 Important Rivers in Taiwan, 1987-2009



- In 1987, a total of 2,820.6 kilometers of 50 rivers were monitored and found that 70.9% was unpolluted, 6.4% lightly polluted, 11.3% medium polluted, and 11.4% heavily polluted.
- The percentages fluctuated year by year but reached a peak in 2003 when 2,904.2 kilometers were monitored and found 59.4% unpolluted, 13.4% lightly polluted, 11.3% medium polluted, and 15.8% heavily polluted. And two rivers were found to be 100% polluted.
- In recent years, the condition of river water pollution had been improved and in 2009, of the 2,933.9 kilometers monitored, 67.2% was unpolluted, 8.1% lightly polluted, 18.9% medium polluted, and 5.9% heavily polluted.



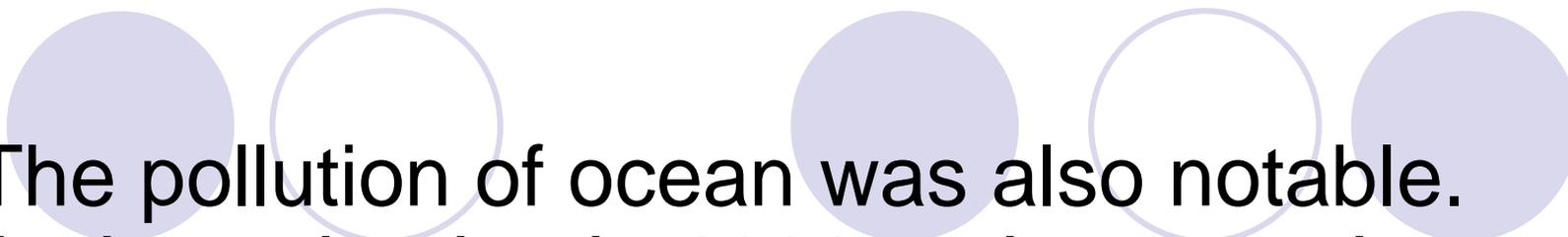
Eutrophication of Reservoirs

- By 2008 Taiwan had constructed 40 reservoirs.
- The available data of Carlson Trophic State Index (CTSI) in Taiwan began in 1993, when 56% (10/18) of reservoirs monitored had CTSI more than 50.
- In 2006, the rate was 40% (8/20); and in 2009, it was 24% (5/21).

Quality of Groundwater

- In 1982-1984, the Taiwan Provincial Environmental Protection Bureau conducted an investigation with 1,405 samples taken from 264 shallow wells. It was found that rates of samples containing pollutants above the standard were as follows: 52.3% contained $\text{NH}_3\text{-N}$, 22.6% contained zinc, 8.3% contained arsenic, 1.9% contained mercury, 1.0% contained chromium, 0.14% contained cadmium, and another 0.14% contained copper.

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- In 1989-1993, the Environmental Protection Administration conducted investigations of 528 wells over 12 counties and cities and found the rates of pollutants above the standard as follows: bacteria 77%, manganese 66%, phenol 47%, arsenic 8%, and cadmium 1%. As phenol is not a natural element, its existence indicated that groundwater had been polluted by industries.
 - Another statistics in 1989-2000 showed that 40% of groundwater was not suitable for drinking and 10% could not be used for irrigation.

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- The pollution of ocean was also notable. An investigation in 1992 at the estuaries all over Taiwan found that coastal areas had been contaminated by heavy metals such as zinc, copper, mercury, cadmium, chromium, lead and nickel. But the results of monitoring in 2009 showed that except for the pH value (99.8%) and the dissolved oxygen (99.5%), the amount of copper, zinc, lead, cadmium and mercury were all 100% qualified.

3.5 Major Sources of Wastewater in Taiwan

- Major sources of wastewater in Taiwan are classified in three categories: domestic, industrial, and agricultural (particularly pig husbandry).
- In 1987, the shares of three categories were 25%, 54%, and 21% respectively. From 1987 onward, due to pollution control measures taken for the wastewater produced by industry and pig husbandry, the shares of industrial and agricultural wastewater decreased, while that of domestic wastewater continued to increase.
- In 2004, the shares of wastewater from three categories were 50%, 24% and 26% respectively.

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- The statistics in 2008 showed that domestic wastewater shared 60% of the total and became the major source of the wastewater.
 - In 1997-2009, the reduction rate of industrial wastewater increased from 70.7% to 81.9%, that of animal husbandry wastewater from 38.1% to 85.4%, and that from municipal sewage from 16.7% to 43.6%.
 - The treatment of domestic wastewater depends on the construction of wastewater sewerage system, but only Taipei City had reached a rate of 100% as mentioned above.

3.6 Hydro-electric Power in Taiwan

- The first power plant in Taiwan was built in 1888 when Liu Ming-chuan (劉銘傳) served as the Governor, but it was a small power plant using coal fuel.
- In 1905, the Japanese colonial government built the first hydro-electric power plant at Kueishan (龜山) along the Hsintien (新店) River in Taipei.
- It was in 1934 when the Sun Moon Lake hydro-electric power plant started to operate and the hydroelectricity became more popular in Taiwan.

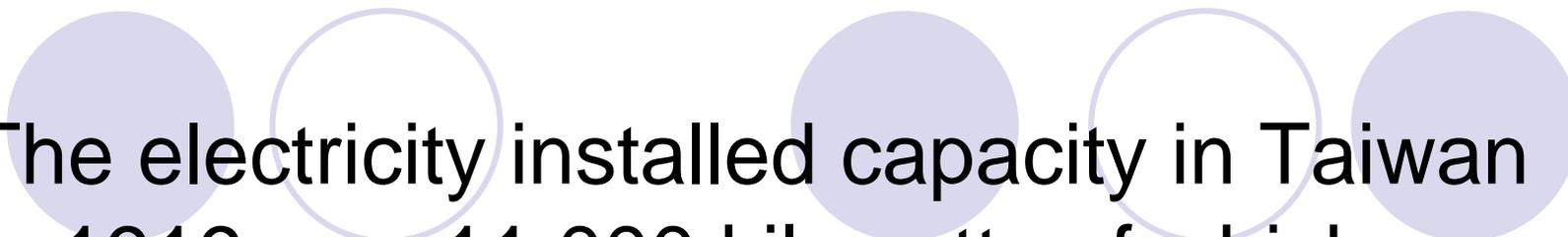
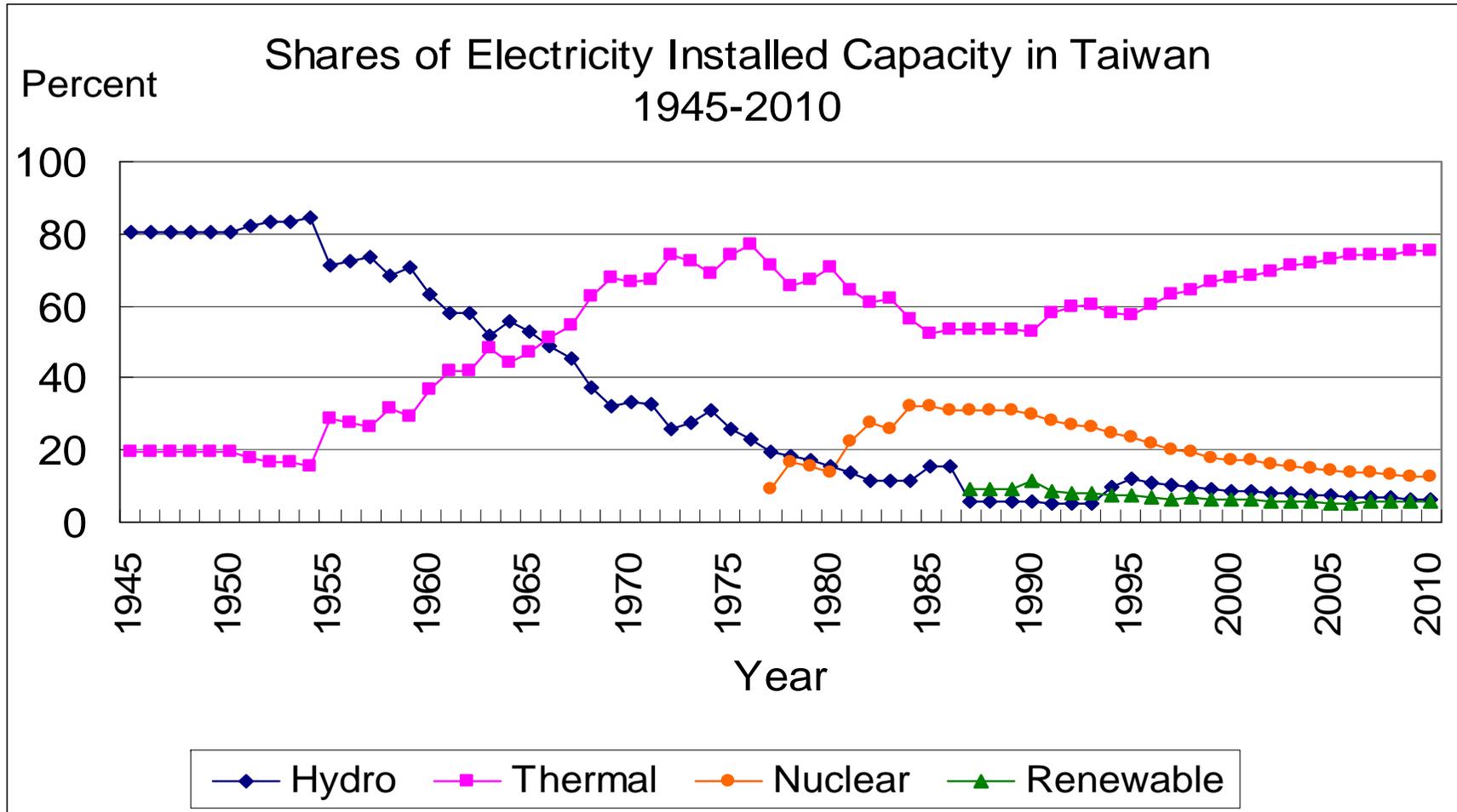
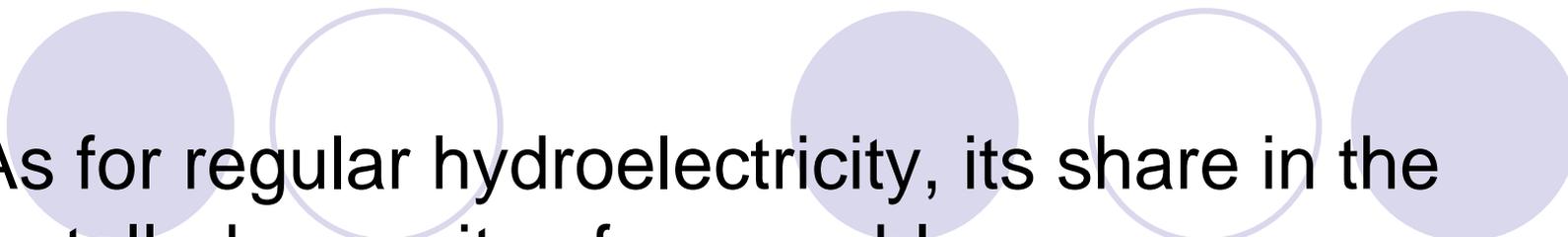
- 
- The electricity installed capacity in Taiwan in 1919 was 11,000 kilowatts of which hydro power shared 79.3%; in 1939, it was 225,000 kilowatts and hydro power shared 75.8%; and in 1944, it was 321,000 kilowatts and hydro power shared 83.1%.
 - Figure 16 shows the shares of electricity installed capacity in Taiwan during 1945-2010.

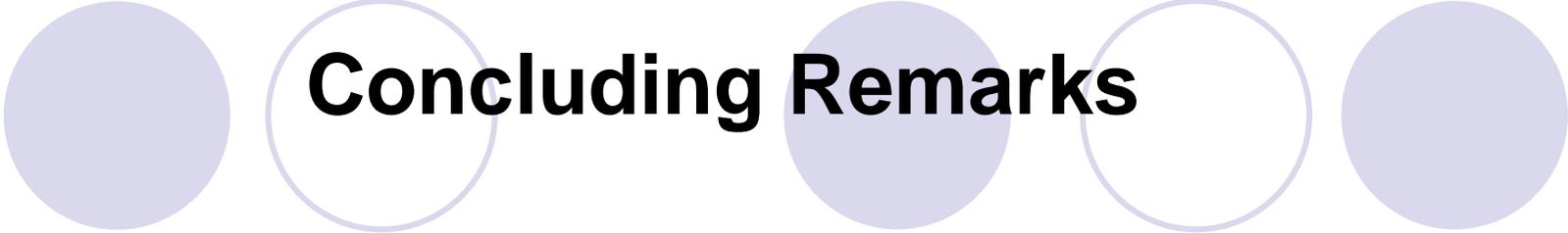
Figure 16: Shares of Electricity Installed Capacity in Taiwan, 1945-2010



- After WWII, Taiwan maintained an electricity installed capacity of 275,255 kilowatts in 1945-1948 and hydro power shared 80.3%. The share of hydro power reached a peak of 84.3% in 1954 and then decreased to 11.4% in 1984.
- From 1987 on, the installed capacity of hydroelectricity was divided into two parts, pumped-storage and regular, and the later was then included in renewable energy. Thus, represented by pumped-storage hydroelectricity, the share of hydro power dropped to 6.0% in 1987, slightly increased to 11.9% in 1995, but decreased again to 6.4% in 2010.

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- As for regular hydroelectricity, its share in the installed capacity of renewable energy was almost 100% in 1987-2004 and still had 80.7% in 2010.
 - If the two categories of hydroelectricity are taken together, the share of hydro power was 15.4% in 1987, increased to 19.1% in 1995, and then decreased to 11.2% in 2010.
 - On the other hand, the share of thermal power reached a peak of 76.8% in 1976 and with some fluctuations it still had 75.1% in 2010.

- Nuclear power shared 9.1% in 1977, reached a peak of 32.4% in 1984 and then declined to 12.6% in 2010.
- Renewable energy power consists of four items: regular hydro power, geo-thermal (in 1987-1994), wind power (in 2001-2010), and solar energy (in 2010). Its share in total installed capacity was 9.4% in 1987, increased to 11.4% in 1990 and then decreased to 5.3% in 2005 before slightly increased to 5.99% in 2010.
- In 2010, the wind power capacity counted for 19.3% of renewable energy, but only 1.2% of the total electricity installed capacity (40,912,406 kilowatts).

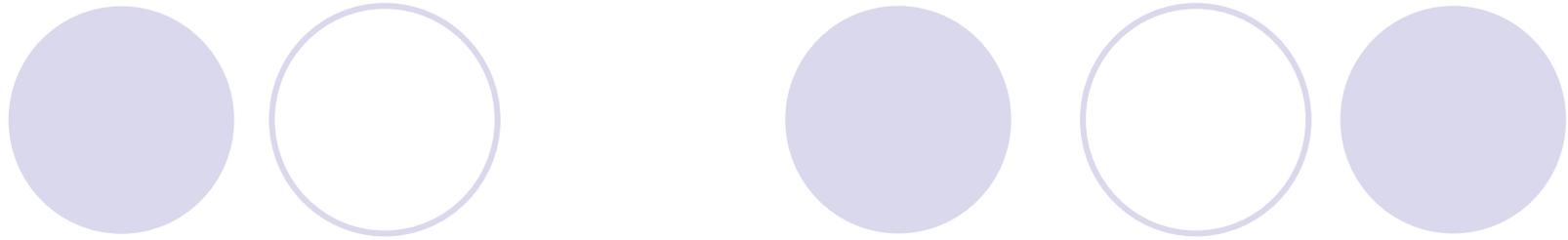


Concluding Remarks

- From the 1990s Taiwan was already in the rank of water-scarce countries in the world. Historical experiences discussed above reflect that Taiwan should devote more efforts to protect water resources, control water pollutions, and promote ways of water conservation.
- From a global perspective, a great challenge in the twenty-first century is how to satisfy the people in the world with enough food, clean water, sanitation and health.

- Particularly, the problem related to water resources allocation and utilization may become even more difficult when facing the condition of global climate change.
- The impact of climate change on water supply and availability will in turn lead to direct and indirect effects on a wide range of institutional, economic, and social factors.
- An estimate by the UN in 2000 showed that in Asia, urban residents without adequate water supply were 35-50%; while those without adequate sanitation were 45-60%.

- It is alarming that Oki and Kanae predicted in a study in 2006 that by 2075 there would be 40 billion people suffering for inadequate freshwater.
- On 28 July 2010, the UN General Assembly adopted a resolution “declares the right to safe and clean drinking water and sanitation as a human right that is essential for the full enjoyment of life and all human rights.”
- In sum, the impacts of climate change on water resources are important issues for us to think over seriously and to act carefully.



**Thank you for your
attention!**

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