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Rainfall Analysis in Kaohsiung and the Solution to Drought

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Abstract

This research consists of two parts, one part studies the rainfall situation in Kaohsiung, and the other part proposes and tries to carry out the solutions to the problem of water shortage in Kaohsiung. Analyzing the annual rainfall in Kaohsiung from 2009 to 2021, we found that the rainfall in 2015 and 2017 was much lower than the average, while the rainfall in 2016 and 2018 was much higher than the average. The rainfall was concentrated in summer, and the rest of the time was relatively dry. Droughts were more likely to occur in November and February. In solving the problem of water scarcity, we referred to the literature, designed dew-capturing device and Mist-capturing device, and set up them late at night until early morning near the center of Kaohsiung in winter, and found it difficult to capture moisture in the air with those homemade devices in Kaohsiung City.

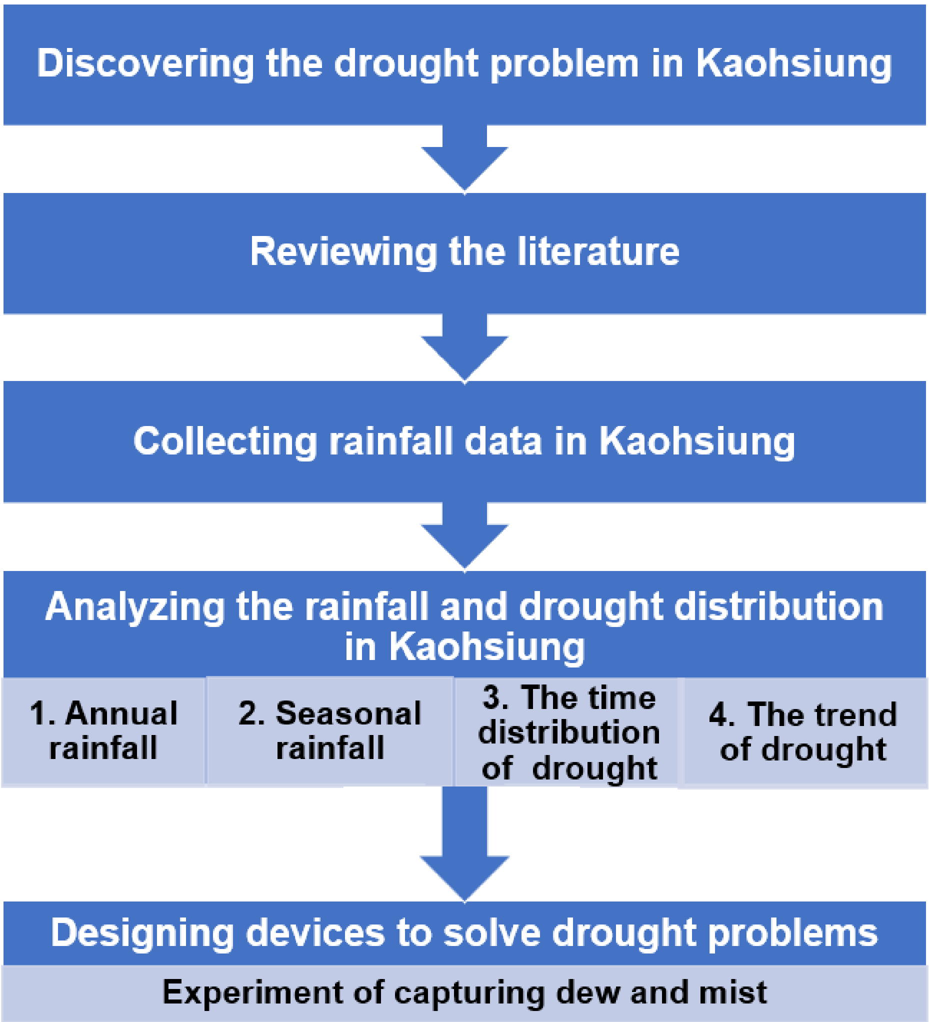
Research motivation and purpose

In recent years, we found that our hometown, Kaohsiung, has met the crisis of water shortage. In order to efficiently distribute the water resources, the government often throws water rationing, which causes inconvenience in our daily life. Therefore, we want to do research on rainfall in Kaohsiung over the past few years. We wonder whether the problem of drought has been more and more serious as time went by. Furthermore, we would like to do some simple experiments and try to find a solution to the problem of water shortage.

Research Question and Hypothesis

1.The characteristics of rainfall in Kaohsiung from 2009 to 2021.
2.The distribution of rainfall among different seasons in Kaohsiung.
3.When do droughts in Kaohsiung mostly happen?
4.Has the problem of drought been more and more serious from 2009 to 2021?
5.Can we capture dew in the crack of dawn in downtown Kaohsiung by using dew make-up devices?
6.Can we capture the water in the air in the crack of dawn in downtown Kaohsiung by using a mist catcher?

Research Methods and Introduction

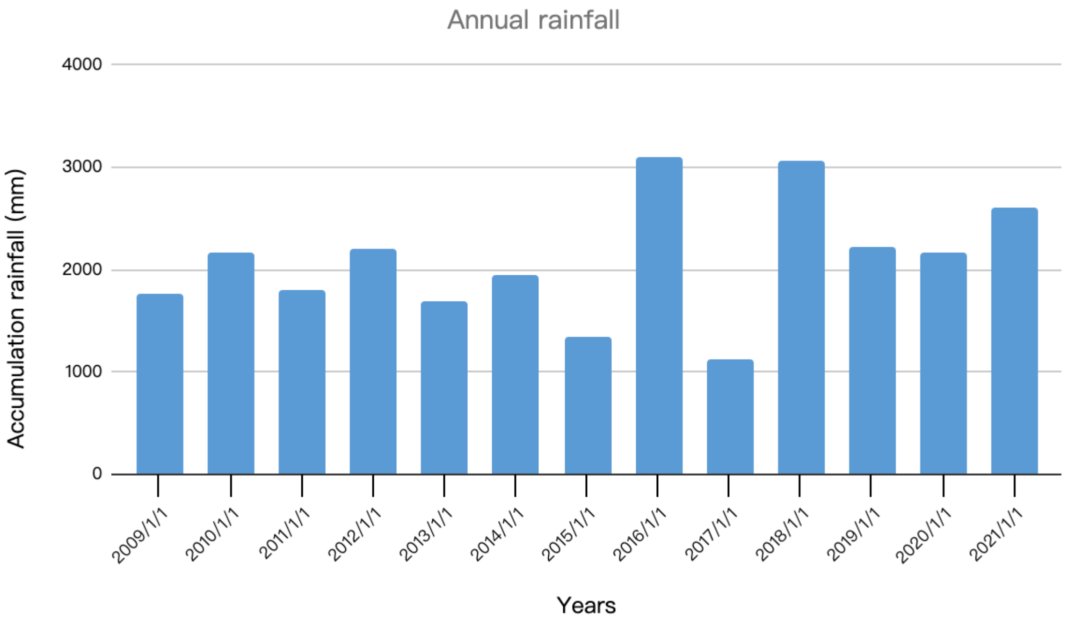


(Figure1. Research flowcharts)

Research Data, Results, and Discussion

1.Analysis of the rainfall and drought distribution in Kaohsiung

(1) Analysis of the annual rainfall in Kaohsiung



(Figure2. Kaohsiung annual rainfall accumulation from 2009 to 2021)

The annual rainfall in Kaohsiung is between about 1500 mm and 2500 mm, except for 2015 and 2017 are less than 1500 mm and 2016 and 2018 are more than 3000 mm(data from the Central Weather Bureau), which is analyzed one by one in the following four years.

In 2015, The average annual rainfall in Kaohsiung was 1344 mm. The rain in 2015 is less than average during to the severe drought in the spring. The rainy season (cause by stranded front) was about 150 mm (30%) less than the same period in average previous years, and the rainfall summer typhoon brings was 118.1 mm less than the average. while in the autumn, except for the rainfall brought by the Typhoon Dujuan, there is no rainfall, and it is 215 mm less than the average. The reason for this phenomenon may be that 2015 is a strong El Niño year, and the high Pressure in the Pacific Ocean is strong, resulting in insufficient rainfall throughout the year, and even the residents faced water restrictions. Due to the less rain in the autumn in 2014 and the spring in 2015, the third phase of water restrictions in Kaohsiung began on May 4, 2015 to implement the "five days offer and two days stop" water restriction policy, and lifted on June 8, 2015.

In 2016, Kaohsiung's average annual rainfall was 3103.5 mm, 564.7 mm (25%) more than the average, the sixth much rain since 1947, the rainfall at the beginning of the year was more, more than the climate average, and the spring rainfall was 42.9 mm more than the average, but the rainy season in 2016 was two weeks later than usual and 128 mm less than the average. During the summer months due to typhoons and tropical low-pressure cloud systems, there was heavy rain in some areas, and the amount of rain is less(15%)than usual, and multiple stations have measured the record of the most autumn rain, and the Kaohsiung station has measured 4 times more than climate.The autumn rains were caused by the low pressure zone and stranded fronts in September, Typhoons Moranti, Malakas and Maki in September, typhoons Aere, Sarika and Haima in October, and several waves of the northeast monsoon with abundant water in October and November.

In 2017, the average annual rainfall in Kaohsiung was 1124.5 mm, the annual rainfall was 760.4 mm less than the average, the spring rainfall was 259.3 mm, which was 88.8 mm less than the average, the rainy season rainfall was less than the average, and the average summer rainfall was 854.2 mm, which was similar to the average, and the autumn rainfall was less than the average, and the rainfall was less than half of the climate average.

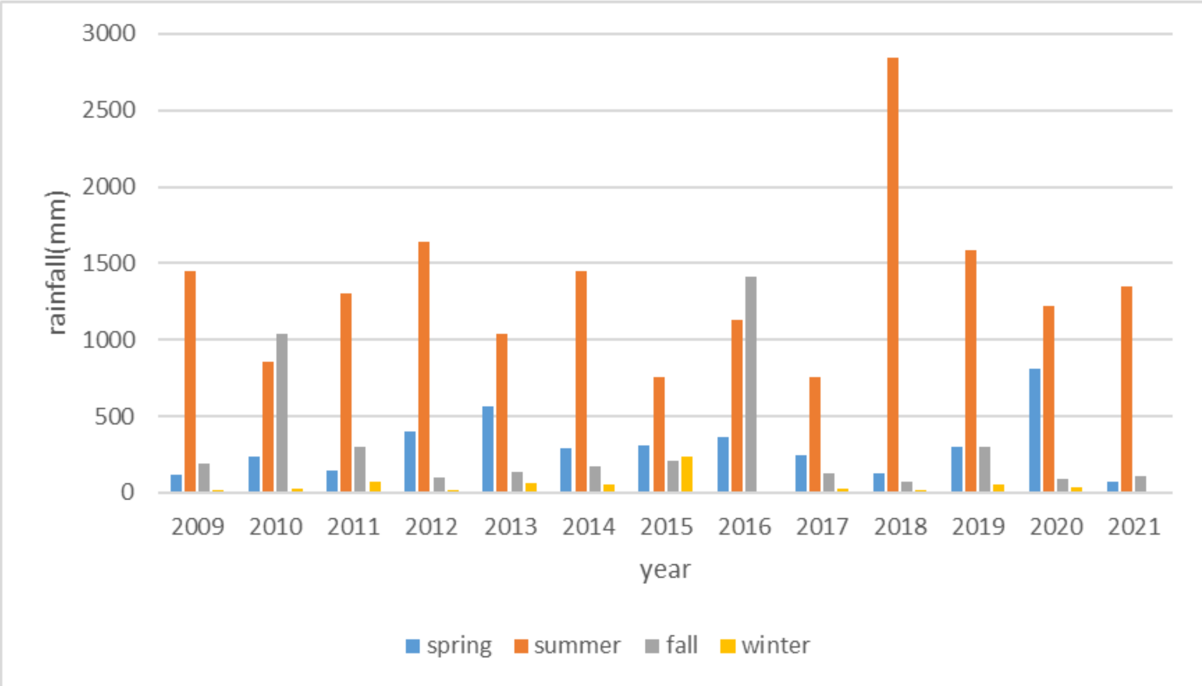
In 2018, the average annual rainfall in Kaohsiung was 3068.2 mm, was 1183.3 mm more than the average, which was the third much rain of the station, the rainy season rainfall was more than the average, the average summer rainfall was more than the average, and it was the summer with the most measured rain in Kaohsiung, which due to tropical low pressure, southwest air currents, resulting in heavy rain for several days, Typhoon Maria invaded Taiwan in July, and August was located in the low pressure zone, and the rain was obvious. Rainfall is relatively low at other times, dominated by midday heat convection, and autumn rainfall is less than the average.

(2)The distribution of rainfall among different seasons in Kaohsiung

After the analysis of rainfall each year in Kaohsiung, we found that generally the yearly rainfall in Kaohsiung tends to be 1500 to 2500 mm per year, which doesn’t seem to be too less. However, people in our city still face the water shortage sometimes and we suffer from the water restrictions. Therefore, we want to know more about the distribution of rainfall among different seasons in Kaohsiung to see if the rainfall in some specific seasons will be much more than the others, which results from the uneven temporal and spatial distribution of rainfall.

First, we defined the time period of four seasons, which goes like this : Spring is from March to May, Summer starts from June to August, Fall starts from September to November,and Winter will be December to February of the next year.

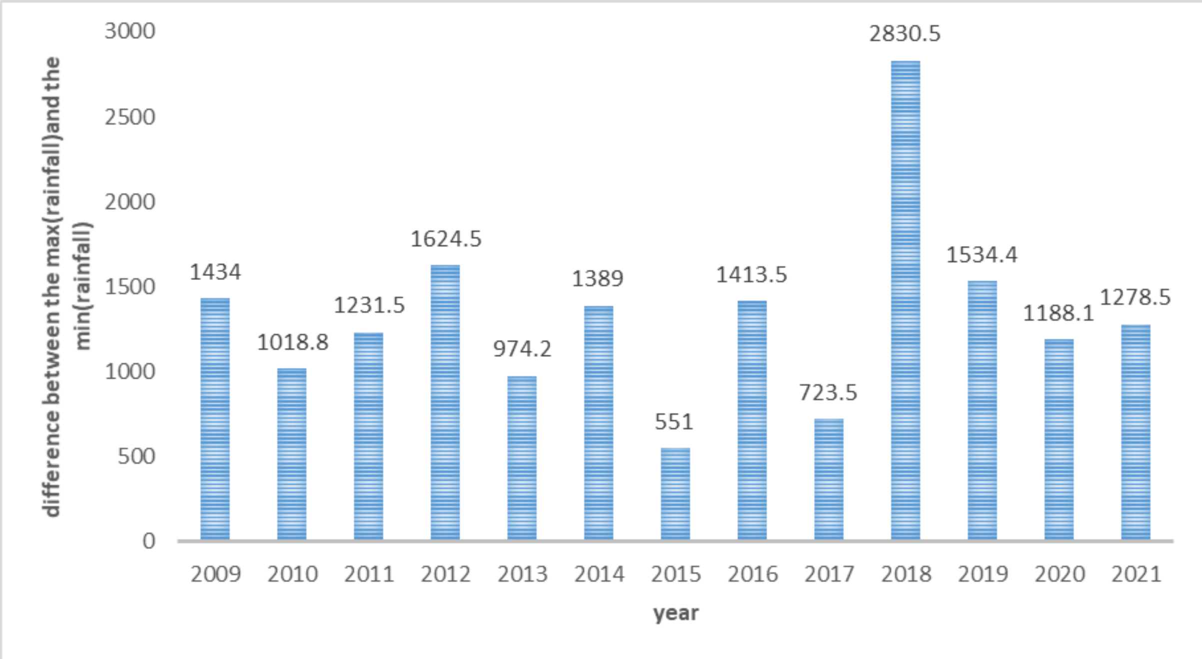
Then we divided the data into four parts each year with different seasons. It reveals that the rain usually falls in the summer, and would be much more than the other seasons. In the chart of rainfall in different seasons in Kaohsiung from 2009-2021 we can see that the rainfall in the summer can be up to 1500 mm each year, while the total of rainfall in spring, fall and winter is often below 800 mm, which means the rainfall do distribute unevenly.



(Figure3. Rainfall in different seasons in Kaohsiung from 2009 to 2021)

Based on the previous discovery, we wonder about the severity of the uneven temporal distribution of rainfall in our city. So we calculated the difference between the maximum of rainfall in the season and the minimum of rainfall in the season. It shows that every year, the difference between the max(rainfall)and the min(rainfall) is about 1500 mm, and it’s quite a lot. We finally realized that as abundant the yearly rainfall is, we can encounter water shortage due to the uneven temporal distribution of rainfall, especially in summer and winter.

The uneven temporal distribution of rainfall can result from many factors such as the climate, terrains, and monsoons. Our next goal will be trying to find a great way to solve the problem of water shortage we meet nearly every year and we will do some experiments to achieve the goal.



(Figure4. The difference between the maximum of rainfall in a season and the minimum of rainfall a the season from 2009 to 2021)

(3)The time distribution of drought in Kaohsiung from 2009 to 2021

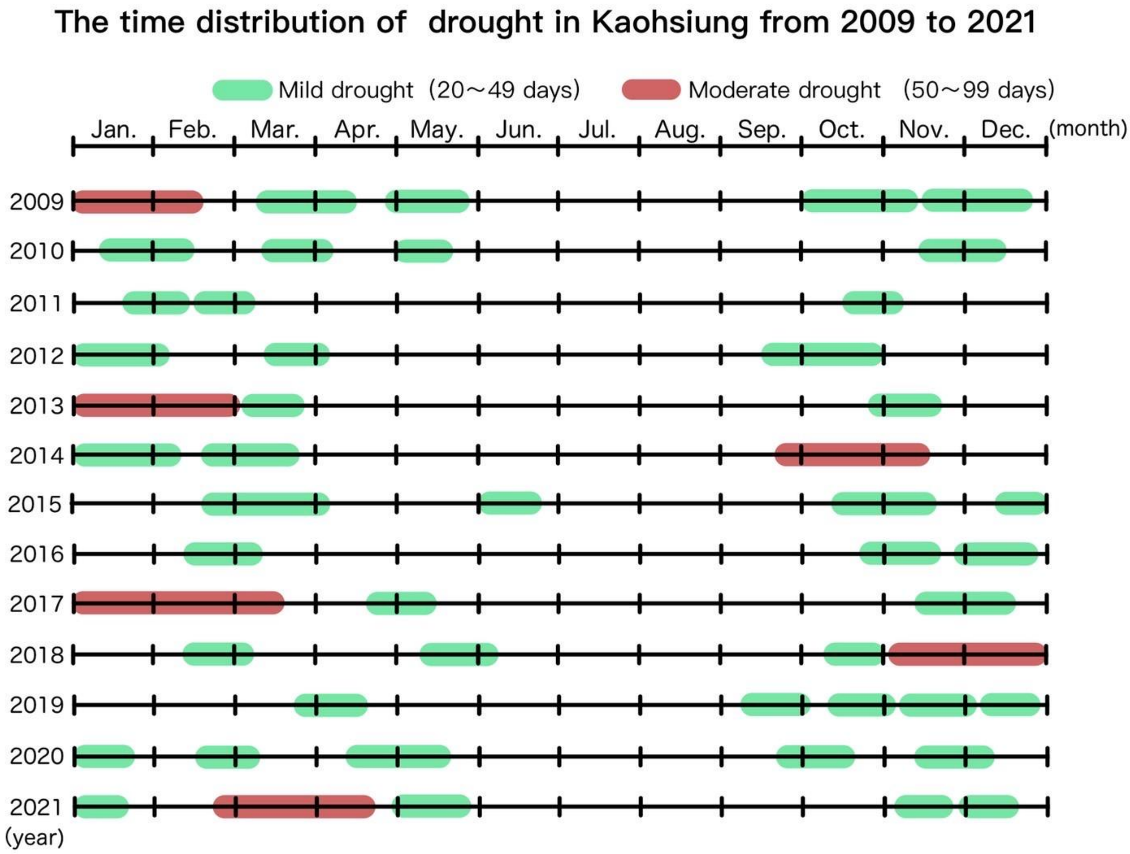
After analyzing the annual rainfall and seasonal rainfall in Kaohsiung, we further calculated the time distribution of droughts in Kaohsiung from 2009 to 2021, trying to analyze and understand the drought problem in Kaohsiung.

According to the definition of the National Disaster Prevention and Relief Technology Center of Taiwan, the types of drought in Taiwan are classified as meteorological drought, agricultural drought, and socio-economic drought. Since it is convenient for us to obtain daily rainfall data from the database of the Central Weather Bureau, the definition of drought used in this study is "agricultural drought", and the number of consecutive days without rainfall is used as the statistical standard. Below are three types of drought:

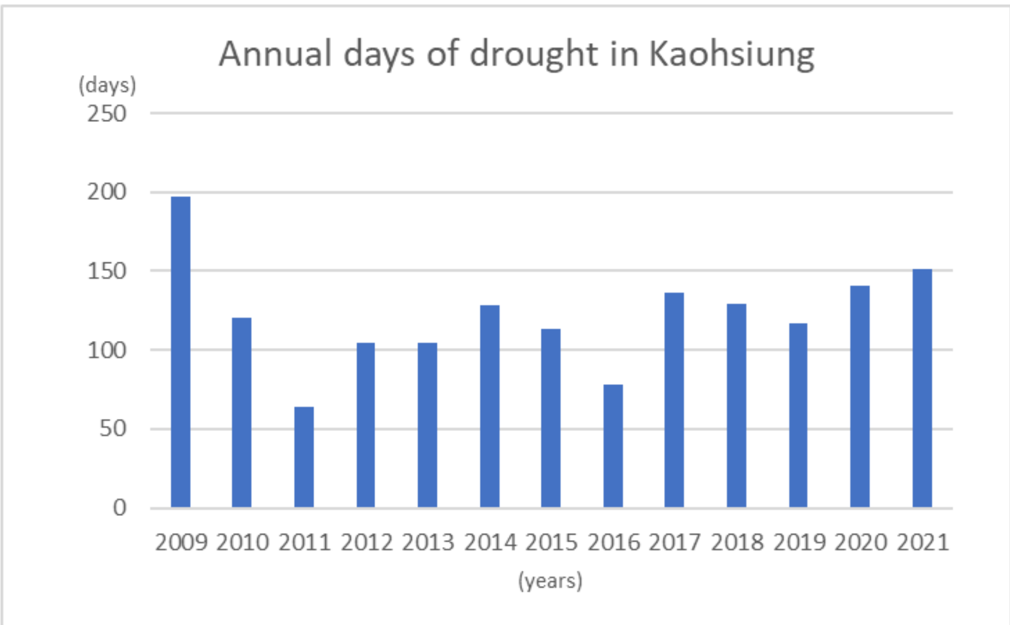
[1]Mild drought: no measurable rainfall for 20 consecutive days.

[2] Moderate drought: no measurable rainfall for more than 50 consecutive days but less than 100 days.

[3] Severe drought: no measurable rainfall for more than 100 consecutive days.



(Figure 5. The time distribution of drought in Kaohsiung from 2009 to 2021)



(Figure 6. Annual days of drought in Kaohsiung from 2009 to 2021)

[1] From the time distribution of drought and the seasonal rainfall in Kaohsiung, we can see that the distribution of rainfall in Kaohsiung is very uneven, mostly concentrated in summer and autumn, while drought often occurs in winter and spring when rainfall is relatively low. In addition,we took drought occured for more than a month as the standard,calculated the occurrence rate of drought in different months, and we found that the highest rate occurs in November and the second highest in February.

[2] From Figure 5, we can find that, unlike other years, a mild drought occurred in June 2015, probably because the autumn rainfall in 2014 and the spring rainfall in 2015 were less than previous years, as mentioned in the annual rainfall analysis, resulting in a drought in 2015 before the summer rainy season.

[3] From Figure 5 and Figure 6, we can see that 2021 is the year with the second-highest days of drought, about 150 days. Due to the low rainfall during the rainy season in the previous year (2020) and the low number of typhoons that hit Taiwan, there was not sufficient rainfall, resulting in a moderate drought from late February to mid-April in 2021. However, with the arrival of the rainy season and typhoon season, the southwestern airflow and typhoon brought significant rainfall, which relieved the prolonged dryness and made the drought less likely in the second half of the year.

[4] From Figure 5 and Figure 6, we can see that 2009 was the year with the highest days of drought, nearly 200 days. In general, Taiwan was in a dry large-scale environmental field in that year, and there was not much rainfall in spring and autumn, which led to a moderate drought at the beginning of the year and two long mild droughts at the end of the year. In August 2009, Typhoon Morakot brought extremely abundant precipitation to Kaohsiung, with an amazing 775 mm of rain falling in three days and causing severe flooding. Unfortunately, because it was not easy to store water during the extremely short period of heavy rainfall, the drought in Kaohsiung was only temporarily relieved, and then a prolonged drought occurred again at the end of the year.

(4)The trend of drought in Kaohsiung from 2009 to 2021

	2009~2014(6 years)	2015~2021(7 years)
Annual average times of mild droughts	3.00 times/a year	3.71 times/a year
Annual average times of moderate droughts	0.50 times/a year	0.43 times/a year
Annual average days of droughts	119.83 days/a year	123.57 days/a year

(Table 1. The trend of drought in Kaohsiung from 2009 to 2021)

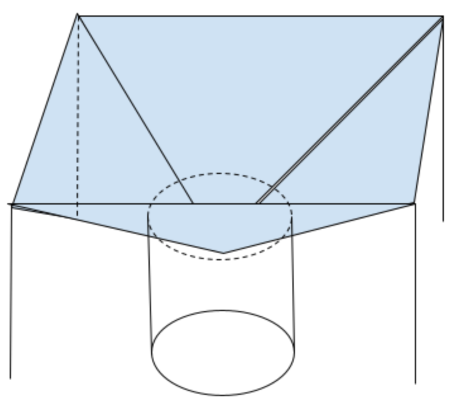
To understand the trend of drought in Kaohsiung over the past 13 years, we divided the period from 2009 to 2021 into two periods of statistics, 2009~2014 (6 years) in the first half and 2015~2021 (7 years) in the second half.

As can be seen from Table 1, in recent years, the average number of droughts per year has increased, and the number of drought days per year has also increased by about 4 days. Therefore, in the face of the worsening drought situation, next part of this research we conducted experiments by making a device to collect the dew water and the water in the air in attempt to solve the water shortage problem in our hometown.

2.Methods to solve the drought problem in Kaohsiung

(1)Dew-capturing experiment

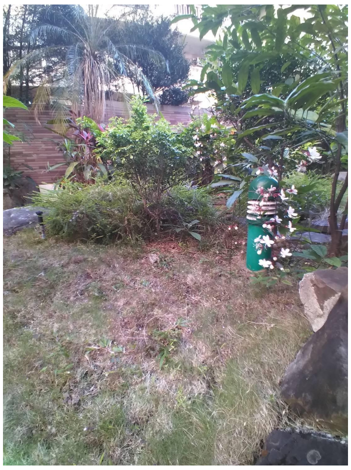
[1]Dew-capturing experimental method



(Figure 7. Schematic diagram of the structure of the dew-capturing device)

As shown in Figure 7, use iron wire to make a frame, fill the area of the frame with a plastic bag and fix it with tape, place a measuring cylinder (measuring cup) under this object, and combine it into a dew-capturing device (each piece of triangular plastic is a positive side length of 15cm triangle). When the outdoor water vapor is saturated, the dew condenses on the plastic surface, and then enters the measuring cup due to the inclined surface. The mouth of the cup is completely covered, and the evaporation of the water at the bottom of the measuring cup will condense and recover again at the mouth of the cup.

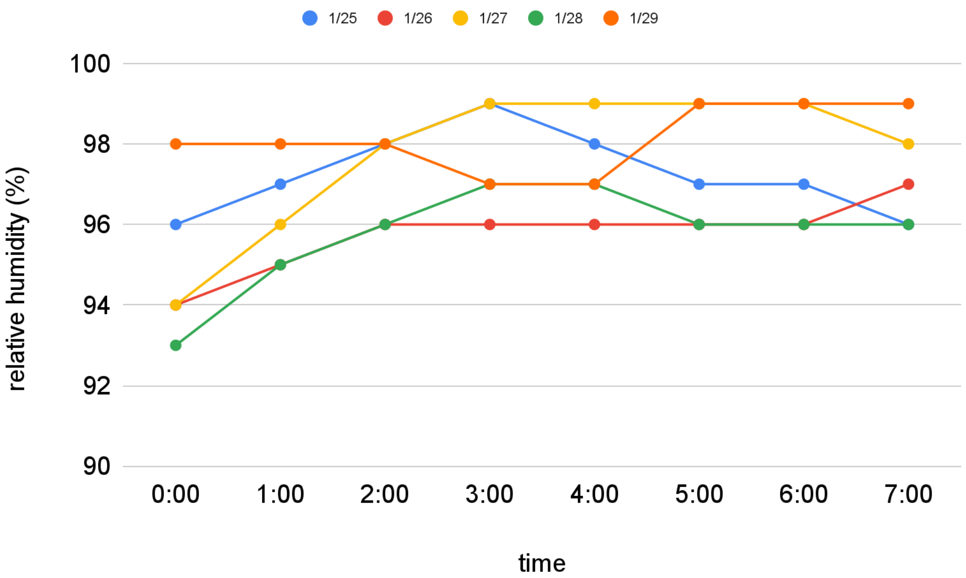
(Figure 8. Location of dew-capturing experiment)

		
Courtyard (Zuoying)	Backyard (Niaosong)	Overhangs of a block of buildings（Fengshan）

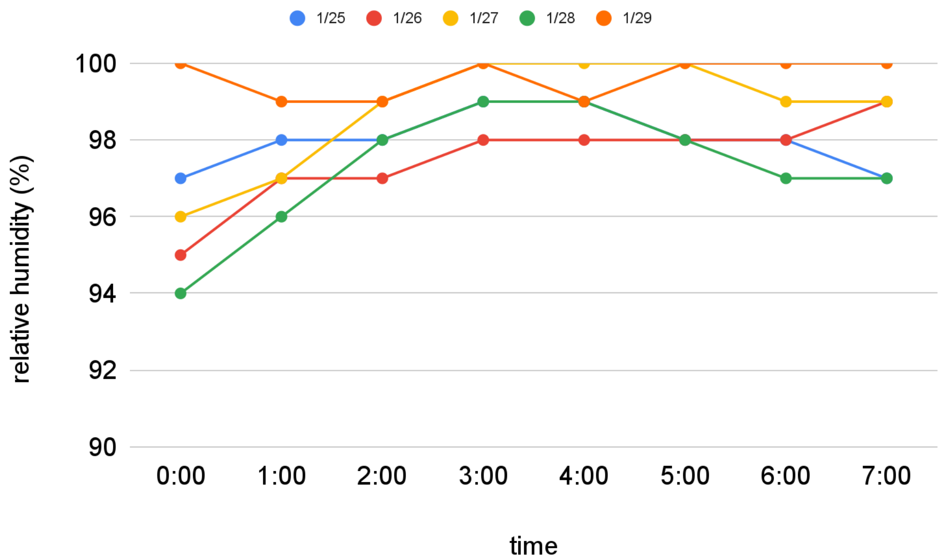
(Table 2. Three environments for placing the device)

After the assembly is completed, select three areas near the center of Kaohsiung as shown in Figure 8, and place them in the environment shown in Table 2 to ensure that the device is in a position near the ground where it is exposed to outdoor air. From 1/25 to 1/29, the amount of water collected by the device was recorded at 7:00 every morning. In this way, the accumulated dew from 0:00 to 7:00 is expected to be collected.

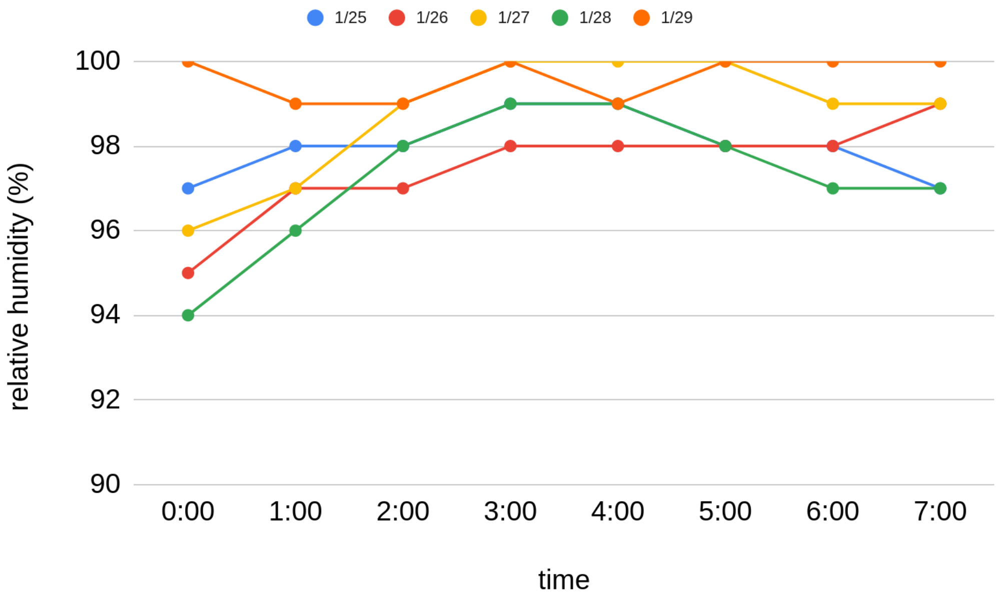
[2] Results and discussion of dew-capturing experiments



(Figure 9. 1/25, 1/26, 1/27, 1/28 and 1/29 0:00～7:00 Relative Humidity in Niaosong District)



(Figure 10. 1/25, 1/26, 1/27, 1/28 and 1/29 0:00～7:00 Relative Humidity in Fengshan District)

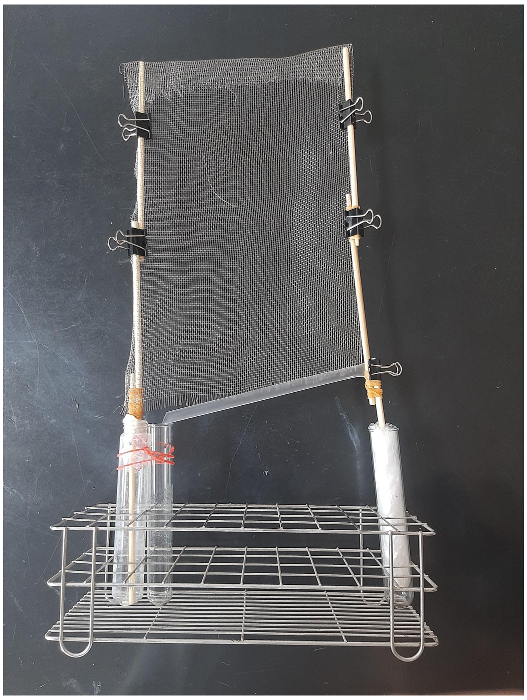


(Figure 11. 1/25, 1/26, 1/27, 1/28 and 1/29 0:00～7:00 Relative Humidity in Zuoying District)

From Figure 9, Figure 10 and Figure 11, it reveals that the relative humidity in Niaosong District and Fengshan District was high at the observation time, and the relative humidity in Fengshan District had reached 100%. When the temperature was the same as the dew point, dew was still not collected. After discussion and inquiry of information Afterwards, it is speculated that the reason for the lack of dew formation may be that the local air has insufficient condensation nuclei, the observation time is not early enough, or the surface temperature of the experimental equipment is not lower than the dew point, resulting in no dew collected in the three places.

(2) Mist-capturing experiment

[1]Mist-capturing experimental method



(Figure 12. Mist-capturing device) (Figure 13. Mist-capturing simulation experiment)

As shown in Figure 12, put a test tube into the test tube rack, insert a plastic bag into the test tube as a base, insert bamboo chopsticks tied with rubber bands as a support, and fix the stainless steel mesh on the bamboo chopsticks with long tail clips and show an open state . In addition, a thick plastic straw is cut longitudinally and fixed on the lower edge of the net as a water collecting groove, so that it is slightly inclined so that the collected water can flow down the water outlet. A test tube or measuring cylinder is placed at the water outlet of the groove to receive the water flowing out of the water collecting groove.

When the wind rich in water vapor blows, the water vapor encounters the net and condenses on the net, and then flows down to the water collecting groove along the net. Because the groove is inclined, it flows down to the water collecting test tube again, so it is expected to collect the moisture in the morning.

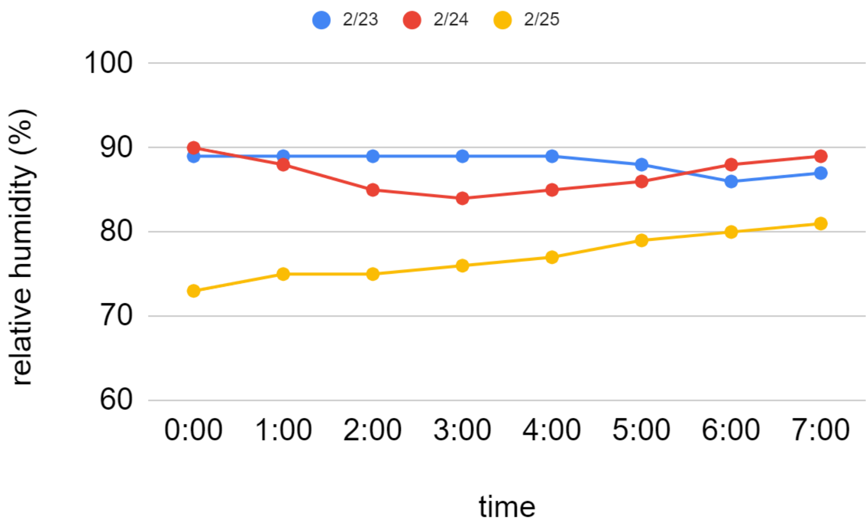
Before actually capturing the water vapor on the campus, we tested the function of the mist-capturing device. As shown in Figure 13, put the prepared mist-capturing device into the box (because the mist-capturing device is less likely to collapse in the simulation experiment, so the plastic bag is not used as the base), and put two cups of about 40 degrees Celsius in the box of hot water to create water vapor, cover and seal for about 8 hours. After 8 hours, the humidity was observed to be 100% in the box, and obvious moisture could be felt after touching the net with hands, but the water on the net could not be seen with the naked eye. The grooves and water collection test tubes also did not collect water. This proves that the mist-capturing device can successfully condense water vapor on the net, but it may take more moisture to condense to allow the water droplets on the net to flow into the groove.

(Figure 14. Location of mist-capturing experiment)

(Figure 15. The environment of mist-capturing experiment (the mist-capturing device is in the middle))

We actually placed the mist-capturing device on campus to try to observe whether our daily environment could capture the moisture in the air with the mist-capturing device. The observation site is located in the Qianjin District of Kaohsiung City (Figure 14) on the ground of our campus meteorological observation pad (Figure 15), with the net facing the north windward. From 2/23 to 2/25 every morning at 7:50, record the amount of water collected in the test tube or graduated cylinder and reset to zero.

[2] Results and discussion of mist-capturing experiments



(Figure 16. 2/23, 2/24, 2/25 0:00～7:00 Relative Humidity in Qianjin District)

According to the three-day experimental record, we found that mist-capturing device did not collect water for three days, and we speculated that the possible reason was that after the water droplets in the fog formed on the fogging net, due to local weather conditions, wind and sun, the water on the network evaporated. It may also be that the relative humidity of the Golden Area from 0:00 to 7:00 before this day has not reached saturation(as figure 16 shows), coupled with the dry and cold climate in Kaohsiung in winter, it is not easy to produce fog, and it is impossible to collect water.

Conclusion

By analyzing the rainfall data in Kaohsiung from 2009 to 2021, we found some characteristics of rainfall in our city. First, the uneven distribution of rainfall which means that in the winter season, we don’t have access to abundant water. Second, the dates when we don’t have rain have risen from 2009 to 2021, which increases 4 days a year on average. And whether this phenomenon is connected to climate change or extreme weather, we still need more research to confirm the relationship by looking at the temperature every year or other factors which might affect the rainfall as well.

As for the results of the water collection experiment, we found that fog or dew capturing may not be suitable for Kaohsiung to solve the water shortage problem. It is speculated that the lack of water vapor in the air in the city center or the temperature is not low enough for moisture to condens on the devices.

Future Work

We have tried two ways to collect water, although the results are not ideal, we hope that in the future, we can learn more about the impact of the environment of the device on the water harvesting efficiency. In addition, the device can be produced using different materials or in different ways, and its influence can be explored and the functionality of the device can be improved.

Review of Literature

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