CHINESE GEOGRAPHICAL SCIENCE
Volume 4, Number 2, pp.159-167, 1994
Science Press, Beijing, China

A STUDY ON MARSH EVAPOTRANSPIRATION IN THE SANJIANG PLAIN

Chen Gangqi (陈刚起) Lu Xianguo (吕宪国)
(Changchun Institute of Geography, the Chinese Academy of Sciences, Changchun 130021, PRC)

ABSTRACT: The Sanjiang Plain is situated in northeast China. It is one of the areas where marshes are distributed concentratedly and widely in China. *Carex lasiocarpa* marsh and the marsh with *Carex lasiocarpa* as dominative species are distributed widely. We chose *Carex lasiocarpa* marsh as observation object in 1990 and 1991. Marsh evapotranspiration includes transpiration of marsh plants and evaporation of water surface. We used evaporimeters to observe the water level, and calculated the water level amplitude. The evapotranspiration of the marsh is one or two times more than the evaporation of water surface in growing season. The larger the vegetation coverage, the greater the daily evapotranspiration. When the vegetation coverage of marsh is less than 10%, the daily evapotranspiration of marsh is close to the evaporation of water surface. The difference between the evapotranspiration of marsh and the evaporation of water surface in sunny days is more than that in cloudy days.

KEY WORDS: marsh, evapotranspiration, the Sanjiang Plain

I. INTRODUCTION

Evapotranspiration is a key component of water cycle in nature and a part of water loss of marsh. Evapotranspiration is a main item of water balance, many problems concerning water are related to evapotranspiration. The characteristics of regional evapotranspiration reflect the effect of human activities on environment. Marsh evapotranspiration includes transpiration of marsh plants and evaporation of water surface. The Sanjiang Plain is one of the areas where marshes are distributed concentratedly and widely in China. Although it has been exploited for many years, there are still about 2,000,000 hectares of marsh. The study on the characteristics of marsh evapotranspiration is valuable to exploit the area further more, forecast the variation of water balance and estimate water resources. The article is based on the data observed in 1990 and 1991 in the

Mire & Wetland Ecology Test Station in the Sanjiang Plain of the Chinese Academy of Sciences. The field is situated at 47 ° 35′N, 133 ° 31′E, 56.4m a.s.l.

II. THE SELECTION OF MARSH TYPE AND OBSERVING METHOD

1. Marsh Type

Marsh is a natural complex developed with mass water. Marsh soil is saturated with water all the year round and is often covered by a thin layer of stagnant water. Water is the major factor in marsh formation, and also the major component of marsh. The Sanjiang Plain is situated in northeast China with temperate damp monsoon climate, the landform is plain in gross, but rise and fall in some local places. There are many shallow low–lying land with various sizes and shapes, therefore, runoff is unfluent. Marsh soil is heavy and water permeates the soil difficultly. So the surface is always covered with water, which is advantageous for marsh forming. All these result in the wide developing of marsh.

The major marsh types includes *Carex lasiocarpa* marsh, *Carex lasiocarpa–Carex pseudocuraica* marsh, *Carex lasiocarpa–Glyceria spiculosa* marsh, *Carex pseudocuraica* marsh, *Glyceria spiculosa* marsh, *Carex lasiocarpa–Carex meyeriana* marsh, *Carex lasiocarpa–Carex schmidtii* marsh and *Phragmites commumis* marsh. The *Carex lasiocarpa* marsh and the marsh in which *Carex lasiocarpa* is dominant species are distributed most widely, with an area of about 450,000 hectares, making up more than 40% of the total marsh area in the Sanjiang Plain. The plants in *Carex lasiocarpa* marsh are all thick, with lanceolate leaf, the density is about 2,500 plants every square meter. The degree of coverage of every kind of marsh is from 60% to 90%. The depth of surface water varies between 5–10cm in the main types of marshes. We choose *Carex lasiocarpa* marsh as an observing object.

The profile of *Carex lasiocarpa* marsh is generally divided into five layers from top to bottom: vegetation, with a height of 30–50cm; thin layer of stagnant water, 5–10cm; sponge–structure grass–root layer, 30–40cm; humus, 5cm or so; the gley with clay or mild clay layer, which is an unpermeable layer. Marsh water cannot exchange with deep underground water.

The Sanjiang Plain is situated in a high latitude area. The air temperature in February is always below −30℃, the winter is quite cold and as long as five months. Although *Carex lasiocarpa* is perennial, the part above ground dies every year and sprouts at the end of April or early May, after September, it loses growth vigour gradually, and dies in October.

2. Methods

We use evaporimeters to observe the change of water level, and calculate the water level amplitude. The evaporimeters are divided into three types: the first is planted with marsh plants, with proper density but different areas; the second is with pure water, no plant; the last is E_{601}. The first and second ones are placed in an extensive marsh area and the last in a meteorological station in the marsh area.

III. RESULT AND ANALYSIS

1. The Evapotranspiration of Marsh More than Evaporation of the Water Surface

The evapotranspiration of underlying surface is decided by the water supply, heat condition, air humidity, intensity of air turbulence, barometric pressure, and the material composition of the underlying surface. The conditions for the comparative observation between marsh evapotranspiration and evaporation of water surface are that both of them are all supplied with water sufficiently, their solar radiation, air humidity and barometric pressure are equal, and the evaporimeters are all placed in marsh, whose sides are far lower than marsh plants. The difference lies in the composition of the underlying surface, which means that the evapotranspiration of marsh includes the transpiration of foliage and the evaporation between individual plants, but the evaporation of water surface only includes pure water evaporation. We think that the results of comparative observation are comparable, they can reflect the evapotranspiration difference under different underlying surfaces. The observed results indicate clearly that the evapotranspiration of marsh is more than the evaporation of water surface and E_{601}(Table 1).

Table 1 The average daily evapotranspiration of marsh and evaporation of water surface (mm/ d)

Month	E_{m1}	E_{m2}	E_{m3}	E_{m4}	E_{m5}	E_w	E_{601}
June	9.9	9.2	7.9	6.6	4.0	3.8	3.1
July	12.5	9.9	9.5	6.3	3.5	3.5	3.4
August	11.1	9.4	9.7	6.4	3.5	3.7	3.5
September	6.6	6.0	6.0	5.2	2.9	2.8	2.7
October	4.5	3.8	5.0	3.8	2.0	2.1	2.0
Average	8.9	7.7	7.6	5.7	3.2	3.2	3.1

Note: E_{m1}, E_{m2}, E_{m3}, E_{m4}, E_{m5} mean the evapotranspiration of marsh 1, marsh 2, marsh 3, marsh 4 and marsh 5. E_w means the evaporation of water surface.

2. The Larger the Vegetation Coverage, the Greater the Daily Evapotranspiration

Table 1 shows clearly that the sequence of evapotranspiration is E_{m1}(with 90% of vegetation coverage) > E_{m2}(80%) > E_{m3}(70%) > E_{m4}(40%) > E_{m5}(10%). This variation reflects that the transpiration is greater than the evaporation decrease between individuals caused by plant cover. The transpiration of stems and leaves is a major composition of marsh evapotranspiration. Therefore, the more the marsh plants, larger the vegetation coverage, the greater the marsh evapotranspiration.

When the marsh vegetation coverage is less than 10%, the marsh daily evapotranspiration is close to evaporation of water surface and E_{601}. *Carex lasiocarpa, Glyceria spiculosa* and *Carex pseudocuraica* all grow thick. Although transpiration in marsh evapotranspiration is very important, but single plant can do nothing, only when they add to a certain number (over 10%), can they show their effect of enlarging marsh evapotranspiration.

3. The Ratio of Evapotranspiration of Marsh to Evaporation of E_{601} Increasing with the Raising of Vegetation Coverage

Observed data show that the ratios of evapotranspiration of marshes to evaporation of E_{601} are all more than 1, varying between 1.5–3.7. The larger the vegetation coverage, the greater the ratio (Table 2).

Table 2 The ratios of average monthly marsh evapotranspiration to evaporation of E_{601} in 1991

Month	E_{m1}/E_{601}	E_{m2}/E_{601}	E_{m3}/E_{601}	E_{m4}/E_{601}	E_{m5}/E_{601}	E_w/E_{601}
June	3.2	3.0	2.5	2.1	1.3	1.2
July	3.7	2.9	2.8	1.8	1.0	1.0
August	3.2	2.7	2.8	1.8	1.0	1.0
September	2.4	2.2	2.2	1.9	1.1	1.0
October	2.2	1.9	2.5	1.9	1.0	1.0
Average	2.9	2.5	2.5	1.9	1.1	1.0

4. The Range of Daily Evapotranspiration of Marshes Every Month Greater than That of Water Surface during Plant Growing Period

According to the observation, with the vegetation coverage ranges from large to little, the average evapotranspiration amplitudes every month were 7.1mm, 5.0mm, 3.6mm, 3.2mm, 2.6mm respectively in 1990 and 8.0mm, 6.1mm, 4.7mm, 2.8mm, 2.0mm respectively in 1991. The amplitudes of the average evapotranspiration variation between marsh water surface and E_{601} were 1.2 and 1.0 in 1990, 1.7 and 1.5 in 1991 (Fig.1).

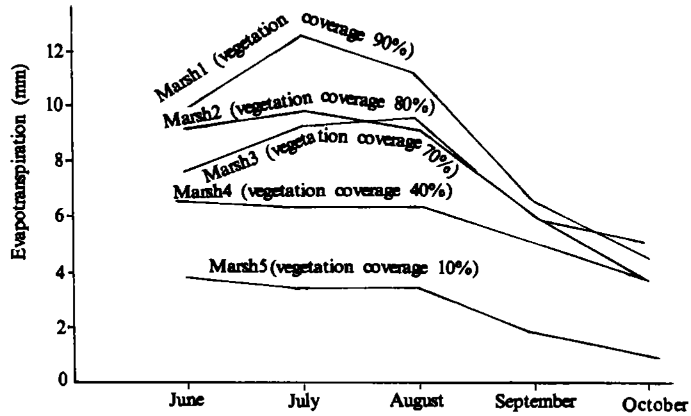

Fig. 1 Average daily course of marsh evapotranspiration

5. The Difference Between Evapotranspiration of Marsh and Evaporation of Water Surface in Clear Days Greater than That in Cloudy Days

In clear days, the temperature is high, air humidity is low. In addition to the increasing of evaporation of water surface, transpiration is strengthened because the leaf stoma open and photosynthesis increases. All these make the marsh evapotranspiration increase greatly, but the water surface evaporation has only one growth—water surface evaporation. In cloudy days, the temperature is low, air humidity is high, so the evaporation of water surface reduce. Photosynthesis decline, the living thing's activity reduce, water quantity needed lessen, therefore transpiration also reduce greatly. All these result in the decline of difference between evapotranspiration of marshes and evaporation of water surface (Table 3).

Table 3 Average daily evapotranspiration of marsh and evaporation of water surface in different weather types in 1990(mm/ d)

Month	Clear day			Cloudy day		
	E_{m2}	E_{601}	Difference	E_{m2}	E_{601}	Difference
June	5.1	3.0	2.1	3.7	2.2	1.5
July	9.3	4.3	5.0	7.8	3.5	4.3
August	9.8	2.8	7.0	6.8	1.7	5.1
September	7.6	3.2	4.4	4.2	1.8	2.4
October	3.2	2.3	0.9	1.8	1.4	0.4

6. Marsh Evapotranspiration Greater than Evaporation of Water Surface at Night

Although marsh plants stop their photosynthesis at night, they must continue respiration, still have physiological activity, thus, there is some transpiration. At night, marsh plants can warm the water between individual plants, this increases the evaporation of water surface (Table 4).

Table 4 Average monthly evapotranspiration of marsh and evaporation of of water surface at night(mm/ d)

Month	E_{m1}	E_{m2}	E_{m3}	E_{m4}	E_{m5}	E_w	E_{601}
June	1.1	1.1	1.9	1.2	0.4	0.6	0.6
July	2.0	1.8	1.6	1.2	0.6	0.8	1.1
August	2.3	1.9	2.0	1.6	0.7	1.1	1.2
September	1.5	0.9	1.7	1.0	1.0	0.9	1.0
October	0.9	0.6	1.0	0.8	0.6	0.6	0.8
Average	1.6	1.3	1.5	1.2	0.7	0.8	0.9

IV. THE STATISTICAL MODEL OF MARSH EVAPOTRANSPIRATION

There are a lot of methods to calculate evapotranspiration, including the models of water balance, heat balance, quality transfer and climatic index. These models are based on certain theories, but they also have hypothetical conditions. Some of the models are used extensively, but they still have some limitations. Using these models, we must consider the local physical geographical conditions, and make some essential observations. Because some observations and calculations are quite overelaborate, even some uncommon instruments are needed, it is difficult to use these models in the areas lacking data and having no appropriate observing methods [1] . According to evapotranspiration data observed and hydrological and climatic data, we established the statistical model of marsh evapotranspiration.

1. Selection of the Model Factors

1.1 Coverage degree of vegetation

Marsh evapotranspiration is the sum of the plant transpiration and water surface evaporation. At present, it is difficult to divide them. But we must consider plant transpiration in establishing model. Plant transpiration is by stomata. The more leaves, the more transpirations. Leaf area is the first factor to be considered. The leaf of marsh plants, especially *Carex lasiocarpa,* is as thin as lanceolate, so it is difficult to measure single leaf area. Even though you can observe the leaf area, the error is bigger. The marsh plants grow thickly, with similar densities, therefore, the transpiration of marsh plant is mainly by plant colony. On the ground of these, we selected vegetation coverage as the factor to reflect plant condition. The result of observation shows that the vegetation coverage is a better factor to reflect transpiration of marsh plants.

1.2 Temperature of water surface

Evaporation is the difference of water molecule escaping from water surface and returning to water surface. The higher the water temperature, the faster the water molecule moves, the easier the water molecule overcomes the pulling force of water surface. Furthermore, the more the water molecules escaping from water surface , the more the evaporation of water surface. As a result, we selected the temperature of water surface as the factor to reflect heat condition.

1.3 The saturation difference of water vapour pressure

Air temperature decides the saturated water content of air. Vapour pressure means present amount of water vapour in air. The difference of saturated water vapour pressure and present vapour pressure is the saturation difference of vapour pressure. It is a function of air temperature. So we selected the saturation difference of vapour pressure as the factor in establishing the model, and did not use the air temperature.

1.4 Wind velocity

Wind velocity influences chaotic dispersion. The bigger the wind velocity, the faster the dispersion , and the greater the evaporation. We selected mean diurnal wind speed at 1.5m height to establish the model.

2. The Model Form

The model of marsh evapotranspiration is as follows:

$$E = 2.65 t_w^{(0.65)} \cdot e^{(-3.25/d)} \cdot s^{(0.4)} + 0.72w - 1.1$$

where, E—diurnal evapotranspiration of marshes (mm/ d); t_w—mean diurnal temperature of water surface(℃); d— mean diurnal saturation difference of vapour pressure at 1.5m height above water surface 1.5m(mb); s—vegetation coverage of marsh (in decimal); w—wind speed at 1.5m height above marshes (m/ s).

3. Reasonability Analysis and Applicable Conditions

The multiple correlation coefficient of the model $R=0.87$. The partial correlation coefficient of the first item of the right side of the model $r=0.86$, the partial correlation coefficient of the second item $r=0.12$. This mean evapotranspiration of marshes relates closely with the saturation difference, water temperature and vegetation coverage, and not closely with wind speed.

T_w, d and s show positive correlation with evaporation. This accords with physical concept and actual observation. If w is positive, it means that wind speed is greater and promote the evaporation. The item of 0.72w−1.1 means that wind has no great effect on the increase of marsh evapotranspiration when wind speed is smaller than 1.53m/ s. When the wind speed at the height of 1.5m is equal to 1.53m/ s, because roughness is bigger, the wind speed near marsh vegetation canopy is smaller. In addition, the height from water surface to and the canopy is about 30cm, horizontal air movement is the smallest because plants block. So we can think it is reasonable that wind speed influences is not great.

d is not negative because $e^{(3.25/d)}$ is always positive. If $d=0$, $-3.25/d \rightarrow -\infty$, $e^{(-3.25/d)}=e^{-\infty}\rightarrow 0$. The first item of the model is equal to zero, it is reasonable.

t_w changes from 0℃ to 28℃ . If $t_w=0$℃, $0^{(0.65)}=1$. Realistically, the model is based on the data of plant growth period, when $t_w=0$, the plant stops growing.

If the first and second items are equal to zero, the E is negative. This is not possible in plant growth period.

All above, we think the model is reasonable. It can be used to calculate marsh evapotranspiration in plant growth period in the Sanjiang Plain.

4. Precision of the Model

The residual standard error of the model $s=0.80$mm. According to the fitting of 29 data in 1991, the absolute errors of 28 data are smaller than 1mm, account ing for 96.6%. Only one is equal to 1.6m. The absolute errors of 20 data are smaller than 0.5mm, accounting for 69%. As for relative error, 28 data are smaller than 20%, accounting for 96.6%. Only one datum is bigger than 20%(23.1%), and its absolute error is 0.6mm. The relative errors of 21 data are smaller than 15% , accounting for 72.4%, and 17 data are smaller than 10% , accounting for 58.6%. On the basis of growth period, only one absolute error is equal to 0.2mm, the others are smaller than 0.1mm, maximum relative error is 2.2% (Fig.2).

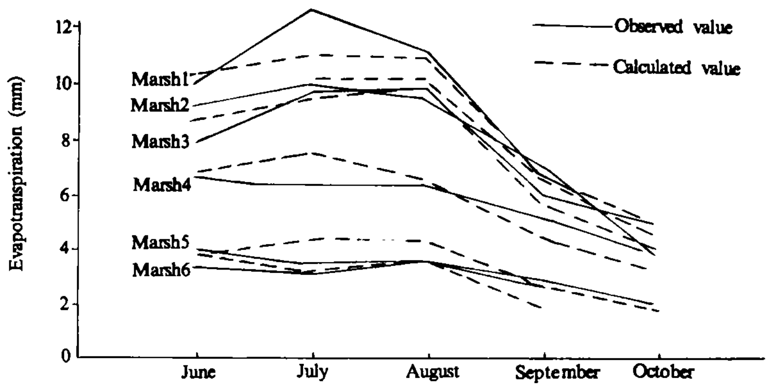

Fig. 2 Fitting curves of the marsh evapotranspiration

V. CONCLUSION

Differing from other grasslands, marsh soil is oversaturated. And differing from general water body, marshes are thickly covered by plants. Two features of marsh evapotranspiration are abundance of supplying water and intensive plant transpiration. These two characters decide that marsh evapotranspiration is one or two times higher than water surface evaporation. Marsh evapotranspiration is sensitive to climatic factors, and changes greatly. The evapotranspiration is higher at night. The greater vegetation coverage, the more obvious these characters.

Based on the data observed in the Mire & Wetland Ecology Test Station in the Sanjiang Plain, considering main influence factors, especially the factors reflecting plant transpiration, the model is established through statistical analysis. Its structure is reasonable and is suitable to calculating marsh evapotranspiration in the Sanjiang Plain.

REFERENCE

[1] 陈久宇. 观测数据的处理方法. 上海: 上海交通大学出版社, 1986.