CHINESE GEOGRAPHICAL SCIENCE
Volume 4, Number 3, pp259 –267, 1994
Science Press, Beijing, China

THE VERTICAL DISTRIBUTION OF AGROTOPOCLIMATIC RESOURCES IN THE WARM SECTORS OF THE THREE GORGES AREA OF THE CHANGJIANG RIVER

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ABSTRACT: The paper expounds the characteristics of the verticaldistribution of agrotopoclimatic resources in the warm sectors of the Three Gorges area of the Changjiang (Yangtze) River, sets up models of vertical distribution of resources, and make a vertical division of the agrotopoclimate. Mean temperature presents a linear decrease with increasing altitude. In general, the mean annual maximum temperature and the mean annual munimum temperature decrease with the altitude increase especially, the absolute minimum temperature presents an indicial decline. Days of high temperature decrease with the altitude increase and days of low temperature in reverse. Accumulated temperature and days of agricultural threshold temperature have negative relation with the height. Both annual sunshine hours and the sunshine hours between April and October present a linear decrease with increasing altitude. The precipitation in sectors above 300m increases with increasing altitude, but the precipitation in sectors below 300m goes in reverse. Annual change of precipitation has typical characteristics of East Asia monsoon climate with two peaks. In lower warm sectors the aridity index decreases with increasing altitude while in upper sectors it increases with the altitude Increase. Nine indices of vertical division are selected to make a quantitative division of agrotopoclimate.

KEY WORDS: agrotopoclimatic resources, vertical division of agrotopoclimate, the Changjiang Three Gorges

I. INTRODUCTION

In the paper, we expound the characteristics of the vertical distribution of agrotopoclimatic resources in the warm sectors of the Three Gorges area of the Changjiang

River, set up models of vertical distribution of resources, and make a vertical division of the agrotopoclimate. Some points should be noted:

1) Scope of study. The well–known Three Gorges of the Changjiang River, consisting of Qutang Gorge, Wu Gorge and Xiling Gorge, extend from Baidicheng of Fengjie, Sichuan Province to Nanjinguan, Yichang in Hubei Province with a total length of 192km, of which the Three Gorges area located in Hubei Province from Bianyuxi, Badong to Nanjinguan with a length of about 130km. This paper examines the northern side of this section (south slope of Shennongjia Mountains). The upper limit of the warm sectors is defined by 800m above sea level because at this altitude the temperature in winter is similar to that of the Jianghan Plain which lies at the same latitude. Here the temperature gradient changes greatest and the altitude coincide with the upper limit of plantation of oranges.

2) Source of data. The research group①is engaged in scientific exploration in the northern side of the Changjiang Three Gorges area in Hubei Province for three years (1983–1986). The measuring spots are located at the height of 150m, 275m, 460m and 770m.

3) Agrotopoclimate. Agrotopoclimate mediates between macroclimate and microclimate is defined as local climatic differentiation caused by relief and its effect on agriculture under given macroclimate. Therefore the warm sectors of the gorges area, as an indivisible part of the mountain range have its particular vertical distribution of climate.

II. VERTICAL DISTRIBUTION OF MAJOR CLIMATIC RESOURCES

1. Heat Resource

Mean temperature presents a linear decrease with increasing altitude (Fig.1 (a)). Mean annual and monthly temperatures have a markednegative relation with altitudes. We obtain the relative equationsby statistical analysis:

$$T_y = 18.423 - 0.604H \quad (r = -0.988) \qquad (1)$$

$$T_1 = 6.732 - 0.547H \quad (r = -0.974) \qquad (2)$$

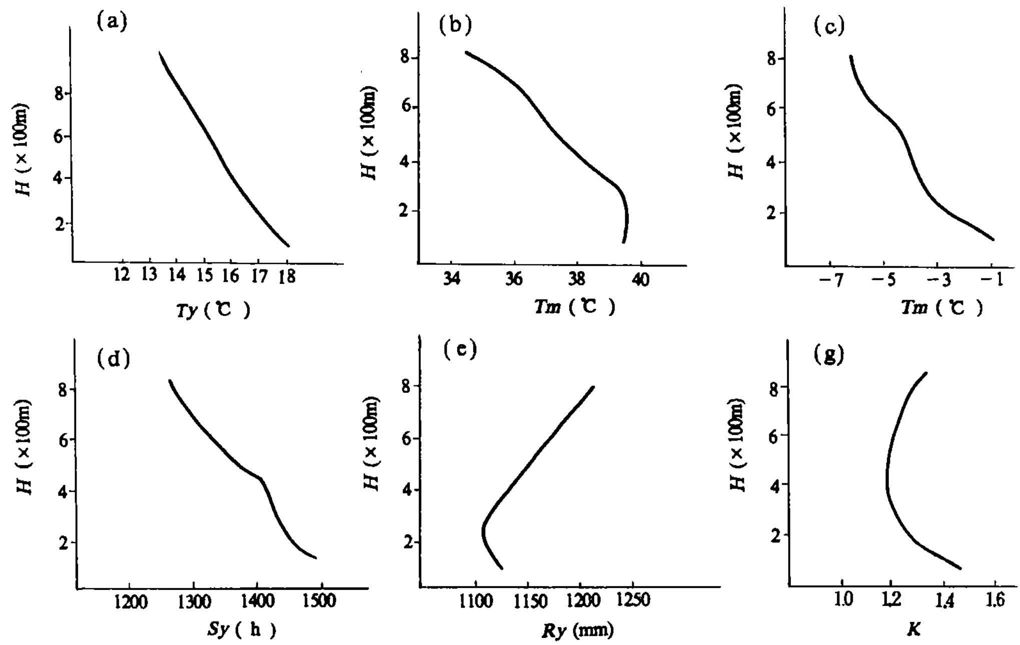
$$T_4 = 19.415 - 0.596H \quad (r = -0.995) \qquad (3)$$

$$T_7 = 28.24 - 0.565H \quad (r = -0.997) \qquad (4)$$

① The research group of agroclimatic resources of hilly and mountainous areas in the subtropics of China.

$$T_{10} = 19.237 - 0.589H \quad (r = -0.971) \tag{5}$$

where T_y, T_1, T_4, T_7,T_{10} in (1)–(5) are respectively mean annualtemperature and mean temperatures of January, April, July andOctober; H is altitude, unit: 100m (the same below);r is relativecoefficient (the same below).



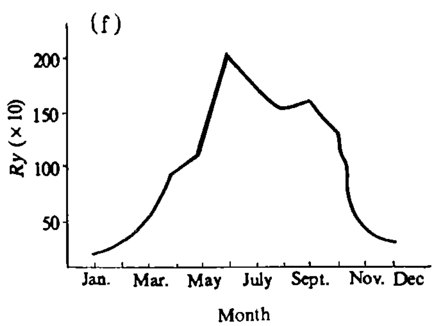


Fig. 1 Vertical distribution of

(a) mean annual temperature

(b) annual maximum temperature,

(c) annual minimum temperature,

(d) annual duration of sunshine,

(e) annual precipitation,

(g) annual aridity index;

(f) annual change of precipitation

In general the mean annual maximum temperature and the meanannual minimum temperature decrease with the altitude increase especially, the absolute minimum temperatures present a indicialdecline (Fig.1 (b), Fig.1 (c)). The fitting equations are written as:

$$T_{ymax} = 40.066 - 0.175H \quad (r = -0.981) \tag{6}$$

$$T_{ymin} = 9.616e^{-0.124}H - 10 \quad (r = -0.981) \tag{7}$$

where T_{ymax} and T_{ymin} are mean annual maximum and minimum temperature respectively.

Days of high temperature decrease with the altitude increase and days of low temperature in reverse. The daily temperature above 30℃ are recorded between April and October, and the daily temperature exceeding 35℃ appears between May and September. The relationship between days of high temperature and altitude is shown as follows:

$$Dtm \geqslant 30℃ = 106.767 - 3.428H - 0.709H^2 \quad (r = 0.988) \tag{8}$$

$$Dtm \geqslant 35℃ = 42.142 - 6.118H - 0.088H^2 \quad (r = 0.954) \tag{9}$$

where $Dtm \geqslant 30℃$ and $Dtm \geqslant 35℃$ are days of temperatures over 30℃ and 35℃ respectively. However, days of annual minimum temperature (below 0℃ or −5℃) increase with increasing altitude. For example, at Zigui andXinshan, Hubei Province (300m below sea level) was not recorded the daily temperature below −5℃ during the three years of observation while at the Pastoral Farm (460m above sea level) was recorded only once in January of 1984.

Accumulated temperature and days of agricultural threshold temperature have negative relation with the height. The fitting equations of active accumulated temperatures above 10℃ and above 20℃, and their durations are written as:

$$\sum t \geqslant 10℃ = 6241.202 - 2.759H \quad (r = -0.990) \ (1985) \tag{10}$$

$$N(t \geqslant 10℃) = 285.471 - 10.446H \quad (r = 0.951) \ (1985) \tag{11}$$

$$\sum t \geqslant 20℃ = 4185.841 - 309.309H \quad (r = -0/995) \tag{12}$$

$$N(t \geqslant 20℃) = 159.507 - 10.068H \quad (r = -0.992) \tag{13}$$

It is shown that the higher the agricultural threshold temperature, the durations decrease progressively with the altitude increase, but their decrease rates have not great difference at the two threshold temperatures.

Through analysing the data of the inversion in January of 1985, we found wherever the cold air mass intrudes, the sky clears up, the inversion layer in the gorges area is near 300m. There is an inversion layer at 300m during the last ten days of January when sunny days prevail, between 570–580m , there is the second inversion layer.

2. Light Resource

Sunshine hours. Both annual sunshine hours and the sunshine hours between April and October (growing period) present a linear decrease with increasing altitude (Fig.1 (d)). The fitting equations are written as:

$$S_y = 1581.094 - 36.751H \quad (r = -0.994) \tag{14}$$

$$S_{4-10} = 1137.332 - 34.469H \quad (r = -0.972) \tag{15}$$

where S_y and S_{4-10} are annual sunshine hours and the sunshine hours between April and October respectively.

Percentage of sunshine. The vertical distribution of annual percentage of sunshine and that between April and October are correspondingly similar to their sunshine hours. Hence the equations are:

$$S'_y = 35.711 - 0.816H \quad (r = -0.987) \tag{16}$$

$$S'_{4-10} = 40.411 - 1.199H \quad (r = -0.969) \tag{17}$$

where S'_y and S'_{4-10} in (16) and (17) are respectively percentage of annual sunshine and the sunshine between April and October.

Foggy duration. Fog in the warm gorge sectors is one of the important factors effecting sunshine. According to the three–year data of observation, foggy days appear mainly between May and November. Annual foggy days present a linear increase with the altitude increase. The vertical distribution is presented as the following equation.

$$F_y = -11.568 + 8.073H \quad (r = 0.989) \tag{18}$$

3. Water Resource

The vertical distribution of annual precipitation in gorges area is different from that of other mountains. The curve in Fig.1 (e) shows that the precipitation in sectors above 300m accords with the general law, i.e. precipitation increases with increasing altitude, but precipitation in sectors below 300m goes in reverse. Precipitation in Zigui (150m), for example, is more than in Xingshan (275m) because of the more moisture in lower sectors and because of the topography—the warm sectors are gentle and broad upslopes and steep and narrow in lower—that makes the ascending current stronger. The vertical distribution of annual precipitation and that between April and October may be written respectively as

$$R_y = 1110.578 - 0.890H + 1.684H^2 \quad (r = 0.947) \tag{19}$$

$$R_{4-10} = 963.583e^{0.12H} \quad (r = 0.986) \tag{20}$$

Annual change of precipitation (Fig.1 (f)) has typical characteristics of East Asia monsoon climate with two peaks. The first peak emerges during the period of mei–yu (plum rains) extending from the early summer through the middle and last ten–days of July or early August, by then the gorges area is under the dominance of subtropical high and gets into hot and dry season, the curve of precipitation becomes a trough. The other peak occurs at September when autumn rain is coming. Then rainfall declines as the winter winds arrive after autumnal equinox. Precipitation concentrates mainly at time from April through October, rainfall in autumn is more than in spring.

The vertical distribution of annual rain days and heavy rain days (daily rainfall is 25mm or more) presents a secondary curve. The fitting equations are:

$$R'_y = 215.944 - 9.825H + 0.614H^2 \quad (r = 0.935) \tag{21}$$

$$R''_y = 13.323 - 1.300H + 0.095H^2 \quad (r = 0.949) \tag{22}$$

Relative humidity depends upon variations of actual vapour pressure and the saturated vapour pressure, therefore the variation with increasing altitude could be complex. The vertical distribution of annual relative humidity in warm sectors is also a secondary curve, its fitting equation is

$$f = 64.362 + 5.23H - 0.519H^2 \quad (r = 0.963) \tag{23}$$

Aridity index (k), ratio of evaporation to precipitation is an assessment of the degree of dryness of a region. Vertical distribution of annual aridity index appears a parabolic line (Fig.1 (g)), that is in lower warm sectors the aridity index decreases with increasing altitude while in upper sectors it increases with the altitude increase. Its fitting equation is

$$K = 1.701 - 0.323H + 0.022H^2 \quad (r = 0.947) \tag{24}$$

(April of 1984 to March of 1986)

III. VERTICAL DIVISION OF AGROTOPOCLIMATE IN THE WARM GORGES SECTORS

The above–mentioned patterns of vertical distribution of climatic resources underlie the vertical division of agrotopoclimate. The vertical division of agrotopoclimate in the warm gorges sectors is designed for revealing a zonal spatial differentiation of climatic resources and its relations with agriculture and forestry, and also for providing the scientific basis for the rational development and utilization of resources.

1. Indices of Vertical Division of Agrotopoclimate

While selecting the indices of vertical division of agrotopoclimate, we have taken into account the genetics of the agrotopoclimate in the gorges area, the selected indices must also have great influence on the allocation of three–dimenssional agriculture. In order to avoid non–standardization and subjective decision frequently occurred in qualitative division. We have made a quantitative division by selecting several indices. Nine indices of vertical division and their models are shown as follows (see Table 1).

Table 1 Indices and models of vertical division

Indices	Models (unit of H: 100m)
Mean annual temperature X_1	$X_1 = 18.423 - 0.604H$
Mean temperature of January X_2	$X_2 = 6.732 - 0.547H$
Absolute minimum temperature X_3	$X_3 = 9.616\,e^{-0.124H} - 10$
Active accumulated temperature (>10℃) X_4	$X_4 = 6241.202 - 2.759H$
Annual precipitation X_5	$X_5 = 1110.578 - 0.890H + 1.684H^2$
Annual relative humidity X_6	$X_6 = 64.362 + 5.232H - 0.519H^2$
Annual aridity index X_7	$X_7 = 1.701 - 0.223H + 0.022H^2$
Hours of sunshine between Apr. and Oct. X_8	$X_8 = 1137.332 - 34.469H$
Net primary productivity X_9	$X_9 = 3000(1 - e^{-0.000664R})$

The first eight indices in Table 1 are cited from the above paragraph. The ninth index (*NPP*) is calculated by Miami model. ①

2. Vertical Agroclimatic Layers

① Miami model was put forward originally at the meeting in Miami in 1971. In general, there are two methods to graduate productivity: function of temperature and function of precipitation.

$$NPPt = 3000 / (1 + e^{1.315 - 0.119T}) \qquad NPPr = 3000(1 - e^{-0.000664R})$$

where T is mean annual temperature (℃), R is annual precipitation (mm). $NPPt$ and $NPPr$ are net primary productivity calculated by temperature and precipitation respectively (g / m^2 · y). According to Liebig's min–amount law, a lower value is selected as the value of productivity of Miami model: $NNP = \min(NPPt, NPPr)$. According to the calculation in warm gorge sectors, $X_9 = NNPr$.

We have made a vertical division of agrotopoclimate in warm gorge sectors by analysing the principal components based on the above–mentioned researching work (details are omitted). such division provides a theoretical basis for the rational allocation of three–dimensional agriculture in the warm gorge sectors.

According to the calculation, three layers are divided in the warm gorge sectors: warm layer (<300m), mild layer (300—600m) and cool layer (600—800m) (see Table 2).

Table 2 Vertical agroclimatic layers in warm gorge sectors

Layer	Height (M)	Major agroclimatic characteristics (mean values)					Distribution of products		
		T (℃)	$T>$ 10℃ (℃)	T_1 (℃)	T_{min} (℃)	R (℃)	Crops and cropping system	Timber,forest products and fruits	Products for priority development
I Warm layer	<300	17.0	>5400	>5.5	>−4.8	<1100	Double cropping of rice and winter crops (wheat or rape) triple crops	Oranges	Oranges, cereals, edible oil
II Mild layer	300–600	15.2–17.0	4600–5400	3.7–5.5	−5.5–−4.0	1100–1200	Rice,rape, wheat,maize, sorghum, ramie,double crops	Oranges, tangerines, tung tree, tea tree, chinese, tallow tree, pine, cypress	Oranges and tangerines,tung tree, ramie
III Cool layer	600–800	14.0–15.2	4100–4600	2.5–3.7	−7.0–−5.5	1200–1300	Rice,wheat, food grains other than wheat and rice,potatoes, double crops	Tea, lacquer, fir, cypress pine, walnut, chestnut, oriental oak, eucommia ulmoides	Tea, rape, chestnut, walnut, lacquer

It is necessary to indicate that the influence of the microclimate produced by the relief must be taken into account while carrying on the allocation of three–dimensional agriculture. Different microclimate environment effected by the relief has distinctive agroclimatic characteristics, so there is different utilization.

It is necessary even in the same layer to select agricultural and forest crops that are suitable to the agroclimatic characteristics of microclimate environments, so that we can bring the agroclimatic superiority and potentiality into full play, develop agriculture and diversified economy, and protect the ecological balance.

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