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Delineation of boundary between tropical/subtropical in the middle section for eco-geographic system of South China

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Abstract: This paper discusses division on tropical/subtropical boundary of middle section in South China. This discussion results in new understanding on eco-geographic regions and their boundaries, especially on gradual changes of natural conditions between eco-geographic regions. It analyzes results of the same area by other researchers, clarifies differences and causes of the differences for the results. Boundaries of eco-geographic regions cannot be drawn as a line as changes from tropical to subtropical are gradual. Therefore, for an eco-geographic region like tropical zone, definite boundaries must be mapped while gradual changes are considered. Temperature, vegetation and soil are the indexes to divide tropical and subtropical. After indexes of tropical zone are confirmed, data of annual average index reflect general state of the tropical zone. Line from such data is called "tropical boundary". On the other hand, affected by the monsoon climate, some years are hotter and some are cooler. In hotter years, temperature of north area of tropical boundary reaches tropical state whereas in cooler years, such area moves southward. Boundary of the hottest year is called annual tropical line and that of the coolest year true tropical line. Temperatures in areas south to annual tropical line can probably reach tropical in some years. Temperatures in areas south to real tropical line reach tropical every year. The area from true tropical to annual tropical is called tropical fluctuating zone. Therefore, new concepts of tropical, annual tropical, true tropical and tropical fluctuating zone are formed to understand tropical area from a new point of view in the paper. Based on the indexes of climate, vegetation and soil, boundaries of tropical, annual tropical, true tropical and tropical fluctuating zone of the study area are established. The tropical fluctuating zone explains different locating of different researchers. The paper also puts forward a new method to display boundary for eco-geographic regions.

Delineation of boundary between tropical/subtropical in the middle section for eco-geographic system of South China WU Shao-hong, ZHENG Du (Institute of Geographic Sciences and Natural Resources Research, CAS, Beijing 100101, China) Eco-geographic system is a hierarchic regional system that is divided or combined according to comparison and integrated analysis on geographic regions related to biological and non-biological factors, and differentiation of the earth surface. Eco-geographic system serves as a scientific basis that is significant for regional corresponding to global change, establishment of environmental monitoring network, setting up ecological observation stations, rational natural resources use, land management, ecological degradation renovation and integrated regional pattern. Delimitation is one of the most important tasks in eco-geographic system study, which enables us to recognize characteristics of eco-geographic regions. Tropical boundary in South China is definitely in east and west sections because of landform patterns. Researchers who study boundary between tropical/subtropical of South China focus on the middle section. Argument has been going on for more than 40 years. 1 Different results in delimitation on tropical/subtropical of China 1.1 Differences Generally, during the past 40 years researchers had made their efforts to seek a line that would be able to divide two regions. That is so-called highly similar inside a region and highly different between two regions. Therefore researchers selected index and drew up boundaries for tropical/subtropical according to their recognition to eco-geographic system. But difference of "tropical boundaries" in the middle section reaches 2 degrees of latitude (Table 1 and Figure 1). 1.2 Causes of the differences Causes leading to difference of the tropical/subtropical boundaries are mainly from definitions of tropical data and cartographic methodology. Firstly, the researchers with different research backgrounds studied tropical boundary from different point of views, such as in physio-geography, cl

imatology, vegetation or agricultural point of views. Definition of tropical area has different meanings in the international research. Researchers had different understandings of the definition and selected different indexes to delineate tropical/subtropical. Consequentially, the results of tropical/subtropical are not the same. Secondly, many data such as climate, soil and vegetation have been accumulated as the research on this topic has been lasting for more than 40 years. Different data result in different index calculation and delimitation. Then in cartography, there were no systematic mapping criteria. Traditional mapping produced artificial error. Figure 1 Various limitations of tropical area by different researchers Table 1 Demarcation of northern boundary in middle section of tropical zone in China 2 New concepts

2.1 Tropical definition

Definitions of tropical area are omnifarious[3]. No definition so far has been accepted by international researchers in this field. In the very beginning tropical is an astronomic area between tropic of Cancer and tropic of Capricorn. As scientific progress made and data cumulated, many researchers introduced climate, vegetation, and soil into tropical research[3]. In fact tropical has been regarded as an integrated landscape. The authors think that tropical is an eco-geographic zone based on temperature, especially the coldest month temperature, i.e., temperature is the principal criterion. Vegetation and soil have been affected by temperature for a long period. Therefore, vegetation and soil are indicators for tropical. Human activities also highly reclaim the nature, which must be fully considered in tropical delimitation. Furthermore, transition from tropical to subtropical is a gradual process.

2.2 Index

Climate (temperature) factors are the leading criterion. The most well known tropical delimitation is from Koeppen's climatic classification. He adopted isoline of 18 °C of the average coldest month temperature as the criterion for tropical boundary. Many researchers have used this criterion. Some researchers modified the criterion. As an understanding to the tropical, the authors think that criteria for tropical delimitation must include climate, vegetation and soil. Because the area of middle section is a humid one, temperature becomes the leading criterion for climate. From biological point of view, $\sum 10^{\circ}\text{C}$ accumulated temperature is secure for natural growth of most plants and crops. Living through the winter for most tropical plants and crops depends on the annual coldest month and the lowest daily temperature. $\sum 10^{\circ}\text{C}$ accumulated temperature, annual coldest month and the lowest daily temperature are selected as climatic criteria. Most Chinese researchers took 8,000 °C for $\sum 10^{\circ}\text{C}$ accumulated temperature. Some researchers suggested taking 7,500-7,800 °C as considering some local factors of the zone[16]. But analysis on climatic data shows that most of the area in the zone reaches 8,000 °C in $\sum 10^{\circ}\text{C}$ accumulated temperature because the warm seasons are hot enough. No restraining low temperature occurs while the coldest month temperature is $\sum 15^{\circ}\text{C}$. Frostbiting will not damage crops when the lowest daily temperature is $\sum 5^{\circ}\text{C}$ [5]. Therefore, 8,000 °C for $\sum 10^{\circ}\text{C}$ accumulated temperature, $\sum 15^{\circ}\text{C}$ for the coldest month temperature, and $\sum 5^{\circ}\text{C}$ for the lowest daily temperature are selected as climatic criteria. For vegetation, rainforest is always thought as an indicator for tropical. Because the area has been affected by human activities for a long period, rainforest no longer exists, which has been replaced with (tropical) crops. The delimitation should pay more attention to crops growing within the area. *Theobroma cacao*, *Piper nigrum*, *Cocos nucifera*, *Anacardium occidentale*, *Elaeis guineensis*, and *Hevea brasiliensis* require higher temperature for growth. They start growing when temperature rises over 18 °C and will be damaged when temperature drops to lower than 5 °C. *Gossypium barbadense*, *Agave rigida*, *Americana*, *Areca catechu*, *Cinchona ledgeriana*, and *Thea sinensis* have lower requirement to temperature as they will not fade even at about 0 °C[19]. The former group is distributed southward and the latter group northward. Because of adaptation of the crops and impact of local landforms, some tropical crops may survive in subtropical area. Consequently, the place having tropical crops may not be certainly recognized as tropical area. Soil reflects natural environment of the last period. Laterite is distributed in tropical zone[20], which is the zonal soil in rainforest or seasonal rainforest areas of China. Laterized red earth is distributed in subtropical area of China[21], which is a transitional type between laterite and red earth. From physical and chemical attributes point of view it has signs of laterite. But differences are definite. Therefore, only laterite is taken as tropical indicators.

2.3 Tropical, annual tropical, true tropical, and tropical fluctuating zones

Differences between two regions are gradual. It is difficult to draw a line that can delimit two regions clearly. Thus subtropical zone was marked off in between tropical and temperate zones. Only special area of subtropical zone in China is vast that is thought as a zone. For a given area, climate there is fluctuating. In some years it would be warmer, colder, dryer or more humid. That is why regions cannot be "cut" with a line. Some Chinese researchers marked off a zone between tropical and subtropical zones, calling semi-tropical [7]. Problem are that it is difficult to differentiate semi-tropical from subtropical because subtropical is a transitional zone. Do we need mark off a transitional zone next to another transitional one? Delimitation of transitional zones cannot be going on endlessly. In order to have a definite boundary for zoning and show the transiting reality at the same time, new concepts must be introduced. For middle section of tropical area of China, boundary is delimited according to the selected criteria. Criterion

n values of long-term average reflect general conditions of the area. Boundary delimited from those criteria shows general pattern of heat, biomass and soil, which is called tropical boundary. Because of uneven climatic cycle, some years are hotter and some are colder. At the same time considering long-term average, it is important to focus on extreme situations. For example, the selected criterion, 8000 oC of $\sum 10\text{ oC}$ accumulated temperature (from west to east) is waving between $21^{\circ} 30' \text{C}$ and $23^{\circ} 10' \text{C}$ in the coldest year but between $23^{\circ} 30' \text{N}$ to $24^{\circ} 30' \text{N}$ in the hottest year. Location difference for the two years is 1 to 2 degrees. The same situation happens for the criterion of 15 oC isoline for the coldest month. The difference reaches 3 degrees, and even 4 degrees for 5 oC isoline for the lowest month. In hotter years areas north to the "tropical boundary" are as hot as the tropical, which means that the tropical boundary moves northward. The authors call the farthest northward boundary "annual tropical boundary", meaning that areas south to the boundary may reach tropical state in some year(s) and that never happened in areas north to the boundary. Similarly during colder years, the tropical boundary moves southward. The farthest southward boundary is called "true tropical boundary", meaning that areas south to the boundary are tropical every year and areas north to the boundary are not always tropical. The area between annual tropical and true tropical is called tropical fluctuating zone in which tropical plants and crops grow. Species of heat-favorite distribute in the southern part and the cold-resisted in the northern part of the zone. The tropical fluctuating zone ranges from tropical to subtropical areas, which shows buffering from tropical to subtropical. The authors do not suggest that the tropical boundary will be extended to the location of annual boundary. From integrated point of view, tropical and subtropical are delimited by tropical boundary.

3 Results

Data of climatic criteria are showed in Table 2. After integration of climate, vegetation and soils criteria for tropical boundary is located at $21^{\circ}40' \text{N}$ - $22^{\circ}10' \text{N}$, annual tropical boundary $23^{\circ}0' \text{N}$ - $23^{\circ}40' \text{N}$, true tropical boundary $21^{\circ}30' \text{N}$, and tropical fluctuating zone $21^{\circ}30' \text{N}$ - $23^{\circ}40' \text{N}$. Coastal areas of Guangdong, Nan'ao, Shantou, Huilai, Shanwei, Shenzhen, and Taishan meet the criteria of $\geq 10\text{ oC}$ accumulated temperature and the lowest daily temperature. However, differences of the coldest month temperature there are great. Moreover, soil there is not laterite and typical tropical crops such as coconut, cocoa, pepper, cannot survive there. Therefore, the coastal area was not included in tropical zone (Figure 2).

Figure 2 Map of tropical, annual tropical, true tropical and tropical fluctuating zone in South China

Station	Location	Annual $\sum 10\text{ oC}$	Coldest month	Lowest daily
1	Guangdong	≥ 8000	≥ 10	≥ 5
2	Nan'ao	≥ 8000	≥ 10	≥ 5
3	Shantou	≥ 8000	≥ 10	≥ 5
4	Huilai	≥ 8000	≥ 10	≥ 5
5	Shanwei	≥ 8000	≥ 10	≥ 5
6	Shenzhen	≥ 8000	≥ 10	≥ 5
7	Taishan	≥ 8000	≥ 10	≥ 5

4 Discussion

4.1 Comparison to the former researches

For the tropical boundary, this location is similar to those of Huang Bingwei [2-4], Yu Xianfang [14], He Dazhang and He Dong [8], Xu Xianghao [9], Qiu Baojian [5,6], Han Yuanfeng [17]. It is also similar to that of Wu Chuanjun in his paper of allocation of tropical crops [19]. It is a half-degree of north latitude north to those of Chen Shijian [12], and Tang Yongluan [13,16]. Their boundaries are close to the true tropical boundary. Comparison to that of Ren Mei-e [10] and Zeng Zhaoxuan [11], the boundary has great difference of one and a half degrees to two degrees southward. Their boundaries are close to the annual tropical boundary. The area between the boundaries of Chen Shijian, Tang Yongluan and those of Ren Mei-e is corresponding to the tropical fluctuating zone.

4.2 Tropical fluctuating zone

Concept of tropical fluctuating zone is very important. The former argument on tropical boundary occurred because of appearance of trace within the fluctuating zone. For eco-geographic units, it is impossible for a zone to have no boundary. However, not only the boundary has to be marked off but also the boundary should show the reality. The only way is to look at the tropical from a different angle. Tropical fluctuating zone lets us recognize the tropical/subtropical from a gradual transitional point of view. Tropical fluctuating zone may end up the former argument. Understanding tropical from this point of view will draw a conclusion that it is not necessary to judge which boundary is correct. Tropical boundary is no doubt important but it is not "a wall". It is an acting line. Within the tropical fluctuating zone tropical characteristics are clearer further southward. Scientific significance of tropical fluctuating zone is the case study for eco-geographic unit delimitation in China. The concept of annual tropical, true tropical, and tropical fluctuating zone leads us to recognize eco-geographic units from another point of view. This recognition and delimitation methodology is a leading case for eco-geographic unit delimitation in China, which can be applied to any eco-geographic transitional zones, such as semi-arid to semi-humid. The area of (tropical) fluctuating zone should be updated with data cumulated.

4.3 Display of eco-geographic unit boundary

It is difficult to display transitional boundary of eco-geographic units. As the general scenario for national eco-geographic unit boundary, annual and true tropical boundaries cannot be drawn onto the "eco-geographic unit map". Therefore, display of eco-geographic unit boundary should be based on the technology of geographic information system and database. Transitional state can be showed in "eco-geographic information system". It also needs text description for the transitional state.

关键词: eco-geographic region; tropical; annual tropical; true tropical; tropical fluctuating zone

