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Automated Landform Classification of China Based on Hammond's Method

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Abstract

The automatic classification of Macro landforms was processed with the program developed by Hammond's Manual procedures, which based on properties of slope, local relief, and profile type, which consists of 5 landform types, 24 landform class and 96 landform subclasses. This program identified landform types by moving a square window with size of 9.8 km × 9.8 km. The data includes 816 sheets of topological map with a scale of 1:250,000. The DEM were buildup with the contours and mark points based on this data with a cell size of 200 m, and merge into one sheet. The automated classification was processed on this DEM data with a AML program of ArcGIS 10.X Workstation. The result indicates it produced a classification that has good resemblance to the landforms in China. The maps were produced respectively with 5 types, 16 classes and, 90 subclasses The 5 Landform types of landforms were Plains (PLA), 20.25% of whole areas; Tablelands (TAB) of 3.56%; Plains with Hills or Mountains (PHM) of 32.84%; Open Hills and Mountains (OHM) of 18.72%; Hills and Mountains (HM) of 24.63%. In the result of 24 landform classes, there are not some classes, such as irregular plains with low relief; open very low hills, open low hills; very low hills, low hills, moderate hills. The result of 96 landform subclass is similar to the 24 class.

Keywords

Landform Classification, Hammond, DEM

1. Introduction

To some degree, landforms influence the distribution and evolution of ecology and other environmental factor, which is the core and the basic content of geography [1]. Landform morphological classification is the basic unit of landform, and also the first step in solving geomorphic problems. The landform classifications of large scale were started in 1950 in China. In 1956, the 1:4,000,000 Landform Classifications and Region Planning Map of China, according to the altitude and surface cutting degree (**Table 1**). In 1979, the Mapping Standard of 1:1,000,000 Landform Classifications in China were completed, and classified the landform types with the altitude, relative altitude and the surface cutting degree, according to the classification schemes of З.А.Сварицевская (1975). Until 1989, only 15 sheets landform maps (1:1,000,000 scale) were completed. This mission was suspended for a long time. Until 2009, the 1:1,000,000 scale landform atlases of whole China is accomplished [2]. The two landform classifications schemes above, is based on manual process.

The 1:40,000,000's scheme is based on forms and exogenic forces, and many parameters are not quantitative. There were many quantitative factors is introduced into the 1:1,000,000's scheme, such as altitude, local relief, and slope. The local relief is classified into 4 classless, less than 500 m is low relief hills; 500 - 1000 m is moderate relief hills, 1000 - 2500 m is high relief mountains and more than 2500 m is very high relief mountains [3]. There are also some papers adopted local reliefs but different classes in whole China's landform scheme. Cai Zongxin (1986) classified grade into 5 classes, less than 20 m is plains; 20 - 200 m is hills, 200 - 500 is low mountains, 500 - 1500 m is middle mountains and more than 1500 m is high mountains (**Table 2**) [3]. Tu Hanming *et al.* [4] classified local relief of China into 7 classes based on the statistics of samples from whole China's DEMs. In 2009, Zhou Chenghu *et al.*, classified the landform of China into 7 types and 25 classes, according to slope, relief and altitude (**Table 3**).

In 1990's, there are some scholars contributing to extracting the single landform parameters in China, such as ridge line and valley line [5] [6] [7], summit [8], shoulder line of valleys [9] [10], micro topography [11]. All above are based on the regions of simple landforms evolutions. There are many limits to automatically whole China's landform classifications. Liu Aili *et al.* (2006) [12] attempted to automate classify the landforms of whole China based on image classifications methods. But the sampling cell is 1000 m × 1000 m, which is coarse enough to omit many small landform units.

Table 1. Mountain and hills classification of China.

Class	Subclass	Altitude(m)	Surface cutting degree
Extremely high mountain		>5000	>1000
High mountain	High mountain	3500 - 5000	>1000
	Mid-high mountain		500 - 1000
	Low-high mountain		<500
Middle mountain	High-middle mountain	1000 - 3500	>1000
	Middle mountain		500 - 1000
	Low-middle mountain		<500
Low mountain	Mid-low mountain	500 - 1000	500 - 1000
	Low mountain		100 - 500
Hills		<500	

Table 2. The basic geomorphologic index of China.

Types	Relative altitude
Plain	<20
Hills	20 - 200
Low mountain	200 - 500
Middle mountain	500 - 1500
High mountain	>1500

Table 3. Basic morphological types of land geomorphology in China.

Altitude	Low altitude	Mid-altitude	High altitude	Extremely high altitude
relief	<1000	1000 - 3500	3500 - 5000	>5000
Plain (<30)	Low altitude plain	Mid-altitude plain	High altitude plain	Extremely high altitude plain
Platform > 30	Low altitude platform	Mid-altitude platform	High altitude platform	Extremely high altitude platform
Hills < 200	Low altitude hills	Mid-altitude hills	High altitude hills	Extremely high altitude hills
Small-relief mountain 200 - 500	Small-relief low mountain	Small-relief mid-mountain	Small-relief high mountain	Small-relief Extremely high mountain
Mid-relief mountain 500 - 1000	Mid-relief low mountain	Mid-relief mid-mountain	Mid-relief high mountain	Mid-relief Extremely high mountain
Big-relief mountain 1000 - 2500		Big-relief mid-mountain	Big-relief high mountain	Big-relief Extremely high mountain
Extremely Big-relief mountain > 2500			Extremely Big-relief high mountain	Extremely Big-relief Extremely high mountain

In this paper, we classified the landform of whole China in Hammond's scheme according of slope, local relief, and profile type [13] [14]. We compare the result with and the scheme by Zhou Chenghu *et al.* (2009) [2]. The computer-program is based on the approach developed by Dikau *et al.* [15]. In order to compare with the international landform maps, the parameters of Hammond's scheme are kept unchanged.

2. Hammond Landform Classification

2.1. Concept

Hammond's hierarchic landform classification is based on properties of slope, localrelief, and profile type.

1) The slope is divided into 4 levels based on the percent of area gently sloping. If the inclination is below 8%, we call this gently slope (**Figure 1**). The percent area is calculated in moving widow (9.8 km × 9.8 km).

A	A	A	A
B	A	D	D
B	D	C	D
B	D	D	C

Figure 1. % area local gently sloping (4 × 4). A: 31.25%, B: 18.75%, C: 37.5%, D: 12.5%.

2) Local relief is the difference between maximum and minimum elevation in moving window. Local relief had a non-linear relationship with horizontal length by examining a variety of mountain belts [16]. Tu Hanming *et al.* [4]-[17] calculated the length scale with the sampling data from the whole land China, 5 optimum statistical length was calculated corresponding to different map scale, which is 2, 6, 16, 20, 22 (km^2). In this paper, we choose the 9.8 km × 9.8 km in order to compare with the Hammond's classification.

3) Profile type subdivide tablelands as upland units and plains with hills or mountains as lowland unit [15].

With these three parameters, Hammond classified 96 landform subclasses theoretically (**Table 4**, **Table 5**). Hammond used only 45 subclasses were common in U.S. [18]. He generalized his results by merging areas smaller than 2072 km^2 into adjacent units to avoid cluttering at a 1:5,000,000 map. Dikau *et al.* [15] developed automated approach identified all 96 landforms units without generalization.

2.2. Method

The data were processed in ArcGIS 10.x Workstation with 64 bit windows OS in Hp xw8400. The Python and ARC/INFO AML were the scripting languages for batching the data. The procedures mainly include two steps, the DEM buildup and automated classification:

The DEM buildup: The contours and mark points features were extracted from the terrain layer. For eliminating the boundary effect, 16 sheets merge into one map before generation of DEM, then clipping the DEM with the boundary of one sheet. The whole China consists of 61 maps with a scale of 1:1,000,000. The DEM were buildup with the contours and mark points with ARC/INFO command of "generate <>", and merge into one sheet with 100 m.

Automated classification: The DEM were resampled into 200m.The moving window is 49 × 49 (9.8 km × 9.8 km). The three parameter layers were derived from DEM firstly, and then they were overplayed to generate one 96-subclasses landform map. A AML was developed according to the Dikau's approach. We merged the three parameter layers to yield a landforms map.

Table 4. Hammond's landform classification.

Percent of area gently sloping	Local relief	Profile type
1) more than 80	1. 0 - 30	1. >75% in lowland
2) 50 - 80	2. 30 - 91	2. 50% - 75% in lowland
3) 20 - 50	3. 91 - 152	3. 25% - 50% in lowland
4) less than 20	4.152 - 305	4. <25% in lowland
	5. 305 > 914	
	6. 5 > 914	

Table 5. The landform classifications of China.

Landform		Class		Subclass				
5 types	area%	24 classes	area%	96 subclasses	area%			
Plains (PLA)	20.25	flat or nearly flat plains	10.86	111, 112, 113, 114	3.41	3.15	2.64	1.67
		smooth plains with some local relief	9.37	121, 122, 123, 124	4.78	2.51	1.52	0.56
		irregular plains with moderate relief	0.02	221, 222, 223, 224	0.02	0.01		
tablelands (TAB)	3.56	tablelands with moderate relief	1.34	133, 134, 233, 234	1.04	0.27	0.02	
		tablelands with considerable relief	1.50	143, 144, 243, 244	0.77	0.22	0.38	0.13
		tablelands with high relief	0.70	153, 154, 253, 254	0.10	0.05	0.37	0.19
		tablelands with very high relief	0.03	163, 164, 263, 264	0.01		0.01	0.01
plains with hills or mountains (PHM)	32.84	plains with hills	7.25	131, 132, 231, 232	4.73	2.17	0.20	0.15
		plains with high hills	12.64	141, 142, 241, 242	7.10	1.89	2.84	0.80
		plains with low mountains	12.45	151, 152, 251, 252	3.19	0.29	8.04	0.93
		plains with high mountains	0.50	161, 162, 261, 262	0.04	0.00	0.46	0.01
Open hills and mountains (OPM)	18.72	open high hills	1.14	341, 342, 343, 344	0.44	0.41	0.24	0.05
		open low mountains	14.85	351, 352, 353, 354	10.37	2.53	1.34	0.61
		open high mountains	2.73	361, 362, 363, 364	2.25	0.19	0.12	0.16
Hills and mountains (HMO)	24.63	low mountains	7.10	451, 452, 453, 454	3.73	2.08	0.99	0.30
		high mountains	17.52	461, 462, 463, 464	7.29	5.19	3.27	1.78

3. Study Area and Data

This automated process was tested on almost whole China, which consists of mainland, Hainan and Taiwan islands. The data includes 816 sheets of topological map with a scale of 1:250,000, which were digitalized by National Geometrics Center of China in 1998. The content consists of 14 layers: hydrological system, Residential, Railway, Road, boundary, Terrain, and some auxiliary ones. The terrain data include contours and mark point, and the contours interval is 50 or 100 m.

4. Result and Analysis

The maps were constructed respectively with 5 types, 16 classes and 90 subclasses (**Table 2**, **Figure 2**, **Figure 3**). The whole area of China is 9482552.72 km^2 besides some small island were not calculated. The 5 Landform types of landforms were Plains (PLA), 20.25% of whole areas; Tablelands (TAB) of 3.56%; Plains with Hills or Mountains (PHM) of 32.84%; Open Hills and Mountains (OHM) of 18.72%; Hills and Mountains (HM) of 24.63%. The PLA were located in Songnen Plain, Sanjiang Plain, Huabei Plain, Huaihai Plain, Jianghai Plain, Aletai Basin, Talimu Basin, Loess Plateau, etc. The TAB were scattered in whole China, which each patch is small. The PHMs were located in Xiao-Xing'anling Mountains, Shandong peninsula, Inner-Mongolian, Qinghai-Tibet Plateau, Sichuan Basin, Guangxi and Hunan province. The OHM were located in Da-Xing'anling Mountains, Shaanxi province, Guizhou province and scatted in North of Tibet Plateau. The HMO is located in East of Tibet Plateau, around the Sichuan Basin, Yunnan, Fujian Taiwan province. The result indicates it produced a classification that has good resemblance to the landforms in China.

Some classes were not generated, such as irregular plains and low hill. The PLA is primary flat or smooth without some relief. The altitude in hill or mountain region is high, so there are almost not low hill.

According to Hammond's scheme, the area of TAB is only 3.56%. The area of tableland in some manual scheme is much more than that [19]. There are several large tablelands, such as Qinghai-Tibet Plateau, Mongolia Plateau, Loess Plateau,

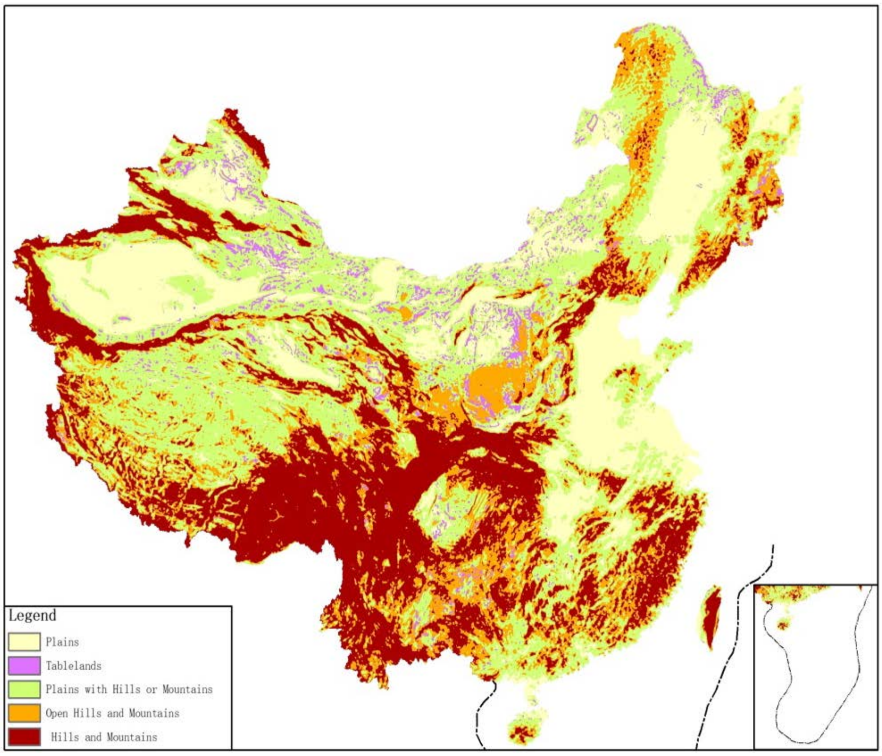

Figure 2. 5-type landforms map of China land.

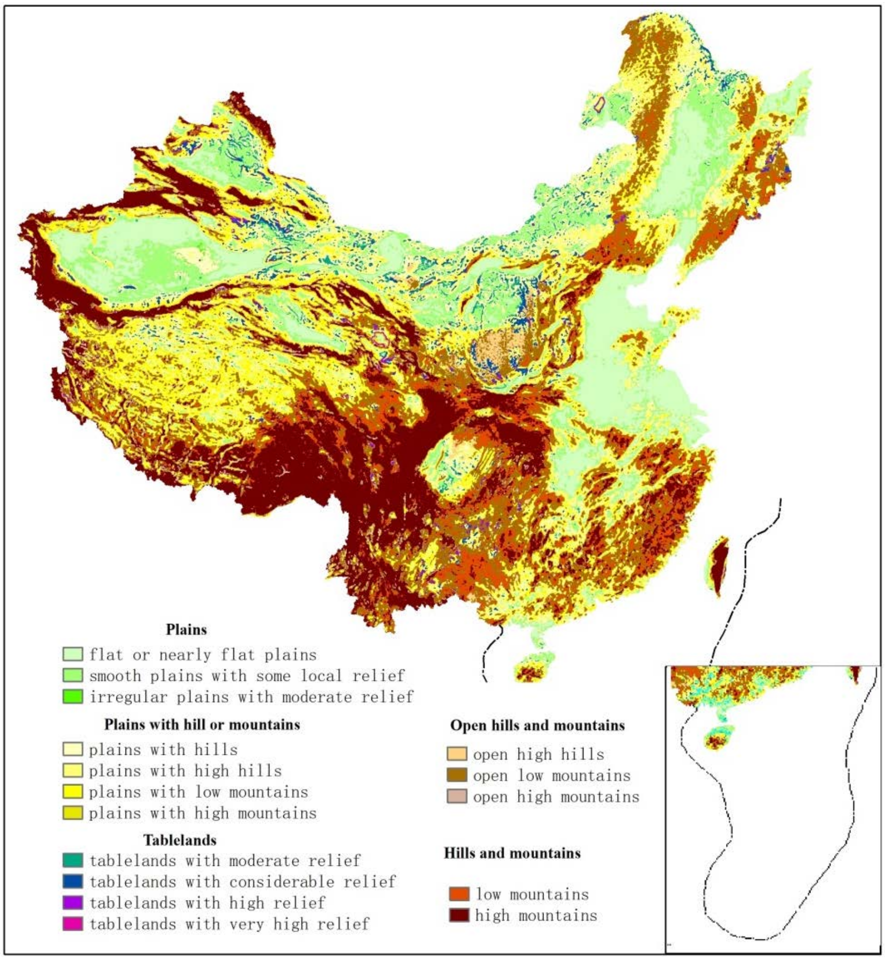

Figure 3. 24-classes landforms map of China land.

Yun-gui Plateau. In **Figure 2**, Qinghai-Tibet Plateau is mainly classified into PHM; Mongolia Tableland and Loess Tableland is classified into PLA or PHM and the Yun-gui Tableland is classified into HMO. There are many hills or mountains in tableland in China. The basin is basically classified into PLA, but the Sichuan Basin is mainly classified into PHM or PLA.

5. Conclusion

Automated landform classification produced a classification that has good resemblance to those of manual approach. However, some classes are different from manual method. There are much more complex landform in China, and the geomorphologic evolution is much more different, so it needs to improve the method to classified more reasonable. Furthermore, the effects of scale and generalization also should be paid special attention.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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