Method and Practice of Quality Inspection and Evaluation of the Land Cover Classification Achievement in the Geographic Conditions Monitoring Project

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Key words: geographic conditions monitoring, land cover, quality inspection and evaluation, quality element, classification accuracy

SUMMARY

This paper discusses the method and practice of the quality inspection and evaluation of the land cover classification achievement (LCC) in the ongoing national geographic conditions monitoring project (GCM) of China. The land cover classification achievement is one of the important achievements of the monitoring project, and quality control plays a crucial role in ensuring product quality. To make a thorough investigation into the situation and distribution of the natural and human geographic elements, the land cover classification achievement mainly uses meter level high-resolution remote sensing images (GaoFen-2, ZhiYuan-3, WorldView-2, etc.) as data source, and has been designed with a hierarchical and detailed three-level land cover classification system, including eight 1st level classes, more than fifty 2nd level classes and over one hundred 3rd level classes. Also, distinguished from the traditional digital surveying and mapping products, such as digital line graph, the land cover classification achievement is mainly produced for the use of geospatial statistic and analysis, rather than for the traditional use of cartographic purpose. To ensure the product quality, the primary problem faced by the quality acceptance of the LCC achievement is that how do the scientific and objective quality inspection and evaluation be conducted. Therefore, a new type of quality inspection and evaluation method has been developed, which is designed based on the characteristics of the land cover classification achievement. The core of the new method is to use the misclassified area rate as quality measure for the core quality element of classification accuracy of the land cover classification achievement. In practical use, this new method has been successfully used and has been proved to be intuitive, easy to operate and adaptable to different regions nationwide, which helps to meet the product quality control target of “comprehensiveness, authenticity and accuracy” of the monitoring project, and also can provide technical references for quality control of the future unified national natural resources monitoring.

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1. Introduction

In 2013 China launched the “Geographic Conditions Monitoring (GCM)” national project, which is a dynamic monitoring of the territory of the country. Geographic condition is the fundamental component of basic national conditions, which reflects the spatial distribution, features and inter-relationship between nature and human geographic elements. Hence, implementing the GCM is a key method to push forward the achievement of scientific management and sustainable development of China. Since 2016, the GCM project has been carried out regularly every year in China (Chen, 2012; Zhang et al., 2016; Li et al., 2017).

As the synthesis of all sorts of materials on Earth and their natural attributes and characteristics, land cover is fundamental for environmental change studies, land resource management, sustainable development, and many other societal benefits (Chen et al., 2014). One of the major tasks of the GCM project is to have a general understanding of land covers as well as monitoring their dynamic changes caused by natural and anthropogenic socio-economic activities through comprehensive utilization of remote sensing and GIS related technologies (Li, 2013; Zhang et al., 2015). Hence, the land cover classification (LCC) achievement is one of the most important achievements of the GCM project.

Data quality is an important guarantee for the effective application of the LCC achievement (Li, 2013). To ensure high-quality data, the GCM project has clearly defined the quality control target of “comprehensiveness, authenticity and accuracy, and the pass rate of results should reach 100%, while the high quality rate should be at least 80%” at the beginning, and established a set of strict quality control system of "two inspections, one acceptance, in-process sampling, and reconfirmation"(Zhang et al., 2017). In the quality control system, quality inspection and evaluation of the achievement plays a crucial role throughout the entire production process. Hence, the prime problem to carry out effective quality control is how to design reasonable quality evaluation criteria for the achievement, including i) quality elements; ii) quality subelements; iii) quality inspection items; iv) corresponding quality evaluation method, which should meet the requirements of technology design and be suitable of the characteristics of the producing way.

2. Quality characteristics of the LCC achievement

Compared with the traditional land cover achievement, such as the GlobeLand30 product (Chen et al., 2014), and the traditional digital surveying and mapping product, such as the

Digital Line Graph (DLG), the LCC achievement in the GCM project is unique with the special design and application of classification system, remote sensing image data source, producing way and vector data model (Zhang et al., 2015; Li et al., 2017; Cheng et al., 2018). **Firstly**, it is designed with a hierarchical and detailed three-level classification system, with eight 1st level classes (including cultivated land and garden, forest and grassland, habitation, transportation network, facilities, artificial heap land, desert and open ground, water area), more than fifty 2nd level classes and over one hundred 3rd level classes. **Secondly**, the meter level high resolution remote sensing images are fully used as data source, such as ZhiYuan-3 (ZY-3, China's first civilian high resolution stereo mapping satellite, 2.1m resolution), GaoFen-2 (GF-2, China's first sub-meter resolution civil satellite, 0.8m resolution), and WorldView-2 (WV-2). **Thirdly**, an integrated producing way is applied, including comprehensive indoor interpretation, field survey and on-site check, and data compilation. **Furthermore**, the achievement is collected and stored in the vector data model of polygon, which is of continuous spatial distribution without gap and overlap. Figure 1 shows a typical sample of the achievement and its corresponding remote sensing image data source.

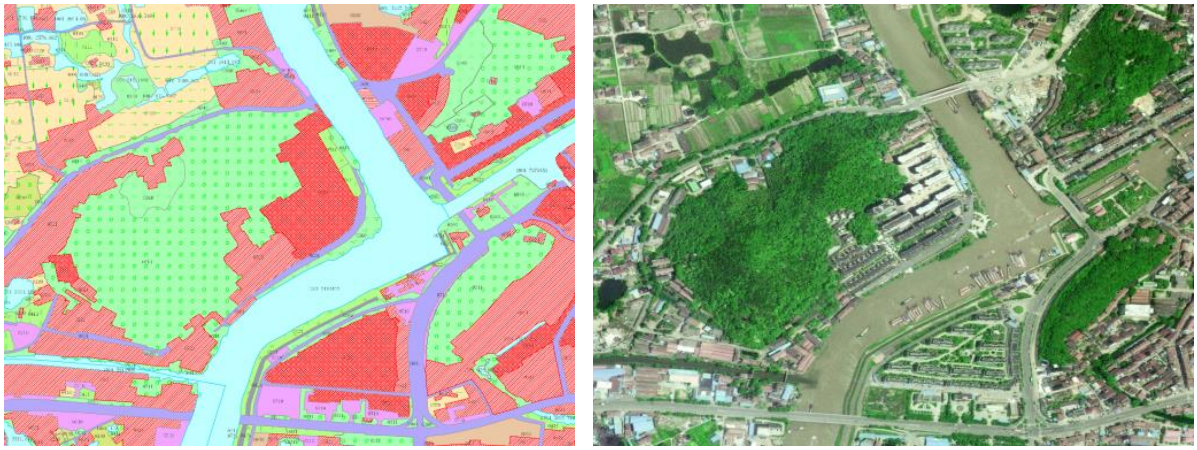

Figure 1. Sample of the LCC achievement and corresponding source image (image curtesy of National Geomatics Center of China (NGCC))

The design and application of the classification system, together with the remote sensing image data source and the integrative producing way provide basic guarantee for the quality of the LCC achievement. However, due to the complexity and diversity of land cover, also the varied geographic phenomena and other objective factors, there are still some errors in the achievement, such as positional error, omission/commission errors, classification error and so on.

3. Quality inspection and evaluation method

In terms of producing way and vector data model, the LCC achievement is similar to the traditional digital surveying and mapping product, such as DLG. However, distinguished from DLG, the LCC achievement is mainly produced for the use of geospatial statistic and analysis, rather than for use of cartographic purpose (Li, 2013; Li, 2017). Therefore, the quality

inspection and evaluation method of the LCC achievements needs to be determined on the basis of fully considering the quality characteristics and referring to the evaluation criterion of DLG product.

3.1 Quality element

3.1.1 Acquisition precision

There are two core quality requirements for the positional accuracy of the LCC achievement, one is the plane accuracy of the remote sensing image data source, and the other is the matching precision between the outlines of polygon feature of land cover and the image data source. The plane accuracy of the image data source is inspected and evaluated independently in the GCM project. Hence, the inspection of the positional accuracy only includes the matching precision between the LCC achievement and the image data source, which only represents the data acquisition precision during production. Therefore, using the term of acquisition precision instead of positional accuracy as the name of quality element can highlight the actual quality requirement.

3.1.2 Classification accuracy

According to the national standard for quality inspection and evaluation for digital surveying and mapping achievements, the quality element of thematic accuracy of DLG includes two quality subelements, i.e. classification correctness, attribute correctness. As for the LCC achievement, classification correctness is undoubtedly the core quality requirement, while the attribute correctness includes checking the correctness of some accessorial attribute value such as change type mark, production mark information, etc. Therefore, the classification correctness should be evaluated separately from the attribute correctness, so that the quality evaluation method of classification correctness can be designed in a targeted manner.

Furthermore, for the LCC achievement, due to the requirement of continuous spatial distribution without overlap and gap, the essence of the completeness error is the overall or local classification correctness error of the polygon feature of land cover. Therefore, it is necessary to combine the completeness and classification correctness into one quality element, namely classification accuracy, and adopt a unified quality evaluation method, so as to highlight the core quality requirement.

3.2 Quality evaluation of classification accuracy

3.2.1 Quality measure

According to the national standard for quality inspection and evaluation for digital surveying and mapping achievements, the error number rate is mainly used as data quality measure for quantitative quality element, such as attribute accuracy, which is usually calculated from:

$$r = \frac{n}{N} * 100\% \quad (1)$$

where n represents total number of errors and N represents total number of features of unit achievement. However, as for the classification accuracy of the LCC achievement, this method does not consider the area size of the erroneous land cover polygon, and cannot reflect the differences between large and small erroneous land cover polygon, local error or overall error of the polygons, therefore is not suitable and cannot be applied directly for the quality evaluation of classification accuracy.

On the other hand, the traditional remote sensing image classification achievement, generally in the form of grid datasets, usually uses the overall accuracy, producer accuracy, user accuracy, kappa coefficient and other quality measures based on the statistics of classification error matrix to evaluate classification accuracy. Among them, the overall accuracy is the percentage of correctly classified pixels in all pixels, which represents the overall situation of the classification accuracy, and is a widely used, quantitative and scientific quality indicator (Chen et al., 2015; Shi et al., 2013).

Therefore, referring to the calculation of the overall accuracy, the misclassified area rate, which can be calculated by the misclassified area divided by the entire area of unit achievement, can be used as the quality measure to evaluate the quality element of classification accuracy. Specifically, the total misclassified area of the land cover polygons of the unit achievement is calculated at first, and then the percentage of the misclassified area to the entire area of the unit achievement is calculated, so as to realize quantitative quality evaluation of the classification accuracy.

3.2.2 Qualified target

A reasonable qualified target of classification accuracy should consider both of the interests of the data producer and end user. If the qualified target is set too high, the producer will need to pay a high price to achieve the target. If the qualified target is set too low, data quality will not be able to meet the requirements of the end user. Because of the complexity of the land cover itself, and the traditional remote sensing classification phenomenon of "different objects which have the same spectrum and the same objects have different spectrum", it is usually difficult to ensure high classification accuracy for traditional land cover classification results of large-scale area simply based on remote sensing technology. Taking the GlobeLand30 product as an example, with the overall technology route of "multi-source image optimization processing, reference service integration, fine extraction of land cover, product quality diversification inspection" is adopted, the overall classification accuracy can only reach better than 80% (Chen et al., 2014; Chen et al., 2017). In the experimental phase of the GCM project, it has been studied that, without field investigation, the overall accuracy of the classification result can reach better than 85% with the use of object-oriented classification method and worldview-2 high-resolution satellite image as data source (Zhai et al., 2014).

For the GCM project, the overall classification accuracy of the LCC achievement should be as high as possible to ensure scientific and authentic statistical analysis at national scale. Hence, to effectively improve and ensure the classification accuracy of the LCC achievement, the project comprehensively applies meter level high-resolution remote sensing image, and carries out a thorough field investigation and on-site check, and takes strictly quality control measures throughout the entire production process. By thoroughly considering the technical feasibility and the application requirement, and with special inspection and evaluation tests carried out based on typical LCC achievements nationwide, the final qualified target of classification accuracy of the LCC achievement are determined as follows: the misclassified area rate should not be more than 0.3% for the 1st level class, and 1.2% for the total of 2nd and 3rd level class. That is to say, the classification accuracy of the 1st level class of qualified achievement should not be less than 99.7%, and that of 2nd and 3rd level class totally should not be less than 98.8% (Zhang et al., 2017).

3.3 Quality evaluation criteria

The quality elements are shown in Table 1, which are designed based on both the quality characteristics mentioned above and the quality evaluation criteria of traditional digital surveying and mapping achievement.

Table 1. Quality elements of the LCC achievement

Quality Element	Quality Subelement	Inspection Item
Spatial reference system	geodetic datum	coordinate system
	elevation datum	elevation datum
	map projection	projection parameters
Temporal quality		source material
		achievement
Logical consistency	conceptual consistency	attribute item
		data set
	format consistency	data format
		data file
		file naming
	topological consistency	gap
		overlap
		continuity
Acquisition precision		geometric displacement
		edge matching
Classification accuracy		classification code value
Attribute accuracy		attribute value
Schema quality		geometry problem

Furthermore, the evaluation indicators for the core quality elements of acquisition precision and classification accuracy are determined and shown in Table 2.

Table 2. Evaluation indicators of core quality element of the LCC achievement

Quality Element	Inspection Item	Inspection Result	Qualified Target
Acquisition precision	geometric displacement	r=n/N×100%	r_0=0.3%
	edge matching		
Classification accuracy	classification code value	r=n/N×100%	1st level class: r_0=0.3% total of 2nd and 3rd level class: r_0=1.2%

Notes: r represents percentage of error ratio; r_0 represents the acceptable threshold for r; n represents the misclassified area for classification accuracy, or the total number of errors for acquisition precision; N represents the entire area of unit achievement for classification accuracy, or the total number of the land cover polygons of unit achievement for acquisition precision.

4. Application practice

In practice, the inspection and evaluation method of the LCC achievement described in this paper has been all-round applied, and effectively guided the implement of inspection and acceptance of the GCM project. Specifically, the technical method of calculating the misclassified area rate as quality measure for the core quality element of classification accuracy has been proved to be intuitive, easy-to-operate and highly adaptable. Taking one sheet of 1:10,000 LCC unit achievement (about 26 km^2 per sheet) as an example, the qualified target of the 1st level class (r0=0.3%) can be intuitively understood as that the total misclassified area should not exceed 80,000 m^2. As for the LCC achievements of different regions nationwide, this qualified target is strictly consistent and easy to operate, and has become a key quality indicator to guide production and quality inspection, and played an important role in ensuring the consistency of the data quality of the LCC achievements nationwide.

For example, in 2015, in the sampling inspection of the LCC achievements located in western region of China in the GCM project, about 830 sheets of unit achievement at 1:50,000 scale (about 400 km^2 per sheet) were inspected and evaluated as samples. The inspection result showed that the misclassified area and area rate of the 1st level class are about 43,508 m^2 and 0.0109% per sheet respectively，and about 67,767 m^2 and 0.01162% for the total of 2nd and 3rd level class. The evaluation results clarified that the data quality fully achieve the product quality control target of the GCM project, with 100% qualified of sample quality and the proportion of high-quality sample reaching up to 98% (Zhang et al., 2017).

5. Conclusion

Based on the systematic analysis of the technical requirements of the LCC achievement in the GCM project, this paper puts forward a suitable quality inspection and evaluation method, which has achieved good performances in the practice of inspection and acceptance of the LCC achievement in the GCM project. The quality elements, quality subelements and inspection items of the LCC achievement can meet general quality requirements, furthermore, can highlight key quality requirements. Besides, the technical method of taking the misclassified area rate as quality measure for the core quality element of classification accuracy makes the quality evaluation indicators to be intuitive, easy-to-operate and highly adaptable, so as to realize a quantitative, scientific and operable quality evaluation.

Hereafter, the GCM project will be integrated into the unified surveying and monitoring of natural resources in China. As a fundamental achievement, the LCC achievement will definitely change in product form, technical route and application requirements. Hence, it is necessary to further adjust and optimize the contents, methods and indicators of quality inspection and evaluation of the LCC achievement, so as to provide technical supports for quality control of the unified surveying and monitoring of natural resources of China.

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BIOGRAPHICAL NOTES

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Haipeng is currently a senior engineer of the national quality inspection and testing center for surveying and mapping products of China (QICS). He has long been engaged in the quality control of state level major surveying and mapping projects. His research interest is mainly focused on the quality control and quality inspection of fundamental surveying and mapping products.

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