Quality Inspection and Evaluation of Land Cover Classification Achievement of Geographic Conditions Monitoring

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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 of the ongoing national geographic conditions monitoring project 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 high-resolution remote sensing images (GF-2, ZY-3, WV-2, et al.) as data source, and has been designed with a hierarchical and detailed three-level land cover classification system, including 8 1st level classes, 52 2nd level classes and 104 3rd level classes. Also, distinguished from the fundamental surveying and mapping products, such as digital linear 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 product quality can meet the requirements of the end users, the primary problem faced by the quality inspection and acceptance of the land cover classification achievement is, how to conduct scientific and objective quality inspection and evaluation. Therefore, a new type of quality inspection and evaluation method has been developed, which is 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

Geographic condition is the fundamental component of basic national conditions, which reflect the spatial distribution, features and inter-relationship between nature and human geographic elements. Hence, implementing the geographic conditions monitoring (GCM) is a key method to push forward the achievement of scientific management and sustainable development of China (Chen, 2012). 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 GCM 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 GCM.

Data quality is an important guarantee for the effective application of the LCC achievement of GCM (Li, 2013). In the GCM project, by comprehensively considering the application requirements and current feasibility of remote sensing and GIS related technologies, the LCC achievement uses high geospatial resolution remote sensing images (GF-2, ZY-3, WV-2, et al.) as data source, and has been designed with a hierarchical and detailed three-level classification system (8 1st level classes, 52 2nd level classes and 104 3rd level classes), as well as using an integrated produce way including comprehensive indoor interpretation, field survey and on-site check, and data compilation (Zhang et al., 2015; Cheng et al., 2018). The design and application of the classification system, together with the data source and produce way provide basic guarantee for 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 inevitable errors, such as positional error, omission/commission, attribute error, and so on in the LCC achievement, which do not meet the design requirements of GCM.

To ensure high data quality, 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 LCC 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 LCC achievement, including quality elements, quality subelements and quality inspection items as well as corresponding quality evaluation method, which should meet the requirements of technology design and be suitable of the characteristics of the produce way.

2. QUALITY INSPECTION AND EVALUATION METHOD

As a new type of digital surveying and mapping product, the quality inspection and evaluation method for the LCC achievement can refer to the traditional fundamental surveying and mapping products, such as digital linear graph. Furthermore, the inspection and evaluation requirements for the quality elements of acquisition precision and classification accuracy of the LCC achievement should be highlighted.

2.1 Quality element

2.1.1 Acquisition precision

There are two core quality requirements for the position accuracy of the LCC achievement of GCM, one is the plane precision 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 precision of the image data source is inspected and evaluated independently in the GCM project. Hence, the inspection of the position 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 position accuracy as the name of quality element can highlight the actual quality requirement.

2.1.2 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 the digital linear graph 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 and no topological errors including overlap and gap allowed, 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.

2.2 Quality evaluation of classification accuracy

2.2.1 Quality measure

According to the national standard for quality inspection and evaluation for digital surveying and mapping achievements, the error number rate, which is usually calculated as total number of errors divided by total number of features of unit achievement, is mainly used as the data quality measure to evaluate quantitative quality element of digital linear graph. 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, 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 of the LCC achievement. Specifically, firstly calculate the total misclassified area of the land cover polygons of the unit achievement, and then calculate the percentage of the misclassified area to the entire area of the unit achievement, so as to realize quantitative quality evaluation of the classification accuracy.

2.2.2 Qualified target

Generally speaking, 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 (GF-2, ZY-3, WV-2, et al.), 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 1^{st} level class, and 1.2% for the total of 2^{nd} and 3^{rd} level class. That is to say, the classification accuracy of the 1^{st} level class of qualified achievement should not be less than 99.7%, and that of 2^{nd} and 3^{rd} level class totally should not be less than 98.8% (Office of the State Council for the 1^{st} general survey of national geographic conditions, 2014; Zhang et al., 2017).

2.3 Quality evaluation indicators

To sum up, referring to the quality inspection and evaluation of the traditional digital surveying and mapping achievement, the quality inspection and evaluation indicators for the LCC achievement of GCM are finally determined and shown in Table 1. The quality elements, quality subelements and inspection items are shown in the first three columns of Table 1, and the inspection result, qualified target, qualification condition involved in the evaluation method are shown in the last three columns of Table 1.

Table 1 Quality evaluation indicators of the LCC achievement

Quality Element	Quality Subelement	Inspection Item	Inspection Result	Qualified Target	Qualification Condition
Spatial reference system	geodetic datum	coordinate system	conformity / non conformity	according to technical design	conformity
	elevation datum	elevation datum	ditto	ditto	ditto
	map projection	projection parameters	ditto	ditto	ditto
Temporal quality		source material	ditto	ditto	ditto
		achievement	ditto	ditto	ditto
Logical	conceptual	attribute item	ditto	ditto	ditto

Quality Element	Quality Subelement	Inspection Item	Inspection Result	Qualified Target	Qualification Condition
consistency	consistency	data set	ditto	ditto	ditto
	format consistency	data format	ditto	ditto	ditto
		data file	ditto	ditto	ditto
		file naming	ditto	ditto	ditto
	topological consistency	gap	$r=n/N\times100\%$	$r_0=0\%$	$r\leq r0$
		overlap			
		continuity	ditto	$r_0=0.3\%$	ditto
Acquisition precision		geometric displacement	ditto	$r_0=0.3\%$	ditto
		edge matching			
Classification accuracy		classification code value	$r=n/N\times100\%$	1st level class: $r_0=0.3\%$ 2nd and 3rd level class totally: $r_0=1.2\%$	ditto
Attribute accuracy		attribute value	ditto	$r_0=0.4\%$	ditto
Schema quality		geometry problem	ditto	$r_0=0.4\%$	ditto

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 other quality elements; N represents the entire area of unit achievement for classification accuracy, or the total number of the land cover polygons of unit achievement for other quality elements.

3. 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. Take a map sheet of LCC unit achievement at 1:10,000 scale as an example, area of which is about 26 square kilometers, so 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 square meters. 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 a very important role in ensuring the consistency of the data quality of the final LCC achievements nationwide.

For example, in 2015, in the sampling inspection of the LCC achievements located in western region of China of the GCM project, about 830 sheets of unit achievement at 1:50,000 scale (entire area per sheet is about 400 square kilometers) were inspected and evaluated as samples. The inspection result showed that the misclassified area of 1st level class is about

43,508 square meters per sheet, and the misclassified area rate is about 0.0109% per sheet. The misclassified area of 2nd and 3rd level class totally is about 67,767 square meters per sheet, and the misclassified area rate is about 0.01162% per sheet. The evaluation result showed that the data quality fully meet the product quality control target of the GCM project, with sample quality was 100% qualified, and the proportion of sample with high quality reached 98% (Zhang et al., 2017).

4. CONCLUSION

Based on the systematic analysis of the technical requirements of the LCC achievements of 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 achievements 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 method to be intuitive, easy-to-operate and highly adaptable, and realize a quantitative, scientific and operable quality evaluation.

Hereafter, the GCM project will be integrated into the unified investigation and monitoring of natural resources in China. As one of the most important fundamental achievements, 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 reference for quantity control of the unified investigation and monitoring of natural resources.

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BIOGRAPHICAL NOTES

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Haipeng works as 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 inspection and evaluation of surveying and mapping products. His research interest is mainly focused on the quality control and quality inspection of surveying and mapping products.

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