RESEARCH ON QUALITY EVALUATION TECHNOLOGY OF BASIC SURVEY RESULTS OF NATURAL RESOURCES

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ABSTRACT:

To execute the overall protection and comprehensive treatment of natural resources, Chinese government has earnestly fulfilled its duties of centralized management and announced the overall plan for the construction of a survey and monitoring system for natural resources. Survey and monitoring of natural resources is the basic work of management of natural resources. Survey and monitoring of natural resources is a survey project of geospatial information for natural resources based on 3S spatial information technology, massive data resources and technical means. Survey of natural resources is classified into basic survey and special survey. Therein, the basic survey, based on the surface coverage, is principally to figure out the scope, area and ownership of all sorts of natural resources projected on the earth's surface. Data quality evaluation is significant means to ensure the authenticity and accuracy of the quality and results of the survey project for natural resources. This thesis studies the inspection and evaluation technology of quality and results, designs the quality model of basic survey for natural resources, including quality characteristics, quality requirements, and quality evaluation process. Apart from that, it selects the results of land survey in some regions of the country and conducts quality evaluation experiments of basic survey data, which verifies the applicability of the quality evaluation methods.

1. INTRODUCTION

1.1 Research Background

Natural resources: the sum total of natural environmental factors that exist naturally, boast use value and can enhance the current and future welfare of mankind, involving seven major categories of factors such as land, minerals, forests, grasslands, water, wetlands and sea islands and covering land and sea, above and below ground. In the passing years, China has successively launched land survey, forest resources inventory, water resources census, grassland resources survey, coastal zone survey and geographical conditions census, and has acquired a large amount of basic data on the distribution and utilization of natural resources.

To execute the overall protection, system repair and comprehensive treatment of natural resources throughout the country and realize the modernization of the natural resources governance system and governance capacity, China's Ministry of Natural Resources has earnestly fulfilled its duties of centralized management and unified survey and monitoring of natural resources, worked out a unified survey, evaluation and monitoring system for natural resources, announced the overall plan for the construction of a survey and monitoring system for natural resources, emphasizing that quality and data accuracy are the lifeline of survey and monitoring of natural resources.

Survey and monitoring of natural resources is the basic work of management of natural resources, aiming at making a thorough investigation of the spatial distribution and quality status of natural resources in an all-round way, forming the basic data of comprehensive and perfect management of natural resources, offering basic data and technical support for management of natural resources, planning and use control of national land space, development and utilization of natural resources, ecological protection and restoration, etc.

Survey and monitoring of natural resources is a survey project of geospatial information for natural resources based on 3S spatial information technology, surveying and mapping precise spatial positioning, massive data resources and technical means. (De-ren Li., 2006)

1.2 Research Content

Survey of natural resources is classified into basic survey and special survey, which are designed to describe the overall situation of natural resources in combination.

Therein, the basic survey, based on the surface coverage, is principally to figure out the scope, area and ownership of all sorts of natural resources projected on the earth's surface, as well as the basic conditions of development, utilization and protection, and to master the most basic background conditions and common characteristics of natural resources throughout the country. The special survey is a professional survey organized and launched based on the needs of professional management and macro decision-making of natural resources, and its main task is to figure out the quantity, quality, structure, ecological function and related human geography and other multi-dimensional information of all sorts of natural resources. The monitoring of natural resources in light of the background data of natural resources formed by means of the basic and special surveys can help to grasp the changes of natural resources and the changes incurred by human activities.

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Survey and monitoring results of natural resources are large amounts of big data of geospatial information, and data quality control and quality evaluation are significant means to ensure the authenticity and accuracy of the quality and results of the survey project for natural resources. (De-ren Li., 2006; Zhang *et al*., 2017)

In combination with the quality management system of the survey project for natural resources, this thesis studies the inspection and evaluation technology of quality and results, designs the quality model of basic survey for natural resources, including quality characteristics, quality requirements, sampling inspection methods and quality evaluation process. Apart from that, it selects the results of land survey in some regions of the country and conducts quality evaluation experiments with regards to integrity, standardization, consistency and accuracy of basic survey data, which verifies the scientificity and applicability of the quality evaluation methods.

2. ANALYSIS OF EVALUATION OBJECTS

2.1 Content of Basic Survey Results

With reference to the published overall plan for the construction of the survey and monitoring system for natural resources, the results of basic survey are classified into the following 4 categories:

- **Data and databases:** including all sorts of remote-sensing image data, basic survey, analysis and evaluation data, as well as databases and shared service systems.
- **Statistical data sets:** including various survey series of data sets, thematic statistical data **sets** and various analysis and evaluation data sets formed by classifying, grading, sub-region and sub-element statistics.
- **Reports:** including work reports, statistical reports, analysis and evaluation reports, as well as special reports and bulletins.
- **Maps or drawings:** including atlas, photo albums, thematic maps, wall maps, statistical **maps**, etc.

2.2 Analysis of R Basic Survey Results

The results of basic survey mentioned herein refer to the basic survey data sets and related results data stored and managed in the basic survey databases at all levels. The results of basic surveys are generally as below: inspection lots are made up of county-level administrative divisions. (Ma *et al*., 2018)

Inspection objects involve original survey results (including original format sub-layer vector data and exchange format vector data), statistical summary data results, map results, text report results, metadata results and other results, and the main body of quality evaluation object is the original survey results.

In light of the above analysis of evaluation objects, the scope of results of basic survey includes three major categories: spatial vector data layer, statistical summary table and other data results.

- **Vector data layer:** Vector data layers (e.g. earth polygon layer, administrative boundary layer, temporary land layer, national park layer, metadata layer, etc.) are specifically classified into three categories: mandatory, conditional and optional. The data is expressed in the form of spatial graphic data and its attribute value table, i.e. "graphic elements of point, line and plane & attribute table & attribute value". In each layer, the data is stored in the form of several spatial element records.
- **Statistical summary form:** Statistical summary forms include editing statistics and data summary, specifically land use status and ownership status statistics, special statistics, and municipal, provincial and national level summaries premised on county-level statistics. For table results, its statistical rules are strictly consistent with the survey business logic requirements, including the correct statistical formula and the rules for rounding off of numerical values. The internal horizontal, vertical and inter-table logic rules for the contents of table cells are in complete agreement, and the statistical results between layers, reports and table results are consistent. The filling of table contents and attributes is strictly restricted by the design requirements of survey technology. Table attribute items include three categories (mandatory, conditional and optional). Table results exist in the form of "table & attribute Value", specifically several table records.
- **Other data results:** Other data results include all sorts of charts, text reports, etc.

2.3 Design of Quality Evaluation Process

The quality evaluation workflow includes pre-inspection preparation, one hundred percent inspection of specific inspection items, results sampling inspection, results quality evaluation, and preparation of inspection reports. (Ma *et al*., 2020)

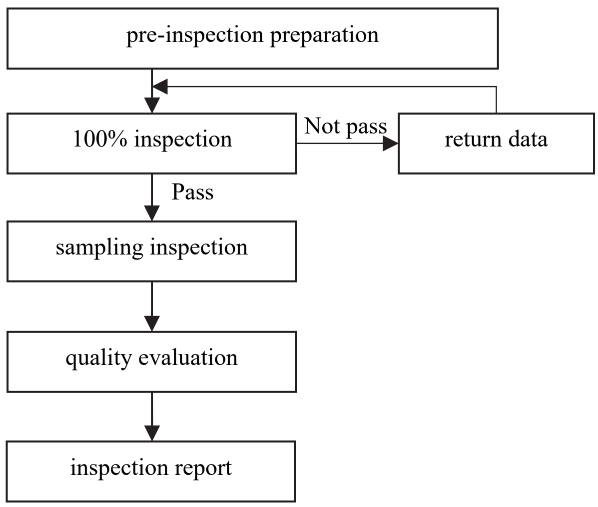

Figure 1. Quality Inspection Process

- Before inspection, it is necessary to collect and analyze the index requirements of results and quality in the project design and related technical standards, determine the sampling scheme, specify the inspection contents and methods, organize personnel training, and prepare instruments and equipment.

- The integrity and standardization of results of the project delivered should be reviewed.
- After the data is verified and approved, it s required to carry out one hundred percent inspection of the inspection contents that can be applied with automatic inspection methods.
- After the one hundred percent inspection is completed, the samples should be inspected one by one for all quality characteristics.
- After the sampling inspection is completed, the quality of the results should be evaluated.
- Inspection reports should be prepared.

3. DESIGN OF EVALUATION METHODS

3.1 Design of Quality Model Headings

To check whether the results of data layers, tables, reports, maps and metadata are in line with the requirements for technical design, a comprehensive scientific evaluation of the quality of the results of basic survey is launched, and quality characteristics, quality sub-characteristics and inspection items are designed herein.

Quality Characteristics	Check Items	Quality Requirements
integrity	*results documents*	All sorts of results documents are valid and readable.
		The number of all sorts of results documents is consistent with the structure of the concurrent catalogue (no redundancy or omission)
	results elements	Records of layer elements and tables are complete without redundancy or missing
	results data	The main contents of the results data are complete
standardization	*results organization*	The file is named and organized correctly.
	file format	The file format is correct
	data structure	The number, name, type, length and decimal places of attribute fields and table fields are defined correctly.
	spatial reference	The spatial reference of vector data layers (coordinate system, elevation datum, projection parameters) is in line with the design requirements
consistency	*topological relation*	There is no overlap, intersection, gap, fragment, combination element, irregular polygon and wrong ring direction on the same surface layer
		There is no overlap, self-intersection, suspension point, pseudo node and broken line on the same line layer
		The edge of the graphic position is within tolerance.
	constraints	The constraints and rules that meet the clear requirements of the basic survey technology design and reflect the business logic such as data structure definition, range of values, data association, etc.
	statistical rules	The statistical rules for the results of tables are strictly consistent with the requirements of the survey business logic (including correct statistical formulas, rules for rounding off of numerical values, etc.)
		The logical rules for filling in the contents of table cells are consistent with those between the internal horizontal, vertical and table.
		The statistical results of the layers and reports are consistent with those of the table results.
accuracy	*position accuracy*	Errors in plane position (check within the scope of lot results, select a certain number of feature points, feature line nodes and feature plane intersection points, which are evenly distributed and counted by county-level administrative division units)
		Register differences in plane position (check sample by sample, count the overrun rate of register differences within the sample range, and the overrun of edging differences of samples is classified as such)
	attribute accuracy	There is no error or leakage in attribute values of layer elements, the attached evidential materials and the time precision are in line with the requirements.
		Layer elements are reasonably integrated (too large in integration and too fine in classification)

Table 1. Quality model.

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3.2 Design of Sample Program

3.2.1 Division of unit results: Unit results are divided with county-level administrative divisions as primary units and graphic elements (records) as secondary units. (Zeng., 2003)

3.2.2 Composition of inspection lots: In the quality acceptance evaluation of results of basic survey, inspection lots are generally made up of multiple or single county-level administrative divisions. Inspection lots should be composed of results of different specifications. (Zhao *et al*., 2010; Ma *et al*., 2020)

3.2.3 Sampling methods: Second-order random sampling is employed for the inspection lot composed of results of basic survey of multiple county-level administrative divisions. When testing isolated lot results composed of results of basic survey of a single county-level administrative division unit, stratified proportional random sampling method is employed to extract samples from lot results, and the stratified method can be premised on spatial vector element layers, spatial element types, spatial element attributes, etc.

For instance, when layering by space vector element layers, the sample size is distributed to each layer in the proportion of the total number of unit results (graphic elements) in each layer to the lot, and the corresponding number of unit results are extracted from each layer in the simple and random principles to form samples together.

3.2.4 Inspection Methods: Inspection is classified into one hundred percent inspection and sampling inspection. One hundred percent inspection should be launched for the inspection items that can pass the software control for production and quality inspection, which are convenient for the application of software automatic inspection in quality inspection, and the inspection items that affect the overall quality of lot results, such as integrity, standardization, consistency, accuracy (error in plane position), etc. Subsequent inspection can be conducted only after the one hundred percent inspection is qualified.

Apart from that to the accuracy-the errors in plane position, the quality characteristics of accuracy are checked by sampling inspection, which includes the position accuracy (register differences in plane position) and the attribute accuracy.

3.2.5 Determination of sampling scheme: Giving overall consideration to factors such as production level, production cost, quality requirements, inspection level, inspection cost, and expected quality level, the quality level of the results is determined through negotiation between the producer and the competent department of natural resources, specifying the risk quality of the producer and the risk quality of the competent department of natural resources and controlling the risk of the producer and the risk of the competent department of natural resources to a certain level. Design the sampling scheme of isolated lot inspection retrieved based on the limit quality (LQ), reasonably determine the sampling scheme (n, Ac), and inspect the attribute accuracy.

3.3 Comprehensive Quality Evaluation

3.3.1 Scoring methods for quality characteristics:
a) Integrity, standardization and consistency: The quality evaluation of the integrity, standardization and consistency of unit results involves 10 quality inspection items. With reference to the one hundred percent inspection of results of various units within the inspection scope, determine whether the inspection results are in line with the design requirements for production technology. For each inspection item, the inspection result is "conforming" or "not conforming", the score of inspection item s is 100 or 0, and the minimum value of the score of each inspection item is the score corresponding to the quality characteristic. When the score of quality characteristic is 0, the evaluation result is unqualified and the lot result is unqualified.

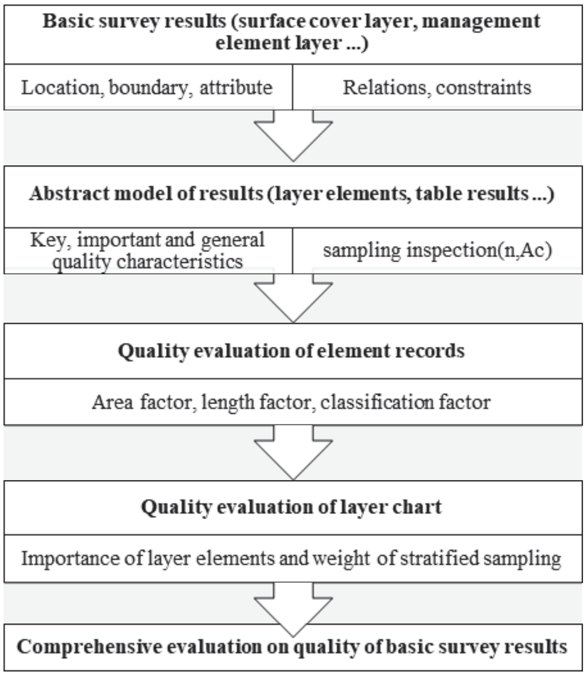

Figure 2. Quality Evaluation and Assessment of Basic Survey Results

b) Position accuracy: The quality evaluation of accuracy of unit results involves two quality inspection items, i.e. accuracy of results position and accuracy of attribute. Of them, the quality evaluation of position accuracy includes accuracy of overall position and accuracy of unit results position.

When evaluating the accuracy of the results position, randomly select feature points, feature line nodes and feature plane intersection points for the point, line and plane results within the inspection range. Each category of feature points should be evenly distributed with a number of not less than 59. Calculate the position errors Δ of the result boundary with respect to the true value or DOM and other reference data. When the gross error rate is not more than 5%, calculate the error in position m, and figure out the score of the accuracy of overall position of the result S based on the following formula (1), where m_0 is the allowable error of the plane position.

$$S=\begin{cases}60+\dfrac{40}{0.7\times m_0}(m_0 - m) & 0.3m_0 < m \le m_0 \\ 100 & m \le 0.3m_0\end{cases} \quad (1)$$

When the gross error rate is greater than 5% or S<60, the evaluation result of accuracy of overall position is unqualified and the lot result is unqualified.
When evaluating the position accuracy of unit results, measure the maximum position error Δ of polygon boundary of each unit

result relative to reference data such as true value or DOM in the sample. With reference to the following formula (2), calculate the score of accuracy of unit results position S, where Δ_0 is the plane position tolerance.

$$S = \begin{cases} 60 + \dfrac{40}{0.7 \times \Delta_0}(\Delta_0 - \Delta) & 0.3\Delta_0 < \Delta \le \Delta_0 \\ 100 & \Delta \le 0.3\Delta_0 \end{cases} \quad (2)$$

When S<60, the evaluation result of accuracy of unit result position is unqualified, and the quality of lot result is unqualified. When $S \geqslant 60$, take the minimum value of the accuracy of evaluation score of overall position and the evaluation score of accuracy of unit results position as the final evaluation result of accuracy of unit results position.

c) Attribute precision: In line with the requirements for correctness evaluation of attribute values of unit results, reasonably classify all sorts of results in basic survey. For each category of results elements, define their element attribute fields as key attribute items, important attribute items and general attribute items based on their importance. Define N_1 and n_1 as the total number of key attributes and the number of errors respectively, N_2 and n_2 as the total number of important attributes and the number of errors respectively, and N_3 and n_3 as the total number of general attributes and the number of errors respectively. In the evaluation, calculate the attribute precision score S by formula (3):

$$S = 100 - 42 \times n_1 - 42 \times \frac{n_2}{N_2} - 26 \times \frac{n_3}{N_3} \quad (3)$$

When S<60, the evaluation result of attribute precision of unit results is unqualified, and the quality results is unqualified.

3.3.2 Quality evaluation of unit results: Based on the technical experiments, we designed and determined the weight of quality characteristics according to the importance of quality elements and quality objectives.

Quality characteristics	**Weight (w_e)**
Integrity, standardization and consistency	0.2
Position accuracy	0.3
Attribute precision	0.5

Table 2. Weight of quality characteristics

Adopt the following formula (4) to sum and calculate the score of unit results:

$$S_{sample} = \sum (w_e \cdot s_e) \quad (4)$$

As per the quality score of unit results, divide the quality grades based on the following table.

Quality score	**Quality grade**
$S \geqslant 90$	Excellent
$75 \leqslant S < 90$	Good
$60 \leqslant S < 75$	Qualified
$S < 60$	Unqualified

Table 3. Evaluation criteria for quality grades

3.3.3 Quality judgment of lot results: Determine whether the lot results are qualified or not in light of the relationship between the number of unqualified samples n_{rd} and A_c, If qualified, the score of layer Slayer can be calculated. When $n_{rd} \leqslant A_c$, the sample quality is qualified and the quality of lot results is qualified. When $n_{rd} > A_c$, the sample quality is unqualified, the quality of lot results is unqualified.

3.3.4 Evaluation of Layer (Layering) Quality: Meanwhile, considering the importance weight w_1, area S_q (or length L_o) weight and the proportion w_2 of the two factors, calculate the layer score S_{layer} after the weight is normalized.

3.3.5 Quality Evaluation of Lot Results: Meanwhile, considering the importance weight of layer, the weight of stratified sampling and the proportion of the two factors, calculate the score S of lot results by weighting after the weight is normalized, and reflect the weight of layer importance and stratified sampling simultaneously.

4. TECHNICAL EXPERIMENTS AND RESULTS

4.1.1 Selection of Test Areas: With the results of earth polygon layer of the national land survey as the test object, under the different regional scales of county, provincial and national levels of the land survey, select the results of three test areas respectively to launch the test of inspection and evaluation. The selection of test areas takes into account the different order of magnitude of polygon and earth complexity.

1) Select a county-level experimental area in each of the provinces in the eastern region and the western region, with the total number of polygon in a single county-level experimental area between 17,000 and 142,000.

2) Select 2-3 county-level task areas in a single province to form a provincial test area, with the total number of polygon in a single provincial test area between 50,000 and 120,000.

3) Select 3-6 county-level task areas in many provinces nationwide to form a national-level test area, with the total number of polygon in a single national-level test area between 552,000 and 601,000.

4.1.2 Test Results: For the land survey results of each test area, employ the inspection software to fully check the integrity of the documents, data and elements of the results, the standardization of the organization, format, structure and spatial reference of the results, the consistency of topological relations and constraints, overally inspecting the position accuracy of regional results, and calculate the score of each inspection item; based on the sample size determined by the sampling scheme, randomly select samples by layers to carry out accuracy check and calculate scores, including sample position accuracy and attribute accuracy.

Sum the scores of each quality characteristic of the sample by weighing, calculate the score of the sample and evaluate the quality. On this basis, compare the number of unqualified samples with the number of qualified judgments in the sampling scheme to judge the quality of the results in the test area.

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Weigh and normalize the area (or length) of unit results, and weigh and calculate the quality score of each layer. Weigh and normalize the importance of types of natural resources, and weigh and calculate the quality score of results in the test area.

test area	polygon number	sampling method	unqualified number	conclusion	sample score
A(county level)	17403	(500,0)	0	excellent	96.26
B(county level)	34729	(500,0)	0	good	89.08
C(county level)	142854	(800,1)	3	unqualified	-
D(provincial level)	50153	(800,1)	1	good	89.35
E(provincial level)	113928	(800,1)	0	excellent	95.43
F(provincial level)	120067	(800,1)	1	qualified	73.91
G(national level)	552143	(1250,3)	3	good	87.89
H(national level)	576251	(1250,3)	2	good	88.97
I(national level)	601162	(1250,3)	1	excellent	93.72

Table 4. Inspection and evaluation results of test area

5. CONCLUSION

The test results suggest that the quality inspection, evaluation and inspection process for the survey and monitoring results of natural resources is reasonable, with feasible methods, comprehensive contents, and appropriate indicators. It can objectively and accurately reflect the quality status of the tested results, and basically meet the requirements of acceptance and review of the quality inspection and evaluation for the basic survey results of natural resources.

1) Fully combined with production practice and technical conditions of quality inspection, and considering the characteristics of classified results of basic survey and the internal relations between different types of results, the technical scheme reasonably abstracts the results model of basic survey, designs reasonable quality characteristics by taking the result element (polygon) as the result unit, and measures the integrity, standardization and consistency of the results as a whole through automated quality inspection methods. The quality inspection focuses on the accuracy of the results and verifies that the quality model is reasonable.

2) Based on the design of production indexes and the application requirements of results, the technical scheme has comprehensively and systematically refined the quality requirements and inspection contents of the basic survey, achieved close connection with quality evaluation indexes and methods, and verified that the quality requirements and inspection contents are systematic and comprehensive.

3) According to the attribute and structure characteristics of different types of elements (polygon), the technical scheme designs general, important and key attribute items in classification, and on this basis, an attribute precision evaluation model is built. By integrating the overall quality conformity evaluation model and the position accuracy evaluation model, it realizes the quality characteristic evaluation and proves that the quality evaluation model is accurate and the indexes are relatively reasonable.

4) Giving overall consideration to the importance of quality characteristics, types of unit results, area (length, quantity) factor and layer importance, the technical scheme establishes a step-by-step upward comprehensive quality evaluation model, which can comprehensively reflect the quality of results upon verification.

5) Giving overall consideration to the production design requirements and the production quality level, the technical scheme establishes the sampling scheme for isolated lot inspection and stratified random sampling method retrieved based on the limit quality (*LQ*). It is verified that the sampling scheme and methods are reasonable and feasible, taking into account both controllable inspection risks and improved efficiency.

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