

Research and Application of Quality Assessment Method for Land-Use Monitoring Products Derived from Remote Sensing

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Abstract: This article focuses on how to scientifically and objectively inspect and analyse remote sensing-derived land-use monitoring data products, so that the inspection of results plays a key role in quality control. Based on the characteristics of these land-use monitoring products, this article designs quality models, quality elements, inspection content, inspection methods, and evaluation methods, as well as remote sensing-derived land-use monitoring data products quality inspection software. Furthermore, typical problems in quality inspection are studied and analyzed, and verified in the 2021-2024 National Land-Use Dynamic Full-Coverage Remote Sensing Monitoring Project. The results show that the integrity, standardization, and accuracy of monitoring results are guaranteed, providing useful reference for future remote sensing monitoring production and quality control.

Keywords: remote sensing monitoring, examination content, inspection method, quality evaluation

1. Introduction

The annual land-use change survey is based on a "unified basemap" to conduct annual updates of natural resource inventories, ensuring that management departments timely grasps the changes in the type, area, scope, and other aspects of every natural resource in the country. Annual National Land-Use Dynamic Full-Coverage Remote Sensing Monitoring is a routine monitoring work in natural resource monitoring. It focuses on the goals of natural resource management and regularly conducts full coverage dynamic remote sensing monitoring of natural resources within China, timely grasping information on annual changes in natural resources, supporting the annual update of basic survey results, and providing a working base map for the annual land use change survey work carried out throughout the country. It is an important foundation for various natural resource management work. Ministry of Natural Resources of the People's Republic of China(2020)

Remote sensing-derived land-use monitoring data products are based on the latest remote sensing image data, combined with natural resource management information, and in accordance with the relevant technical requirements of annual change surveys. The monitoring discovers changes in land use types that are inconsistent with those in the previous year's land survey database (hereinafter "previous year database"), and extracting changed parcels by category China Land Surveying and Planing Institute (2024). To ensure data quality of the results, this article adopts a "graded and

staged quality inspection" method to implement full process quality control of remote sensing-derived land-use monitoring data products. Based on the characteristics of the results, a quality model, quality elements, inspection content, inspection methods, and evaluation methods are specified. For monitoring key points such as new construction and " non-agricultural uses" and " non-grain cultivation" of cultivated land, a quality inspection content and evaluation index system are studied and developed. A software for quality inspection of remote sensing-derived land-use monitoring data products was designed and implemented, and typical quality problems and their causes that occur in actual inspections are analyzed in depth to ensure the authenticity, accuracy, and reliability of remote sensing-derived land-use monitoring data products, providing efficient quality support and data guarantee for conducting annual land use change surveys.

2. Quality Inspection Process

The quality inspection of remote sensing-derived land-use monitoring data products is divided into two stages: batch result inspection of change patterns and final result inspection of change patterns. According to the classification principles of the third land survey LENG et al (2017) and management elements GAO et al (2015), the results mainly consist of the following types of changes:

(1) Monitoring of suspected newly added construction land: Monitor the changes in the database land category of non construction land in the previous year, but the

image characteristics are suspected of newly added construction (including newly added construction dumping soil and changes in the use of facility agricultural land), and extract suspected newly added construction spots by type.

(2) Monitoring of changes in cultivated land outflow: Monitor the changes in the database land type of cultivated land but with obvious non cultivated land image features in the previous year, extract suspected cultivated land outflow changes by type, and annotate greening and afforestation, lake excavation and landscaping, etc.

(3) Monitoring of changes in construction land and facility agricultural land: Monitor the changes in the database land types of construction land and facility agricultural land in the previous year, and extract change patterns such as suspected demolition and reclamation by type.

(4) Non cultivated agricultural land change monitoring: Monitor the changes in the database land types of gardens, forests, grasslands, and other agricultural land in the previous year, and extract image features that are significantly inconsistent with the previous year's database land types by type.

(5) Unused land change monitoring: Monitor the changes in the database land category as unused land in the previous year, extract image features that are significantly inconsistent with the previous year's database land category by type, and focus on extracting changes caused by human activities.

(6) New monitoring of land reclamation: Based on the orthophoto remote sensing images of the previous and subsequent periods, combined with the database results of the previous year, image features are extracted by type as the spots of the newly added land reclamation.

Based on the characteristics of the results, this article designs a quality inspection process for remote sensing-derived land-use monitoring data products, as shown in Figure 1.

Carry out a general survey of the received results, check the quantity of the land-use remote sensing monitoring data, organizational catalog, readability of data files, review the quality self-test report, record files and other materials, and use the quality inspection software to carry out the inspection of the consistency check items of map spot results. If it is found that the results are not in conformity or unqualified in the overall inspection, the batch of results shall be returned and submitted for inspection again after modification and perfection.

Through the overall general inspection results will be software-assisted inspection, human-computer interactive inspection and manual interpretation and interpretation, using the data review, internal inspection analysis, reference data comparison and other methods of combination, according to the remote sensing-derived land-use monitoring data products quality elements, inspection items and quality requirements, quality inspection. And according to the evaluation method

designed in this article, evaluate the quality of the change pattern results in stages. ZENG et al (2004)

Record the non conformance of consistency check items, and calculate the accuracy of various types of spot omission rate, over extraction rate, type judgment accuracy, hook and other attribute annotations. The quality inspection results are fed back to the quality inspection results in the form of "Quality Inspection Opinions" and "problem vector layer file".

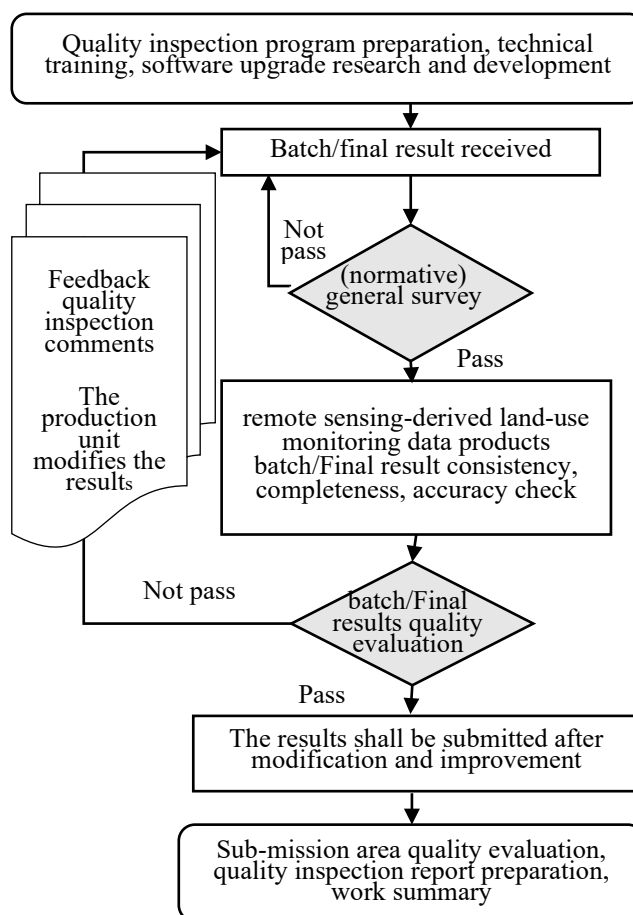


Figure 1. Quality control process design

3. Check the content and method

3.1 Check the Content

According to the quality requirements of remote sensing-derived land-use monitoring data products Hord et al (1976), the latest orthophoto maps and database data are overlaid. Based on the latest image characteristics and relevant technical requirements, software automatic inspection, software assisted inspection, human-computer interaction inspection and other methods are comprehensively used to check the quality of the batch and final results of remote sensing-derived land-use monitoring data products DENG et al (2008). This article designs three quality elements and ten inspection items to conduct item by item quality checks on the consistency, completeness, and accuracy of the batch results and final results of change patterns Servigne et al (2000). It checks whether the remote sensing-derived land-use monitoring

data products are consistent or meets the requirements in terms of file organization structure, pattern extraction rules, attribute logical constraints, topological relationship processing, and associated pattern processing. It also checks whether the remote sensing monitoring change patterns and newly added reclaimed land patterns are completely or redundantly extracted, and whether the pattern types are correctly judged.

The quality elements, inspection items of the batch results and final results of change patterns are shown in Table 1.

Quality elements	Check item
Consistency	File organi-zation
	Chart structure
	Extraction Rules
	Property Logic
	Topology Relationship
Completeness	Same Spot
	Pattern spot omission
	Map spot redundant
Accuracy	Type Judgment
	Location and other properties

Table 1. Contents of quality inspection of remote sensing-derived land-use monitoring data products.

The contents of the consistency check include:

(1) File organization: Whether data files and file directories are missing or redundant; Whether the names of data files and file directories are correct; Whether the organization of data files and file directories is correct; Whether the format of data files is correct; Whether the data file can be read normally.

(2) Chart structure: Whether the structure of the map plaque attribute table is strictly consistent with the specified requirements; Whether the structure of the property table of the map spot extraction scope file is strictly consistent with the requirements; Whether the property sheet structure of the quality check record file is strictly consistent with the prescribed requirements.

(3) Extraction Rules: Whether it is common to draw the spot boundary randomly; Whether there is widespread improper handling of fine edges and corners; Whether there is widespread misextraction along the base of the overall building area; Whether there is a common mention of "map spots extracted last year that have not been changed after field proof and verification and have no obvious changes in image texture features this year"; Whether there is widespread improper grasp of other extraction rules.

(4) Property Logic: The contents of the integrity check include: Whether the attribute items such as county-level administrative code, county-level administrative name, map spot number, post-phase, individual layer name, center point X coordinate, center point Y coordinate, monitoring area are complete and accurate; Whether the attribute items such as land type, scope of change, and reasons for not changing after the change are superfluous; Whether the pattern type, pattern characteristics and other

attribute items are filled in the range of enumerated values; Whether the pattern numbering rules meet the requirements.

(5) Topology Relationship: Monitor whether there are common topological relationship errors such as duplication, overlap, and boundary self-intersecting; Whether there is duplication and cross extraction of pattern spots at the edges of results.

(6) Same Spot: Whether the boundaries and positions of the same spots in the final results and batch results are strictly consistent; Whether the attribute values of the same spots in the final results and batch results are strictly consistent; Whether there is unreasonable deletion of image spots in the final product compared with the batch product.

The contents of the completeness check include:

(1) Pattern spot omission: Extraction of suspected new construction spots omission, statistical number of omissions; Missed extraction of cultivated land outflow change map spots, and counted the number of missed extraction; Construction land and facility agricultural land change map spot omission extraction, statistical missing number; Non-tillage agricultural land change map spot omission extraction, statistical number of omissions; Omission extraction of unused land change map spots and statistical number of omissions; Added missing extraction of spot on reclamation map and counted the number of missed extraction; Omitted extraction of monitoring pattern spots with an area greater than 10 acres, and counted the number of omissions.

(2) Map spot redundant: Extraction of excess of suspected new construction map spots, statistical number of excess; Surplus extraction of cultivated land outflow change map spots and statistical number of excess extraction; Extraction of excess spots on the change map of construction land and facility agricultural land, and statistical number of excess extraction; Extraction of excess spots on the change map of non-tillage agricultural land and statistical number of excess mentions; Unutilized map spots were extracted and the number of overextracts was counted; Added redundant extraction of reclamation map spots and counted the number of overextraction.

The contents of the accuracy check include:

(1) Type Judgment: The type of suspected new construction pattern spot is wrong, and the number of wrong judgments is counted; The pattern type of cultivated land outflow change was wrongly judged and the number of wrong judgments was counted; The pattern types of construction land and facility agricultural land changes were wrongly judged and the number of wrong judgments was counted; The pattern types of non-tillage agricultural land changes were wrongly judged and the number of wrong judgments was counted; The pattern type of unused land change map was wrongly judged and the number of misjudged was counted; Added the wrong

judgment of spot type on reclamation map, and counted the wrong number.

(2) Location and other properties: Monitor whether the position accuracy of the map spot drawing is beyond the limit (the non-universal map spot boundary drawing beyond the limit is classified as such), and count the number of beyond the limit; Monitor the annotation errors of other attributes except the type of pattern spots, and count the number of errors and omissions; Other errors of monitoring pattern spots (including improper handling of non-universal connectivity and upper and lower relationships, improper synthesis or refinement extraction, topological relationship errors, etc.), and the number of errors and omissions.

In view of the different accuracy of orthophoto images used in the inspection of results in different monitoring areas, we should strictly check the omission of important remote sensing-derived land-use monitoring data products based on low-resolution- image quality inspection, and strictly check the multiple errors, position drawing and type accuracy of image spots based on high-resolution image quality inspection. LIU et al (2015)

Based on the principle of curbing the "non-agricultural" and preventing "non-grain" of cultivated land, for the inspection contents in Table 1, the following types of map spot omissions should be checked in the new construction map spot layer and the cultivated land outflow remote sensing-derived land-use monitoring data layer:

- (1) Non-construction land, new residential areas, factories, high-rise buildings, large-scale centralized rural settlements and other large construction projects within the scope of separate layers, as well as construction/structure map spots that can be identified as the above types of land construction foundation and other clear construction purposes.
- (2) Non-construction land, new water construction, built roads, railways, large ditches, photovoltaic, golf, park green space and other map spots within the scope of a separate layer.
- (3) Hardened map spots on non-construction land and newly added independence square, parking lot, driving school, open-air cargo station, etc., within the scope of separate layers.
- (4) Clearly for afforestation on cultivated land, construction of green channels, planting fruit and tea trees, construction of pond water surface, planting artificial turf, digging lake landscape, construction of aquaculture facilities, etc., cultivated land changes into garden land, forest land, water surface, green grassland and other map spots.

3.2 Inspection methods

Carry out item-by-item quality inspection on the batch results and final results of change patterns in terms of consistency, completeness and accuracy. The inspection method is shown in Figure 2.

The software automatic check method is used to check the consistency of the remote sensing-derived land-use monitoring data layer, mainly checking the file organization structure, map spot extraction rules, attribute logical constraints, topological relationship processing and so on. The integrity (including missing and multiple spots) and accuracy of the remote sensing-derived land-use monitoring data layer are checked by software-assisted and human-computer interaction methods. The inspection results given by the software need to be manually checked one by one.

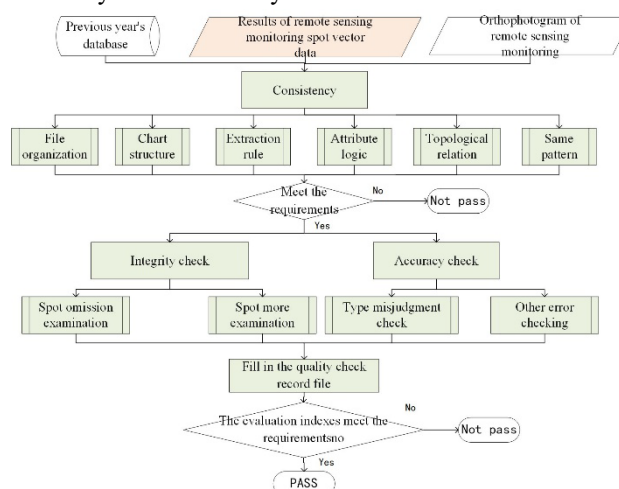


Figure 2. Remote sensing-derived land-use monitoring data products inspection method

4. Design of Quality Evaluation Method

4.1 Design of Quality Evaluation Index for Remote Sensing-Derived Land-Use Monitoring Data Products

4.1.1 The overall quality evaluation index of the remote sensing-derived land-use monitoring data products

The quality evaluation indexes of the remote sensing-derived land-use monitoring data products stipulated in the technical plan of remote sensing monitoring project are shown in Table 2.

According to the requirements, the results of the remote sensing-derived land-use monitoring data products should "meet" the requirements of the technical scheme in the consistency processing of file organization, chart structure, extraction rules, attribute logic, topological relations, and the same map spots, and at the same time meet the following requirements in terms of the completeness and accuracy of map spot extraction: the leakage rate of two types of monitoring map spots, such as suspected new construction and farmland outflow change, is not more than 1%; The leakage rate of 4 types of monitoring pattern spots is not more than 5%, such as the change of construction land and facility agricultural land, the change of non-arable agricultural land, the change of unused land, and the newly reclaimed sea; In the above 6 types of monitoring pattern spots, the leakage rate of large pattern spots with an area of more than 10 acres is not more than 1%; The multi-extraction rate of the above 6 types of monitoring pattern spots is not more than 10%, the accuracy rate of type judgment is not less

than 95%, and the accuracy rate of hook drawing and other attribute labeling is not less than 98%. The accuracy rate of pattern spot type judgment is not less than 95% in the verification result of daily change pattern spot.

Layers	Consistency	Completeness		Accuracy	
		Miss Extr-action	Over-extr-action	Type judgment accur-acy rate	Accur-acy of other attrib-utes
The former two types	Confor-mance	$\leq 1\%$	$\leq 10\%$	$\geq 95\%$	$\geq 98\%$
The other four types		$\leq 5\%$			
Large patches with an area greater than 10 acres		$\leq 1\%$	—	—	—

Table 2. Overall quality evaluation indexes of the remote sensing-derived land-use monitoring data products

4.1.2 Design of evaluation indicators for batch and final result classification of remote sensing-derived land-use monitoring data products

According to the quality elements, inspection items and inspection contents of the remote sensing-derived land-use monitoring data products specified in Table 1, combined with the overall quality evaluation indicators of the remote sensing-derived land-use monitoring data products, and according to two types of evaluation objects such as batch results and final results, the remote sensing-derived land-use monitoring data products quality evaluation indicators are segmented, as detailed in Table 3-5.

In the table, the correct (wrong) rate and other error (accurate) rate of spot omission rate, multiple rate, type misjudgment (correct) rate, spot drawing and other attribute error (accurate) rate are calculated as follows: take the ratio of "correct (wrong) number of spot extraction" within the statistical range and "total number of spot" within the statistical range, where: "Total number of graph spots" = "Total number of graph spots extracted" + "Total number of graph spots missed" - "total number of graph spots lifted".

4.2 Quality evaluation method for batch results of remote sensing-derived land-use monitoring data products

Taking the batch results as the evaluation unit, according to the 6 consistency evaluation indicators, 2 integrity evaluation indicators and 2 accuracy evaluation indicators

specified in Table 3-5, the batch results of the remote sensing-derived land-use monitoring data products were evaluated item by item according to the inspection results, and the evaluation results were obtained respectively. The evaluation conclusions of batch results quality were drawn by synthesization of the results.

The corresponding contents of the consistency check items meet the requirements of the technical scheme, and the single evaluation result is "meet". According to the number of missed mentions, multiple mentions, type misjudgment and other errors recorded and counted in the integrity and accuracy checks of various pattern spots, the accuracy rate of missed mentions, multiple mentions, type judgment accuracy rate, hook drawing and other attribute labeling was calculated according to Table 3-5.

Check item	Main items to check	Examination results
File organization	File organization structure, format, naming	Conformance
Chart Structure	annex file property table structure definition	Conformance
Extraction rules	Grasp the pattern extraction rules	Conformance
Property logic	Attribute value logical relation, value range, pattern numbering rules	Conformance
Topological relationships	Topology relationship processing	Conformance
Same spot	Consistency between batch result pattern and final result pattern	Conformance

Table 3. Quality evaluation indexes of the consistency

In Table 4, according to the principle of strict inspection of cultivated land outflow spots in the inspection content of 3.1, if the result of r1 is passed, and a single spot with an area exceeding 2000 square meters is significantly missed based on high-resolution orthophoto images such as 0.5 and 1 meter, or a single spot with an area exceeding 4000 square meters is significantly missed based on orthophoto images with a resolution below 1 meter, it is judged that this item does not meet the standard.

The results of each consistency check item are "yes", and the accuracy rates of all kinds of pattern spot extraction integrity, pattern spot type judgment accuracy, pattern spot drawing and other attribute labeling are all up to standard. The quality evaluation conclusion of batch results is "pass", otherwise, the conclusion is "not pass".

According to the quality evaluation of the batch results, the number of quality inspection times that the batch results passed the inspection was recorded. After the

completion of the quality inspection of the batch results, the passing rate of the first quality inspection of the batch results was calculated according to different statistical regions (county, province, mission area, monitoring area, etc.).

Check item	Main items to check	Examination results
Pattern spot omission	Suspected new construction, cultivated land outflow change and other 2 types of monitoring pattern spot leakage rate	$r1 \leq 1\%$
	The leakage rate of 4 types of monitoring pattern spots, such as construction land and facility agricultural land change pattern, non-arable agricultural land change pattern, unused land change pattern and new reclamation map spot	$r2 \leq 5\%$
	Monitor the leakage rate of large pattern spots larger than 10 acres	$r3 \leq 1\%$
Chart spots are redundant	Monitor the excess rate of pattern spots	$r4 \leq 10\%$

Table 4. Quality evaluation indexes of the completeness

Check item	Main items to check	Examination results
Type	Monitor the pattern spot type judgment error rate	$r5 \leq 5\%$
Location and other properties	Monitor the error rate of spot drawing and other attribute labeling	$r6 \leq 2\%$

Table 5. Quality evaluation indexes of the completeness

4.3 Quality evaluation methods for final results of the remote sensing-derived land-use monitoring data products

With the final result as the evaluation unit, according to the 6 consistency evaluation indicators specified in Table 3, the final result of the remote sensing-derived land-use monitoring data products is evaluated item by item according to the inspection results, and the evaluation results are obtained respectively. The evaluation conclusions of the batch result quality are drawn by combining the results.

The corresponding inspection contents of the consistency inspection items are in line with the requirements of the technical scheme, and the single evaluation result is "in line". The results of each consistency check item are

"compliant", and the final result quality evaluation conclusion is "qualified", otherwise it is "unqualified".

After the final product quality inspection is completed, according to the number of spot omission, multiple mention, type misjudgment and other errors recorded in the first quality inspection of the batch results and the evaluation method specified in Table 3, the accuracy rate of spot omission, multiple mention rate, type judgment accuracy rate, drawing and other attribute labeling is calculated according to different regions (such as: county, province, mission area, monitoring zone, etc.).

5. System Implementation

5.1 System Verification

Based on the research and design of quality control methods in this article, a remote sensing-derived land-use monitoring data products quality inspection software adapted to various situations was developed according to the changing needs of remote sensing monitoring focus each year. Based on human-machine collaboration, intelligent extraction and interactive verification of remote sensing change information and spatiotemporal database technology were developed, and more than 40 functional items were developed to achieve automatic inspection and completeness auxiliary inspection of vector image spot batch results and final results, quality problem information positioning and annotation, and fine statistical and evaluation of quality information.

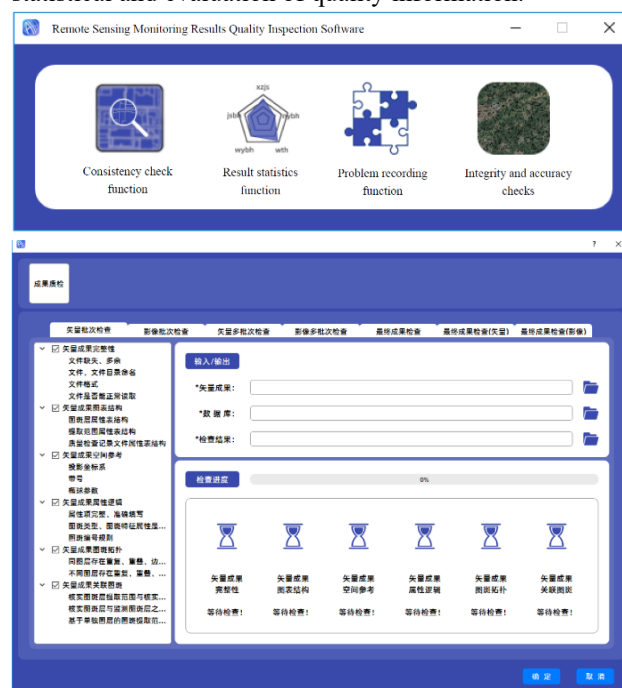


Figure 3. Remote sensing monitoring quality control software

5.2 Results Evaluation

The quality inspection software was applied in the 2021–2024 National Land-Use Dynamic Full-Coverage Remote Sensing Monitoring Project, with results demonstrating significant improvements in both inspection efficiency and evaluation accuracy.

During field validation, the following recurrent issues were identified in monitoring outputs:

(1) In the scope of non-construction land in the database, there are construction/structure, built roads, large ditches, parks, mining and other map spots missing, such as: in the scope of arable land missing residential areas, factories, concentrated construction of large-scale rural settlements and other "non-agricultural" map spots; Within the scope of agricultural land, there are missing raised buildings, independence squares, parking lots, open cargo stations, hardened slope protection, etc.

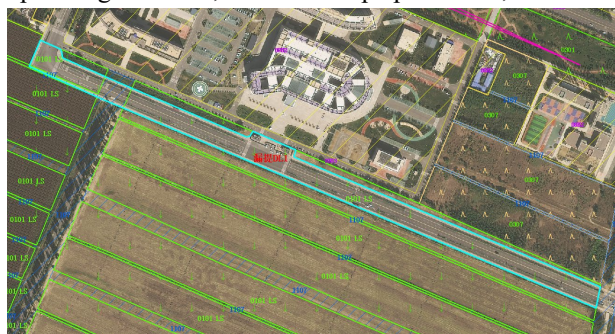


Figure 4. Roads are omitted from cultivated land.



Figure 5. High-rise buildings are omitted from other grasslands.



Figure 6. Large factories are omitted from other grasslands.

(2) In the scope of cultivated land in the database, there are cases of missing extraction of map spots on water surface, forest land and garden land, such as: missing extraction of green afforestation in cultivated land, construction of green channels, planting fruit and tea trees, construction of pit water surface, planting artificial turf, digging lake landscape, construction of aquaculture facilities and other "non-grain" map spots.



Figure 7 Forest land is omitted from cultivated land.



Figure 8. Garden land is omitted from cultivated land.

(3) In the scope of construction land in the database, there are cases of missing extraction of demolition map spots of construction land.



Figure 9. Previous year Image Current year image

Judging from the annual quality inspection of the batch and the final results, there are large areas and obvious changes in the new construction map spot missing, agricultural land change map spot missing, wrong mention of the situation, in the grasp of the control of land use "non-agricultural", prevent "non-grain" and other monitoring priorities, need to be further strengthened. In view of this situation, it is suggested to strengthen the professional technical training of remote sensing monitoring, do a good job in production technical

support and guidance, improve the accuracy and efficiency by automated means and information means, ensure the high quality of production results, and further strengthen the quality self-check in the production link, move forward the quality control gateway, and ensure the effectiveness of quality control. In this paper, through the research of quality inspection technology methods and the accumulation of practical experience, the typical problem case base is finally formed, which provides quality control for each process of the next year remote sensing monitoring project.

6. Closing remarks

Remote sensing monitoring, as a prerequisite for annual land use change surveys, is the first process of national monitoring of land use changes. The quality of its results directly affects the efficiency of subsequent field surveys and the accuracy of land use data statistics. This article establishes scientific and objective quality requirements, quality models, quality elements, inspection content, inspection methods, and evaluation methods for remote sensing-derived land-use monitoring data products. A software for quality inspection of remote sensing-derived land-use monitoring data products was developed, and typical problems frequently encountered during quality inspection are analyzed in depth. The research results have been practically verified in the 2021-2024 National Land Use Dynamic Full Coverage Remote Sensing Monitoring Project. The results show that this quality control method is effective and feasible, ensuring the integrity, standardization, and accuracy of monitoring results, and can provide useful references for future remote sensing monitoring production and quality control.

7. References

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