Discussion on the ‘Integration of Four Databases’ for Natural Resources Survey and Monitoring in Beijing Based on the ‘Jiaxing Experience’

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Abstract

Drawing on the "Integration of Four Maps" from the "Jiaxing Experience" ,and starting from Beijing's own data context, this paper proposes a "Integration of Four Databases" workflow. This model is based on four operational tasks: New Fundamental Surveying and Mapping (NFSM), National Land Change Survey (NLCS), Urban Territorial Spatial Monitoring (UTSM), and Territorial Spatial Planning (TSP). It aims to resolve the issue of accumulating discrepancies in conflicting land use polygons by refining these polygons. This enables high-precision verification of NLCS data by NFSM data and facilitates the detection of dynamic changes. Differences are gradually "digested" year by year to achieve the goal of integration. Concurrently, it proposes using NFSM data to resolve building spatial location information, and UTSM to resolve operational building information. This achieves a dual expansion in both content and elements for NFSM and UTSM, progressively leading to reliable and accurate data on changes in building floor area and volume, thereby providing accurate data for leadership decision-making and urban planning in Beijing.

1. Introduction

In March 2018, following the State Council's institutional reform plan, the functions of the former National Administration of Surveying, Mapping and Geoinformation were fully integrated into the Ministry of Natural Resources. This resulted in significant reforms in the systems and mechanisms of surveying and mapping, shifting its service model from a "universal service" for the whole society to one "centered around core governmental functions while considering public welfare." In January 2019, the National Natural Resources Work Conference explicitly stated: "Accelerate the transformation and upgrading of fundamental surveying and mapping, enhance the public service capability of surveying, mapping, and geoinformation, and promote the high-quality development of the geoinformation industry." In recent years, the Ministry of Natural Resources has initiated numerous pilot projects for NFSM in various provinces and cities, including Shanghai, Wuhan, Xi'an, Ningxia, and Jiaxing. Among these, the Jiaxing pilot project is application-oriented, demand-driven, involves categorized and zonal production as needed, and promotes the construction of NFSM across the entire region. The primary goal of the Jiaxing pilot was to serve natural resources planning and management operations. It effectively integrated four spatial layers – NFSM, NLCS, UTSM, and TSP – to form a "Single Map of Current Status and Planning" (referred to as "Integration of Four Maps"). This reduced inconsistencies and contradictions among current status data and effectively supported territorial spatial planning regulation and control. Learning from the "Integration of Four Maps" of the Jiaxing Experience, and based on Beijing's own context and the four operational tasks of NFSM, NLCS, UTSM, and TSP (Wang etc., 2022; Li Zhaoyu and Zhang Baogang, 2025), this paper proposes a "Integration of Four Databases" workflow. It effectively adopts the polygon refinement method from the Jiaxing Experience to solve the problem of accumulating discrepancies in conflicting polygons, gradually "digesting" the differences year by year to achieve the integration goal.

2. Current Analysis

Beijing's multi-source data inherently possess interrelationships. For instance, the physiographic entities (e.g., agricultural and forest land, soil types) in NFSM overlap spatially with the primary classifications of the NLCS (cultivated land, forest, garden plot, grassland, wetland), the primary classifications of UTSM (planted vegetation, forest and grass cover, water bodies), and the primary classifications of TSP (forest and grass protection zones, ecological mixed zones, water body protection zones, permanent basic farmland protection zones). However, their definitions and attributes differ(Li etc., 2025). Among them, NFSM, NLCS, and UTSM all describe current characteristics based on different technical standards(Wang etc., 2025; Yang etc., 2025; Qiao etc., 2025; Zeng etc. 2024; Wen etc., 2025), while TSP outlines a long-term blueprint(Guo etc., 2025). Similarly, artificial geographic entities also have overlapping aspects (Table 1). The differences among the "Four Databases" need to be mutually transformed according to certain principles to resolve

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technical-level discrepancies.

NFSM	NLCS	UTSM	TSP
Physiographic Entities (NFSM)	Agricultural/forest land & soil VS "Cultivated, Forest, Garden, Grass, Wetland"	Agricultural/forest land & soil VS "Planted Vegetation, Forest/Grass Cover, Water Bodies"	Agricultural/forest land & soil VS "Forest/Grass Protection Zones, Ecological Mixed Zones, Water Protection Zones, Permanent Basic Farmland Protection Zones"
Artificial Entities (NFSM)	Courtyard VS Residential land, Public Management & Service land, Commercial Services land, Specialized land, etc.	Courtyard VS "Building Areas"	Courtyard VS "Urban Construction Land, Village Construction Land"

Table 1. Comparative Analysis of the "Four Databases"

To visually represent spatial differences, as shown in Figure 1, the red polygon corresponds to urban residential land in the Change Survey, while NFSM refines it into four patches: urban residential land entity, urban attached green space entity, urban community service station entity, and urban internal road entity. The NFSM polygons are more refined than the NLCS patch, better expressing the actual spatial situation. Figure 2 shows discrepant land use polygons between the Change Survey and UTSM. Based on the urban residential land patch from the NLCS, UTSM refines it further, distinguishing commodity housing and indemnificatory housing.

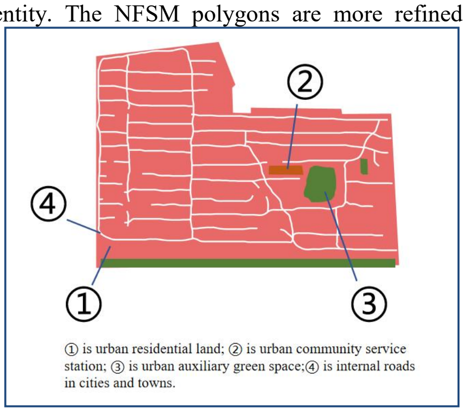

Figure 1. Discrepant Land Use polygons between NFSM and NLCS

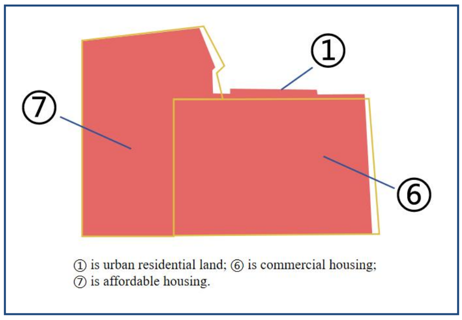

Figure 2. Differential Land Use polygons between NFSM and Urban Land and Space Monitoring

3. Solution

3.1 Overall solution

In view of the differences in the integration process of new basic surveying and mapping, land change survey and urban land space monitoring, the classification processing is carried out according to the spatial location and business rules. First, check whether the different patches intersect in space. For the intersecting parts in space, check whether the elements are expressed consistently. If the expressions are consistent, handle them separately according to the boundary conditions; If they are inconsistent, they will be handled separately according to the business rules. The solution is shown in Figure 3.

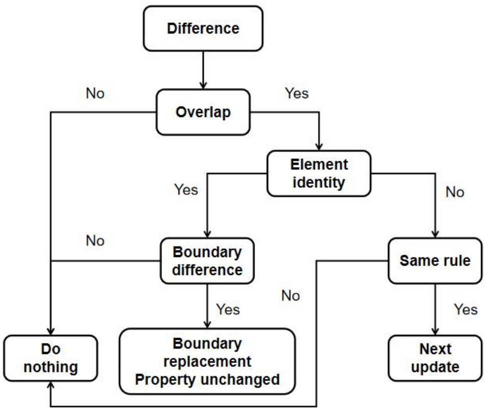

Figure 3. Framework of solution

3.2 Integration Plan for NFSM & NLCS

As the NLCS and UTSM are both under the unified organization and planning of the Survey and Monitoring Department, they are already in a process of operational integration. National technical standards stipulate that the spatial information refinement and element collection for UTSM should be carried out based on the NLCS(Wu, 2023), avoiding duplicate collection. The collected information serves as a reference for urban physical examination and land use regulation. According to the collection of land cover for UTSM, also follows new development directions(Wang and Li 2024). Based on Beijing's Technical Guidelines for Land and Sea Use, we have established corresponding "Single Map" standards, primarily adhering to three principles(Wang etc., 2022; Cui and Ni, 2022): 1) Within construction land areas, refine the non-construction elements inside – for example, using a park green space from the Change Survey, collect the individual buildings, roads, and park lake within it, i.e., "refining non-construction elements within construction land." 2) Similarly, within non-construction areas, construction activities that occur need refined collection – for example, using forest land from the Change Survey, collect houses in the forest farm, roads built in the forest farm, and artificial excavations in the forest farm, i.e., "refining construction elements within non-construction space." 3) Interface with specialized surveys like forest, grass, and wetland surveys, following their more detailed collection requirements for forest land, subdividing forest land into more categories to effectively meet the needs of producing a single map for Gross Ecosystem Product (GEP) estimation citywide(Wei etc., 2022).

Similarly, regarding the connection between NFSM entities and the NLCS/UTSM, the "fundamental" and "supportive" nature must be fully considered. As a fundamental national surveying and mapping task, NFSM provides basic services for various specialized surveys and mappings. Content with solidified business requirements can be incorporated into NFSM, while content still needing alignment with professional business needs remains in specialized surveys and mappings. Furthermore, rule sets must be established to enable the transformation of changes between the two.

Based on these two principles, content where NFSM physiographic and artificial entities differ from the NLCS requires refined segmentation. Through refinement, the area/volume of discrepant polygons between the two is reduced, and the elements are aligned with the NLCS. Simultaneously, discrepancies are annotated to provide a basis for the following year's Change Survey updates. Updates are primarily handled according to three aspects folloewing.

3.2.1 Boundary precision differences: The Change Survey can directly adopt these, using the higher precision boundary while retaining the original business attributes unchanged. For instance, if the same patch is forest land in both, but NFSM has a more precise boundary, the Change Survey directly adopts the high-precision patch boundary without modifying the area attribute.

3.2.2 Technical standard differences: The Change Survey can remain unchanged. For example, if NFSM collects building entities within forest land, but the Change Survey, according to its own ownership management business standards, does not collect them (as finer polygons do not always advance business management), such differences can persist.

3.2.3 New change differences: The Change Survey has not yet captured this difference, which can provide the basis for changes in the coming year. Through discrepancy handling, the two datasets gradually converge towards consistent expression, achieving integration, allowing NFSM to play its "fundamental" and "supportive" role, and effectively advancing the "Integration of Four Databases."

3.3 Integration Plan for NFSM & UTSM

There are many similarities between NFSM products and survey & monitoring products(Zhao etc., 2024; Wang etc. 2024; Xiao etc., 2022). Internal questionnaires also included opinions from the Survey and Monitoring Department and R&D Center stating the need to "clarify the relationship between NFSM, NLCS, and UTSM; they should not involve duplicate collection." From the perspective of "Integration of Four Databases," this paper analyzes the respective focuses of NFSM products and survey & monitoring products. NFSM products serve the survey and monitoring business from a macro perspective of being "fundamental" and "supportive." The integration plan for these two is analyzed below from the perspective of building elements.

Both the individual building entities from NFSM and the individual buildings under Geographical Conditions (hereinafter referred to as Geographical Conditions Buildings) are collected across the entire city domain. The scale is 1:2,000 within the Sixth Ring Road and 1:10,000 in other areas. Geographical Conditions Buildings are comprehensively updated annually according to two time points, June 30th and December 31st. The data completion time lags the data time point by approximately six months, giving the data relatively high currency. In contrast, the currency of NFSM data is relatively weaker. Currently, the individual building entity data completed by the end of 2023 has a time point of the end of 2022. The updated building entity data in 2024 will have a time point of the end of 2023, with a lag of about one year between data completion and the time point. Constrained by the high requirements for building data currency from supporting the Master Urban Plan, the annual urban building thematic physical examination work, and relevant departments , a strategy prioritizing timeliness over precision (where necessary) is required for individual buildings. NFSM needs to balance data currency with data precision. Under the premise of ensuring precision, the Geographical Conditions Buildings can be used as an update source during annual updates to continuously refresh the original base database. The updated, precise boundaries can then provide the boundary basis for the Geographical Conditions Buildings update in the following year, without updating the attributes. This achieves mutual utilization between individual building entities and Geographical Conditions Buildings: NFSM data resolves building spatial location information, while UTSM resolves operational building information.

The following uses the single building as an example to analyze and deal with how the single building entity of the new foundation surveying and mapping corresponds to the houses expressing the national conditions.

4. Case Analysis

4.1 Difference Analysis

Based on 4,029 polygons in Shijingshan District, the base areas of NFSM polygons and were compared respectively. Among them, the total base area of UTSM polygons was 1.31 million square meters, and that of NFSM polygons was 1.29 million square meters, with a total difference of 16,200 square meters. However, by calculating the absolute values of the differences in each polygon, the total absolute value of the differences was 74,800 square meters, accounting for approximately 5.78% of the base area of NFSM polygons. Assuming that the base area of polygon in NFSM is the true value, then the error of UTSM is 5.78%. There are mainly two reasons for the difference: 1) First, the monitoring images of UTSM are relatively blurry, and some houses with tree shadows cannot be obtained (Figure 4); 2) Due to the different precision levels of the image sources for the two tasks, when describing the same house, NFSM often provides a more detailed description of the house's boundaries, including the concave and convex parts of balconies and the entrance hall, while UTSM often fails to detect such detailed areas, and the collected house polygons’ boundaries are often more macroscopic (Figure 5).

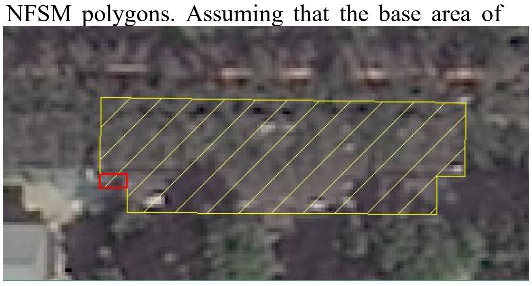

Figure 4. Type 1: difference between house examples in NFSM and UTSM (the red is UTSM and the yellow grid is NFSM)

Figure 5. Type 2: difference between house examples in NFSM and UTSM (the red is UTSM and the yellow grid is NFSM)

In response to the first reason, 241 house patches were selected. After statistics, the total absolute value difference was approximately 14,900 square meters, accounting for about 52.82% of the base area of NFSM polygons. For the second reason, the remaining 3,788 housing patches were selected. After statistics, the total absolute value difference was approximately 59,900 square meters, accounting for about 4.73% of the base area of NFSM polygons.

Through case analysis above, it is found that the accuracy of houses collected by NFSM is relatively high. In the case of shadow occlusion, houses can be obtained through high-precision images, while it is difficult to obtain houses through low-precision images. In the uncovered area, there are boundary differences between the houses obtained with two different accuracies. Assuming that the boundary of NFSM polygon is the true value, there is approximately an error of about 5% in the boundary of UTSM polygon.

4.2 Integration Processing

For the integration scheme of NFSM and UTSM, the following takes housing building construction as an example to carry out specific handling.

4.2.1 Revision principle: The entity data of individual buildings identified in accordance with national conditions shall be used as the source of updated graphics, and the entity data shall be added to the database of non individual buildings according to the polygons identified as non individual buildings, and shall not be used as the source of graphics; There are many patterns of monomer and non monomer in a classification of housing entities. The corresponding figure is replaced for monomer, and no operation is performed for non monomer.

The principle of graphic correction is divided into three categories according to the overlapping relationship between individual building entities and national housing: full overlap, partial overlap and no overlap. The specific conditions and treatment methods are as below (Table 2).

Spatial relationship	Situation analysis	Treatment method
Full overlap	Graphic representation as the same building	replace
Partial	Graphic representation as the same building	replace

overlap	The single building entity is inconsistent with the current image	Do not replace
	The image has no house shape, and the single building entity exist	Do not replace
	Monomer building entity is non monomer	replace
	The entity data of individual buildings has data, the image has buildings, and the national housing has no data	supplement
	Single building entity has data, image has no building, and national housing has no data	No supplement
No overlap	National conditions housing has data, single building entity has no data, image has buildings	No operation
	National conditions housing data, image without building	Delete national housing
	National conditions housing has data, and the building is non monomer	Change the building to non monomer, supplement the non monomer database, and delete it synchronously in the monomer database

Table 2. Data analysis and processing

4.2.2 Topological problem graphic position correction: Due to graphic correction, if the national housing data graphics retained around have topological problems with the newly corrected graphics, the uncorrected graphics will be translated as a whole to ensure that they are basically compatible with the image and do not intersect with the corrected graphics.
4.2.3 Data current situation: After the graphics are corrected, the data and images need to be matched and analyzed to select the data that conforms to the monitoring time point.
4.2.4 Spatial matching analysis: Classify the overlap between the entity data of the single building of the new basic surveying and mapping and the national housing, and use manual verification and other means to classify and process, and do not refer to the data that is inconsistent with the status quo.
4.2.5 Definition of data integration: In terms of the area overlap relationship, if the two-way overlap between the national housing graphics and the new basic surveying and mapping monomer building entity graphics is greater than or equal to 80%, it is identified as complete overlap, and if the two-way overlap is less than 80% or both, it is identified as partial overlap, and if the graphics are not intersected, it is identified as non overlap; In terms of spatial correspondence, the intersection relationship between the national housing graphics and the entity graphics of the new basic surveying and mapping single building is divided into one-to-one, one to many, and many to one.
4.2.6 Convergence application principle: Take the entity data of individual buildings identified in line with national conditions as the location replacement source; In the single building entity, delete the corresponding single building data according to the patch identified as non single building, and supplement the graphics to the non single building database; There are many patterns of monomer and non monomer in a classification of monomer building entities. If the national housing is identified as a monomer, replace the corresponding national housing figure with the figure. If the national housing is not collected, no additional collection will be made, and the national housing identification standard will be updated synchronously.
4.2.7 The principle of graphic correction is divided into three categories: Full overlap, partial overlap and no overlap according to the overlapping relationship between houses and individual buildings in China.

5. Conclusions

Learning from the "Jiaxing Experience," this paper effectively addresses the inconsistent expression of discrepant polygon by refining them, gradually digesting the differences to achieve the integration goal. At the same time, taking the single building as an example, this paper analyzes the housing construction in NFSM and UTSM in detail, and from a quantitative perspective describes the different processing methods of correcting the spatial graphics position of the housing construction in UTSM according to the different conditions of the single building entity. Through research and analysis, the solutions proposed in this paper are suitable for the current data situation in Beijing and are worthy of promotion in production practice. Meanwhile, the relevant working ideas can be extended to the cities that carry out these two tasks. The integrated ideas in this paper can serve and provide references for the collaborative advancement of investigation and monitoring work at different scales, promoting the organic coordination of various tasks.

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