

Post-print: Accuracy Assessment of Land Cover Data Products for Urban Agglomerations on the Northern Slope of the Tianshan Mountains in Xinjiang

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Abstract

Land cover products provide crucial land surface cover information for various global Earth system science applications, such as CLCD30 (30 m), GlobeLand30 (30 m, hereafter referred to as Globe30), GLC_{FCS30} (30 m), FROM-GLC10 (10 m), Esri_{\{\{\{Land\}\}\}\{Cover\}\}\{2020\}} (10 m, hereafter referred to as Esri10), and ESAWorldCover2020 (10 m, hereafter referred to as ESA10); however, their local accuracy and applicability remain unclear. Based on Sentinel-2 imagery, this study investigated and analyzed the accuracy and error characteristics of the aforementioned six land cover data products in the Tianshan North Slope Urban Agglomeration through sample accuracy evaluation and category confusion evaluation, and discussed the causes of errors and the applicability of different data products. The results indicate: (1) Among the six data products, except for Esri10, the remaining five products exhibit relatively consistent type composition and area proportions. (2) The overall accuracies of GLC-FCS30, Globe30, CLCD30, FROM-GLC10, ESA10, and Esri10 are 0.8080, 0.8147, 0.7880, 0.8531, 0.8047, and 0.4725, respectively. (3) Regarding product applicability, GLC_{FCS30} is suitable for analyzing cropland and bare land, CLCD30 for forest and bare land, FROM-GLC10 for grassland, water bodies, ice/snow, and built-up areas, ESA10 for cropland and grassland, Esri10 for forest, ice/snow, and built-up areas, while Globe30 demonstrates more balanced accuracy evaluation results across all categories. (4) Category confusion primarily involves mutual confusion among cropland, forest, and grassland, as well as between these categories and others, particularly in areas with complex land cover, such as urban fringe regions.

Full Text

Evaluation of Land Cover Data Product Accuracy in Urban Agglomeration on the Northern Slope of Tianshan Mountains in Xinjiang

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Abstract

Land cover data products provide essential surface cover information for various earth system science applications globally, such as CLCD30, GlobeLand30, GLC_{FCS30}, FROM-GLC10, Esri_{Land}_{Cover}_{2020}, and ESAWorldCover2020. However, their accuracy and suitability at local scales remain unclear. Based on Sentinel-2 imagery, this study evaluates the accuracy and error characteristics of these six land cover data products in the Tianshan Mountains urban agglomeration through sample accuracy assessment and category confusion evaluation, and discusses the causes of errors and the applicability of different data products. The results indicate that: (1) Among the six data product sets, except for Esri10, the composition and area percentages of land cover types are relatively consistent across the other five products. (2) The overall accuracies of these products are: GLC_{FCS30} (0.8080), Globe30 (0.8147), CLCD30 (0.7880), FROM-GLC10 (0.8531), ESA10 (0.8047), and Esri10 (0.4725). (3) Regarding product applicability, GLC_{FCS30} is effective for analyzing cropland and bareland; CLCD30 is optimal for forest and bareland; FROM-GLC10 excels in representing grassland, water bodies, snow/ice, and built-up areas; ESA10 is suitable for cropland and grassland; Esri10 performs well in forest, snow/ice, and built-up areas; and Globe30 maintains overall stability in accuracy across all categories. (4) Major category confusion occurs between cropland, forest, grassland, and other categories, especially in areas with complex land cover, such as urban fringes.

Keywords: land cover data products; remote sensing; accuracy analysis; cate-

gory confusion; northern slope of Tianshan Mountains

1. Introduction

1.1 Study Area Overview

The Tianshan Mountains urban agglomeration (81°44′–91°33′ E, 42°44′–46°19′ N) extends from west to east, encompassing Wusu City, Karamay City, Kuytun City, Shawan City, Shihezi City, Manas County, Hutubi County, Changji City, Wujiaqu City, Urumqi City, and Fukang City—totaling 11 counties and cities [Figure 1: see original paper]. As one of China’s 19 key national development zones, this region concentrates most of Xinjiang’s industry and possesses well-developed urban, transportation, and energy infrastructure, serving as a prominent population distribution and economic hub in the region. The Tianshan Mountains urban agglomeration represents a typical arid oasis economic zone characterized by fragile ecosystem stability and weak resistance to disturbance. The primary natural vegetation consists of grassland and shrubland, with forests mainly distributed in the southern mountainous areas. Glaciers and frozen soils are widely distributed across high-altitude mountain regions.

1.2 Data and Preprocessing

This study selected six land cover data products: GLC_{FCS30}, Globe30, CLCD30, FROM-GLC10 (referred to as GLC10), Esri_{{{Land}}}{Cover}}{2020} (referred to as Esri10), and ESAWorldCover2020 (referred to as ESA10). Detailed parameters of these products are presented in . All products utilize the WGS84 coordinate system, so preprocessing primarily involved mosaicking, clipping, harmonizing classification systems, and removing special values (e.g., fill values) to ensure no pixel interference or null sampling points in subsequent analyses.

Reference data consisted of Sentinel-2 L2A imagery downloaded free of charge from the European Space Agency’s website (<https://scihub.copernicus.eu/dhus/#/home>). Given that snow and ice cover large areas of the study region during winter, imagery was selected from summer and autumn periods to ensure clear land cover representation.

1.3 Methods

1.3.1 Sample Accuracy Assessment A total of 1,000 sample points were generated using a stratified random sampling approach based on blank areas, with 960 points retained after removing 40 unidentifiable locations. Visual interpretation was performed using Sentinel-2 L2A imagery. To eliminate the influence of sample size on accuracy assessment results, accuracy evaluations

were repeated for all six products using sample sets ranging from 100 to 1,000 at intervals of 100.

A unified classification system is prerequisite for comparing different land cover products. All six products adopted variants of the IPCC classification system with varying levels of detail. Using the CLCD30 system as the baseline, categories were aggregated into a “harmonized type” system as shown in . For categories with small area proportions (water bodies, snow/ice, built-up areas, and wetlands), a separate accuracy assessment was conducted using 300 sample points to specifically analyze category-level precision. Wetlands were excluded from discussion due to their minimal area proportion, which rendered accuracy assessment results unrepresentative.

Confusion matrices were calculated for all six products, from which overall accuracy, Kappa coefficient, producer’s accuracy, and user’s accuracy were derived. Overall accuracy and Kappa coefficient evaluate general product performance, while producer’s and user’s accuracy assess precision and confusion levels for individual land cover types.

1.3.2 Category Confusion Evaluation While various accuracy metrics can statistically assess product precision, they fail to describe the degree of confusion between specific land cover categories. Therefore, confusion matrices were visualized as stacked bar charts to quantitatively analyze category confusion. Additionally, 30 m resolution products and 10 m resolution products were overlaid separately to obtain pixel-level spatial correspondence, which was classified into three types: complete consistency (all products agree), partial consistency (some products agree), and no consistency (all products differ). The causes of category confusion were then investigated from perspectives of data sources, mapping methods, classification systems, and spectral characteristics.

2. Results

2.1 Land Cover Characteristics of the Tianshan Mountains Urban Agglomeration

Following data preprocessing, the land cover composition of the study area was determined [Figure 2: see original paper]. Bareland dominates, accounting for over 50% of the total area and primarily distributed in the Gurbantünggüt Desert, the southern margin of the Junggar Basin, and regions between urban areas and the Tianshan Mountains. Cropland is concentrated around urban centers. Grassland is extensively distributed not only in low-altitude mountainous areas and around cities but also across the Gurbantünggüt Desert, though vegetation is mixed with bareland and difficult to distinguish clearly in imagery. Water bodies are mainly located in lakes, reservoirs, and mountain pools (e.g., Tianchi). Built-up areas cover approximately 1–2% of the region, while snow/ice

accounts for about 1–3% in high-altitude Tianshan Mountain areas. The combined area of bareland, cropland, and grassland exceeds 90% of the total study area.

2.2 Sample Accuracy Assessment Results

Visual interpretation of 960 sample points and 300 special-category points yielded confusion matrices for all six products [Figure 3: see original paper]. Overall accuracies and Kappa coefficients were similar across most products, all exceeding 0.78. The highest values were GLC10 (0.8531) and Globe30 (0.8147), followed by GLC_{FCS30} (0.8080), ESA10 (0.8047), and CLCD30 (0.7880). Esri10 showed significantly lower accuracy (0.4725).

For the three dominant categories, cropland achieved both producer's and user's accuracies above 0.85 across all products. Grassland showed substantial variation, with most producer's accuracies ranging from 0.70 to 0.85. Esri10 exhibited the lowest grassland producer's accuracy (0.4725), while GLC10 and ESA10 achieved the highest user's accuracies (0.8531 and 0.8047, respectively). Bareland accuracies were generally high, mostly between 0.75 and 0.95, though CLCD30 showed lower producer's accuracy (0.7880).

For categories with smaller area proportions: Forest showed moderate confusion, with producer's accuracies ranging from 0.70 to 0.85. Water body accuracies exceeded 0.85 across all products, with Globe30 achieving the highest user's accuracy (0.8147). Snow/ice categories showed strong performance except for Esri10, with producer's accuracies above 0.85 and GLC10 reaching the highest values (0.8531). Built-up areas displayed the largest variation among products, with GLC10 showing the highest producer's accuracy (0.8531) while Esri10 performed poorly (0.4725) [Figure 4: see original paper].

2.3 Category Confusion Evaluation Results

Confusion matrices visualized as stacked charts reveal that primary confusion occurs among cropland, grassland, and forest, as well as between these vegetation types and other categories [Figure 5: see original paper]. Built-up areas, grassland, and cropland show high mutual confusion because built-up areas and grassland are scattered within cropland, increasing landscape complexity. Snow/ice exhibits dynamic seasonal variation, transforming into bareland and water bodies (mountain pools) between winter and summer, which introduces classification challenges for annual products.

Spatial overlay analysis shows that 30 m resolution products (GLC_{FCS30}, Globe30, CLCD30) achieve 75.18% complete consistency, primarily in urban cropland, mountainous grassland and forest, and parts of the Gurbantünggüt Desert. Partial consistency regions are scattered across the study area, while no-consistency regions (4.482% for 30 m products) are concentrated at urban fringes where land cover types are mixed. The 10 m resolution products (GLC10, ESA10, Esri10) show similar patterns but with more extensive no-consistency

areas due to finer resolution revealing greater landscape heterogeneity [Figure 6: see original paper].

2.4 Impact of Sample Size on Accuracy Assessment

Accuracy assessment results are influenced by sample point quantity [Figure 7: see original paper]. When sample size is below 500, overall accuracy shows significant upward trends with an average fluctuation of 7.937%. When sample size exceeds 500, accuracy stabilizes with average fluctuation of 2.183%. Therefore, 500 samples are sufficient to reflect overall accuracy characteristics for major land cover types in this region. For minor categories (water bodies, snow/ice, built-up areas), 300 samples provide stable category-level accuracy assessment.

3. Discussion

This study evaluated six land cover data products in the Tianshan Mountains urban agglomeration. Results show that: (1) Five products (excluding Esri10) exhibit consistent type composition and area proportions, with bareland dominant, followed by grassland and cropland, and built-up areas, water bodies, and snow/ice accounting for 1–3%. (2) All products except Esri10 achieve overall accuracies around 0.80, indicating high quality. (3) For user-oriented applications, GLC_{FCS30} is recommended for cropland and bareland analysis; CLCD30 for forest and bareland; GLC10 for grassland, water bodies, snow/ice, and built-up areas; ESA10 for cropland and grassland; and Globe30 provides the most balanced performance across all categories.

Category confusion primarily involves mutual misclassification among cropland, forest, and grassland, particularly in complex transition zones between urban and mountainous areas. This pattern aligns with findings from the Yellow River Basin and Henan Province studies, highlighting that vegetation classification remains a critical challenge. The confusion indirectly contributes to poor built-up area accuracy in some products.

Resolution enhancement allows more detailed representation of land cover boundaries, avoiding the large-patch coverage issues of 30 m products. However, since sampling points represent single pixels, 10 m products do not demonstrate clear advantages in accuracy assessment over 30 m products. Additionally, temporal inconsistencies among products introduce errors, particularly for dynamic categories like water bodies in shrinking lakes (e.g., Ebinur Lake). Future research should incorporate more products to compensate for temporal discrepancies.

4. Conclusions

This study conducted theoretical sample accuracy assessment and category confusion evaluation for six land cover data products in the Tianshan Mountains region. The main conclusions are:

- 1) Among the six products, type composition and area proportions are similar (except Esri10), with bareland dominant, followed by grassland and cropland, and built-up areas, water bodies, and snow/ice comprising 1–3%.
- 2) All products except Esri10 achieve overall accuracies around 0.80, with minimal quality differences. When high resolution is not required, GLC_{FCS30} and Globe30 are adequate. These products perform well for cropland, water bodies, snow/ice, and bareland, though forest, grassland, and built-up area classifications need improvement.
- 3) For user-oriented applications, GLC10 is recommended for this region, providing the most balanced accuracy across categories. Other products offer specific advantages for particular land cover types.
- 4) Category confusion primarily involves cropland, forest, and grassland misclassification, especially in urban-mountain transition zones, resulting in low built-up area accuracy across all six products.

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