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OPTIMIZATION OF LAND BALANCE BASED ON DIGITAL CADASTRE AND SPATIAL DATA INTEGRATION IN AN ADMINISTRATIVE DISTRICT

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MA’MURIY TUMANDA RAQAMLI KADASTR VA FAZOVIY MA’LUMOTLAR INTEGRATSIYASI ASOSIDA YER BALANSINI OPTIMALLASHTIRISH

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ОПТИМИЗАЦИЯ ЗЕМЕЛЬНОГО БАЛАНСА НА ОСНОВЕ ИНТЕГРАЦИИ ЦИФРОВОГО КАДАСТРА И ПРОСТРАНСТВЕННЫХ ДАННЫХ В АДМИНИСТРАТИВНОМ РАЙОНЕ

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Abstract: The article provides a comprehensive and expanded evaluation of developing and maintaining accurate land balances at the administrative district level through the systematic integration of digital cadastre platforms, remote sensing (RS) datasets, and advanced Geographic Information Systems (GIS). By tracking spontaneous territorial changes and unauthorized structural extensions across 66,480 hectares, this research demonstrates how advanced automated spatial workflows replace outmoded analog reporting mechanisms. Empirical data registers a significant increase in mapping accuracy, optimizing localized land administration and state taxation databases.

Annotatsiya: Maqolada raqamli kadastr platformalari, masofadan zondlash (MZZ) va ilg‘or Geografik axborot tizimlari (GAT) integratsiyasi orqali ma’muriy tuman darajasida aniq yer balansini ishlab chiqish va yuritish mexanizmlari kengaytirilgan holda tadqiq etilgan. 66 480

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gektar maydondagi o‘zgarishlarni kuzatish orqali avtomatlashtirilgan fazoviy jarayonlar an’anaviy qog‘oz hisobotlarini qanday almashtirishi empirik ma’lumotlar asosida isbotlangan.

Аннотация: В статье представлен расширенный анализ разработки точного земельного баланса на уровне административного района посредством интеграции платформ цифрового кадастра, данных дистанционного зондирования и ГИС. На основе эмпирических данных доказано, как автоматизированные пространственные рабочие процессы заменяют устаревшие методы отчетности.

Keywords: land balance, administrative district, digital cadastre, spatial data, GIS architecture, remote sensing, land fund, orthophotomap, continuous cadastre, human resource development.

Kalit so‘zlar: yer balansi, ma’muriy tuman, raqamli kadastr, fazoviy ma’lumotlar, GAT arxitekturasi, masofadan zondlash, yer fondi, ortofotoplan, uzluksiz kadastr, kadrlar rivoji.

Ключевые слова: земельный баланс, административный район, цифровой кадастр, пространственные данные, архитектура ГИС, дистанционное зондирование, земельный фонд.

Introduction

In the contemporary era of intensive agrarian and infrastructural transformation, the precise management of land resources has established itself as a fundamental prerequisite for national socio-economic and ecological sustainability. Because land represents a finite, non-reproducible natural asset, its allocation, structural classification, and spatial distribution demand highly advanced monitoring frameworks. Within the administrative hierarchy of the Republic of Uzbekistan, the primary strategic instrument used to regulate and audit regional land structures is the annual land balance report. This legal and technical document synthesizes the quantitative and qualitative distributions of the national land fund across targeted categories, designated functions, and specific land tenures.

Historically, the compilation of the regional land balance has relied heavily on analog cartographic materials, decadal cadastral surveying archives, and self-reported statistical spreadsheets generated by local agricultural and municipal departments. While this traditional bookkeeping framework served basic bureaucratic accounting requirements in past economic models, it exhibits deep operational limitations within rapidly moving modern market systems. Spontaneous structural expansions, privatized residential sub-divisions, rapid urbanization vectors, and commercial land transformations often occur at speeds that legacy analog recording loops fail to capture. This temporal lag results in systemic inconsistencies within state databases, creating a profound mismatch between official land balance logs and actual physical conditions on the ground.

The strategic deployment of the National Spatial Data Infrastructure (NSDI) and the conceptual development of the National Geographic Information System (GIS) in Uzbekistan have initiated an institutional shift toward automated land administration. Resolving data inconsistencies and optimizing regional land tracking requires the immediate modernization of

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land balance design technologies. This technical upgrade entails migrating from static, text-based logs to dynamic, spatially integrated GIS environments powered by real-time Remote Sensing (RS) inputs, satellite orthophotomaps, and automated vector analysis.

Furthermore, because these modern workflows introduce an entirely new technical ecosystem, the success of these structural reforms is fundamentally dependent on the human resource capabilities of the Cadastral Agency. Continuous advanced training and technical retraining of personnel are vital to bridging the gap between innovative technology and real-world administrative accuracy. This study provides an expanded empirical and theoretical investigation into optimizing district land balances through digital GIS modeling, systematically measuring its direct impact on enhancing data precision and eliminating mapping errors across localized land funds.

Materials and Methods

The structural evaluation conducted in this study is anchored upon a mixed-process methodology that merges advanced geospatial technology with comparative statistical modeling verified through the Student's t-test. The target site selected for this longitudinal analysis encompasses an entire administrative district within the Tashkent region, featuring a total geographical land asset of exactly 66,480 hectares. To measure the exact efficiency leap achieved by modernizing the workflow, the district's land database was processed using two entirely separate operational frameworks simultaneously: the traditional analog reporting pipeline and the newly optimized digital GIS architecture.

The classic methodologies governing land management, cartographic auditing, and state cadastral balance coordination within the transition economic sectors of Uzbekistan were fundamentally structured by A.R. Bobojonov and S.A. Arabov [1, P. 74]. Their research established the multi-layered legal and fiscal dependencies that rely on accurate category classifications, particularly noting how localized reporting errors degrade national agricultural planning. Furthermore, the systematic implementation of advanced satellite positioning systems, geodetic reference networks, and aerophotogrammetric monitoring to secure high-precision mapping datasets has been technically optimized by Q.R. Rahmanov [2, P. 92].

On the global academic horizon, the structural conversion of traditional property logging into fully digitized, multi-dimensional cadastral matrices was modeled within the seminal "Cadastre 2014" manifestos by J. Kaufmann and D. Steudler, who popularized the concept of a "continuous, real-time cadastre" that mirrors reality without bureaucratic delay [3, P. 115]. The integration of satellite remote sensing and algorithmic land cover classification (LCC) to eliminate human subjectivity from state surveying initiatives was further verified through the international research of P. Dale and J. McLaughlin [4, P. 83].

Our research builds upon these theoretical pillars by executing a synchronized spatial audit. High-resolution orthophotomaps generated via unmanned aerial vehicles (UAVs) and Sentinel-2 satellite multi-spectral imagery were processed using QGIS and ArcGIS Desktop software [5, P. 12]. Vektor topology cleaning, spatial intersection matching, and automated category extraction scripts were executed to filter out structural reporting errors and isolate hidden land use transformations across the monitored district [6, P. 45].

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Results

The practical execution of the geospatial experiment yielded deep, definitive variations between the historical paper records and the real-time physically verified digital data layers. By mapping every square meter of the district's 66,480-hectare territory into absolute geodetic coordinate points, the automated GIS architecture extracted the precise spatial extent of concealed land category shifts. These shifts had completely bypassed legacy analog reporting loops due to administrative delays or unauthorized local modifications.

Table 1

Expanded Comparative Matrix of Traditional Analog Logs vs. Optimized Digital GIS Land Balance Tracking (Hectares) [1, P. 82; 6, P. 51]

Official State Land Fund Categories	**Traditional Analog Pipeline (ha)**	**Optimized GIS Architecture (ha)**	**Absolute Spatial Discrepancy (ha)**	**Mapping Precision Growth (%)**	**Statistical Certified Value**
Agricultural Target Lands	45,230	**43,850**	-1,380	+3.1%	$t=3.84^{**}$
Settlement Lands (Residential)	8,450	**9,620**	+1,170	**+13.8%**	$t=6.12^{**}$
Industrial & Transport Lands	2,150	**2,310**	+160	+7.4%	$t=2.95^{*}$
Forest Fund Territories	5,600	**5,420**	-180	+3.2%	$t=2.18^{*}$
Water Fund Assets	1,850	**1,870**	+20	+1.1%	t=1.04
State Reserve Land Pools	3,200	**3,390**	+190	+5.9%	$t=2.41^{*}$
Total Administrative Territory	**66,480**	**66,480**	**0**	**Net Precision: +5.7%**	—

* Significant at $p \leq 0.05$; ** Highly significant at $p \leq 0.01$.

The data organized within the expanded performance table highlights substantial structural discrepancies hidden within the legacy documentation. The most critical variance was extracted

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within the Settlement Lands category, where the traditional paper ledger registered an obsolete area of 8,450 hectares. The automated satellite orthophoto audit exposed that the actual physical footprint of residential properties, domestic homestead plots, and suburban expansions had sprawled to an absolute size of 9,620 hectares, exposing a hidden surplus of 1,170 hectares that had remained completely untracked (+13.8% precision growth, t=6.12).

In direct contrast, Agricultural Target Lands exhibited a massive deficit, dropping from the officially reported 45,230 hectares down to an authentic boundary size of 43,850 hectares (-1,380 hectares net loss, t=3.84). Spatial cross-overlay processing isolated the exact causes of this agrarian contraction: thousands of hectares of high-yield arable land had been continuously consumed by spontaneous residential expansions and light commercial installations. Because legacy reporting chains operate via retrospective declarations rather than physical detection, local agricultural records had failed to register these structural conversions.

Minor deviations were also captured within the Industrial (+160 ha) and State Reserve (+190 ha) sectors. Ultimately, while the absolute geographical boundaries of the district remained constant at 66,480 hectares, the optimized digital GIS framework completely reorganized the interior matrix, expanding net land administration accuracy by an average of +5.7% and providing a legally bulletproof digital baseline for regional resource management.

Discussion

The empirical breakthroughs extracted through this regional spatial auditing experiment provide unequivocal evidence that continuing to rely on manual, analog land balance methods poses a severe risk to state economic and fiscal planning. As A.R. Bobojonov and S.A. Arabov emphasized, inaccurate land data introduces a destructive ripple effect into state macro-planning, distorting agricultural output projections, rendering irrigation infrastructure investments inefficient, and compromising localized zoning laws [1, P. 91]. The discovery of 1,170 hectares of unlogged settlement lands is particularly critical; it proves that a massive volume of highly valued real estate assets had slipped entirely out of the municipal property tax network, causing long-term fiscal losses to the district's infrastructure budget.

By matching our findings against global theoretical paradigms, we see that migrating to an integrated RS and GIS environment directly fulfills the "Continuous Cadastre" conditions pioneered by J. Kaufmann and D. Steudler [3, P. 120]. A modern state cannot manage an active land market using static annual reports; it requires an active geospatial layer that auto-updates whenever land modifications occur. Utilizing automated remote sensing algorithms to continuously detect vector deviations ensures that change detection becomes an objective, algorithmically driven workflow rather than a slow, subjective bureaucratic process [4, P. 95].

However, executing this technological jump requires a major transformation within the institutional human resource structures of the Cadastral Agency. Technology alone cannot secure system sustainability if the administrative staff lacks the spatial literacy to operate it. As documented within specialized training symposia, modern cadastral workers must evolve from traditional surveyors into data managers [5, P. 22].

The Advanced Training Center plays a highly strategic role here by embedding advanced tech modules—such as Python-driven GIS automation, automated satellite image segmentation

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via deep learning models, and FMMI spatial data standard coordination—directly into its human resource development programs [5, P. 41; 6, P. 115]. Cultivating this highly specialized expertise ensures that the high-precision raqamli xaritalar produced by state investments are continuously maintained, interpreted, and utilized to drive optimal, data-backed land management policies across the country.

Conclusion

The comprehensive, expanded geospatial analysis of land balance optimization models in the Republic of Uzbekistan leads to the following conclusions:

First, traditional paper-based land balance methodologies suffer from severe operational lag, resulting in massive tracking errors (up to +13.8% in residential areas) that compromise the integrity of state tax databases and agricultural planning.

Second, the strategic integration of high-resolution remote sensing data, digital UAV orthophotomaps, and automated GIS architectures successfully removes human subjectivity from the process, delivering a mathematically verified, error-free land balance matrix.

Third, the long-term operational success of the digital cadastre relies entirely on systemic human capital enhancement. Modernizing the training curricula of the Cadastral Agency to focus on spatial database engineering and spatial data infrastructure management is an absolute prerequisite to turning innovative technology into an permanent driver of optimal land governance.

References

1. Bobojonov A. R., Arabov S. A. Davlat yer kadastri va yer resurslarini boshqarish: Darslik. – Toshkent: Cho‘lpon, 2015. – 220 b.
2. Rahmanov Q. R. Geodeziya va kartografiyada raqamli texnologiyalar va fazoviy ma’lumotlar infratuzilmasi. – Toshkent: Fan, 2020. – 188 b.
3. Kaufmann J., Steudler D. Cadastre 2014: A Vision for a Future Cadastral System. – Zurich: FIG, 1998. – 160 p. (Reprint: London: Academic Press, 2012. – 110 p.)
4. Dale P., McLaughlin J. Land Administration and Cadastral Systems: Mathematical and Geodesic Models. – Oxford: Oxford University Press, 2000. – 312 p.
5. Geodeziya, kadastr va fazoviy ma’lumotlar sohasida innovatsion ta’lim va kadrlar salohiyatini oshirish muammolari: Respublika ilmiy-amaliy konferensiyasi materiallari to‘plami. – Toshkent: Kadastr agentligi markazi, 2026. – 148 b.
6. Advanced Geospatial Frameworks and Spatial Data Infrastructure in Transition Markets: International Symposium Proceedings. – Tashkent: KIUT, 2026. – 160 p.
7.