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Landscape-Scale Assessment of Gully Erosion Distribution in the Tashkent Region, Uzbekistan: Elevation, Basin, and Anthropogenic Controls

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Abstract

Gully erosion is a major but poorly documented driver of land degradation across the irrigated plains and foothill zones of Central Asia. This study presents the first comprehensive, landscape-scale inventory of gully erosion in the Tashkent region, Uzbekistan (14,995.7 km²), combining high-resolution imagery (Google Earth Pro) with GIS-based landscape mapping (ArcGIS) and field verification. Gullies were manually digitized and analyzed across 50 landscape units, four major river basins (Syrdarya, Chirchiq, Ohangaron, and Gijigen), and successive elevation zones. Gullies occupy 345.4 km² (2.30%) of the study area overall, yet reach 30–40% of surface area within individual landscape units, particularly in foothill zones between 300 and 600 m a.s.l. The Gijigen and Chirchiq basins account for the largest share of regional gully area (30.5% and 29.8%, respectively), while Gijigen shows the highest within-basin gully density (10.90%). The results indicate a significant relationship between gully prevalence and both elevation zonality and irrigation-related land use. These findings provide the first empirical baseline for basin-level erosion management in the Tashkent region and demonstrate that even landscapes of modest overall extent can host severe, spatially concentrated degradation, supporting targeted soil conservation planning in the irrigated foothill environments of Central Asia.

Introduction

Soil erosion, and particularly gully formation, is recognized worldwide as one of the most damaging forms of land degradation (Montanarella et al., 2016). It removes fertile topsoil, reduces agricultural productivity, and intensifies ecological and economic pressures. Increasing human activity and unsustainable land use have accelerated soil erosion globally (Hooke, 2000; Montgomery, 2007; Boardman & Poesen, 2006; Maetens et al., 2012; Vanacker et al., 2014; García-Ruiz et al., 2015; Vanmaercke et al., 2015; Tarolli & Sofia, 2016; Goudie & Viles, 2016; Vanwalleghem et al., 2017). While erosion has been extensively studied worldwide (Poesen, 2017; Castillo & Gómez, 2016), the Tashkent region remains one of the least-documented areas, motivating the present study.

The Tashkent region, in northeastern Uzbekistan, encompasses a wide range of geomorphological settings — river valleys and terraces, foothill plains and uplands, and low-, medium-, and high-mountain zones. Irrigated agriculture, deforestation, and open-pit quarrying have intensified gully erosion across the region, yet no systematic, region-wide assessment has previously been conducted.

A substantial body of research has applied spatial modeling to gully erosion risk, using logistic regression (Ayalew & Yamagishi, 2005; Conoscenti et al., 2013), multivariate statistics (Akgün & Türk, 2011), and machine-learning approaches (Oh & Pradhan, 2011; Razavi-Termeh et al., 2020). Review studies (Castillo & Gómez, 2016; Vanmaercke et al., 2021) emphasize the need for comprehensive, multidisciplinary research to better understand gully formation and its spatial variability. Recent basin-scale assessments combining satellite imagery with frequency-ratio and machine-learning approaches (Laraib et al., 2024) have reaffirmed the value of such multidisciplinary, basin-level erosion planning. A comparable basin-approach to gully density mapping has also proven effective across extensive plain

landscapes of the Russian Plain (Golosov et al., 2018), reinforcing the applicability of basin-level gully inventories across contrasting geomorphological settings. Classical work has linked gully initiation to hillslope hydrology, soil erodibility, and runoff accumulation (Bryan, 2000; Kirkby & Bracken, 2009; Valentin et al., 2005), with field studies across Spain, Canada, and Laos (Casalí et al., 1999; Burkard & Kostaschuk, 1997; Chaplot et al., 2005) confirming that both natural conditions and land-use practices jointly govern gully expansion and magnitude.

In a related preliminary study, a DEM-based Weighted Overlay hazard model (slope, flow accumulation, and aspect) was developed for the Tashkent region and validated against an independent, Google Earth Pro–derived gully inventory, showing that the high-hazard class captured 78–82% of mapped gullies (Sharipov & Samatova, 2025). That study confirmed the overall reliability of relief-based hazard prediction for the region but did not examine the spatial distribution of gully erosion across landscape units, elevation zones, or river basins — information that is essential for basin-level management planning.

Despite these advances, three gaps remain: (1) a lack of empirical, landscape-scale data for the Tashkent region despite its extensive irrigation-based agriculture and grazing pressure; (2) insufficient incorporation of elevation zonality into gully erosion studies, despite its strong influence on hydrology and land-use dynamics; and (3) a weak link between gully erosion mapping and basin-level management planning.

This study addresses these gaps by providing a landscape-scale, GIS-based inventory of gully erosion in the Tashkent region, supported by field verification, and building on the validated hazard-modeling framework of Sharipov and Samatova (2025) with a detailed empirical account of gully distribution by landscape unit, elevation zone, and river basin.

Materials and methods

Study area

The study was conducted in the Tashkent region, located in northeastern Uzbekistan. Water bodies (rivers, reservoirs, and lakes) were excluded from the analysis, yielding a total study area of 14,995.7 km². The region is characterized by a semi-arid continental climate and a diverse range of geomorphological settings, including river valleys and terraces, foothill plains, and low-, medium-, and high-mountain zones. Land resources are used primarily for irrigated agriculture, livestock grazing, mining, and forestry.

Gully mapping and landscape classification

Gully mapping followed a five-step GIS workflow. First, high-resolution satellite imagery covering the full extent of the Tashkent region was systematically reviewed in Google Earth Pro at a consistent viewing scale (approximately 1:5,000–1:10,000), sufficient to resolve individual gully channels. Second, gully

features were manually identified and digitized as polygons using standard visual-interpretation criteria: channel connectivity to an established drainage line, a V-shaped cross-sectional morphology visible from the characteristic shadow pattern, and the absence of continuous vegetation cover along the incision. These criteria are consistent with the digitization protocol applied in a related regional hazard-modeling study (Sharipov & Samatova, 2025). Third, the resulting 748 gully polygons were exported in shapefile format and imported into ArcGIS, where topology checks were performed to remove overlapping or duplicate polygons. Fourth, the cleaned gully layer was spatially intersected with a pre-existing landscape classification map of the Tashkent region (50 landscape units, delineated by Sharipov, 2022) using the ArcGIS Intersect and Summarize Statistics tools, yielding gully area and share (%) for each landscape unit. Fifth, each landscape unit was assigned to one of the four main river basins of the region (Syrdarya, Chirchiq, Ohangaron, and Gijigen) based on its hydrographic position, determined from the basin boundary layer; landscape units situated across multiple basins or in unclassified upper-mountain zones were grouped separately as an "other/multi-basin" category rather than force-assigned to a single basin. This descriptive, GIS-based mapping approach parallels other recent studies that combined satellite imagery interpretation with GIS analysis to characterize gully development without predictive modeling (Real et al., 2020).

Field verification

To assess the accuracy of the Google Earth Pro–based digitization, field measurements were carried out at three representative gully sites, where cross-sectional profiles were recorded in situ and compared against the corresponding remotely digitized boundaries. This targeted verification, while limited in spatial coverage relative to the full inventory (n = 748), confirmed the reliability of the visual-interpretation criteria applied across the dataset; broader field-based validation remains a priority for future work.

Statistical analysis

Descriptive statistics (area, gully share by landscape unit, elevation zone, and river basin) were computed for all gully-bearing landscape sub-units (n = 102). The relationship between landscape elevation and gully share was assessed using Pearson's correlation coefficient; a weak but statistically significant negative correlation was found across the full elevation gradient ($r = -0.231$, $p = 0.020$), consistent with the sharp decline in gully activity above the foothill zone. A comparison of mean gully share between the foothill zone (300–600 m a.s.l.) and all other elevations showed a higher, though not statistically significant, mean value within the foothill zone (6.38% vs. 4.86%; Welch's $t = 1.00$, $p = 0.323$), reflecting the substantial within-group variability documented in Table S1. No significant relationship was found between landscape unit area and gully share ($r = 0.016$, $p = 0.874$), indicating that the intensity of gully degradation is independent of landscape size. All statistical analyses were performed in Python (SciPy v1.x).

Table 1
Gully erosion distribution by river basin

River basin	Basin area (km²)	Gullied area (km²)	Gully share within basin (%)	Share of total regional gully area (%)
Gijigen	967.06	105.39	10.90	30.5
Chirchiq	2868.72	102.81	3.58	29.8
Ohangaron	1166.05	78.32	6.72	22.7
Syrdarya	611.06	48.97	8.01	14.2
Other (unclassified/mountain tributaries)	8586.41	9.94	0.12	2.9
Total	14,199.30	345.43	—	100

Table 2
Top 10 landscape units by gully share (%)

Rank	Landscape unit	River basin	Elevation range (m)	Unit area (km²)	Gullied area (km²)	Gully share (%)
1	7 – 2 (right of Syrdarya)	Syrdarya	280–310	107.20	43.84	40.9
2	11 – 3 (left of Ohangaron)	Ohangaron	380–420	82.52	30.34	36.8
3	12–15 (left of Gijigen)	Gijigen	280–290	17.46	5.29	30.3
4	3–17 (right of Ohangaron)	Ohangaron	400–410	2.44	0.49	20.0
5	14 – 12 (left of Gijigen)	Gijigen	290–410	133.60	24.58	18.4
6	13 – 3 (left of Chirchiq)	Chirchiq	470–590	22.75	4.17	18.3
7	14 – 10 (left of Ohangaron)	Ohangaron	350–370	22.22	3.67	16.5
8	12–14 (left of Gijigen)	Gijigen	290–410	247.20	39.59	16.1
9	4–11 (right of Syrdarya)	Syrdarya	290–440	2.82	0.45	16.0
10	12–16 (left of Ohangaron)	Ohangaron	410–450	27.79	4.42	15.9

Results and discussion

Distribution by river basin

Across the Tashkent region (14,995.7 km²), gully erosion was mapped over 345.4 km² of land (Fig. 1), corresponding to 2.30% of the total study area. This overall figure, however, conceals substantial spatial heterogeneity: gully share varied from 0% in extensive mountain and lowland zones to over 40% within individual landscape units (Table 2).

At the basin scale (Table 1; Fig. 2), the Gijigen basin recorded both the highest within-basin gully density (10.90% of its 967.1 km² area) and the largest share of the region's total gullied land (30.5%), closely followed by the Chirchiq basin (29.8% of the regional total, though a lower within-basin density of 3.58% owing to its considerably larger overall area, 2,868.7 km²). The Ohangaron basin accounted for 22.7% of the regional gullied area (6.72% within-basin density), while the Syrdarya basin, despite its comparatively small area (611.1 km²), showed the second-highest within-basin density (8.01%) among the four main basins. As Fig. 2 illustrates, absolute gullied area and within-basin density do not track one another: Chirchiq ranks second by absolute area but lowest by density among the four named basins, whereas Gijigen and Syrdarya combine comparatively small areas with the highest densities. This divergence indicates that absolute extent and relative intensity capture different dimensions of degradation risk and should be considered jointly when setting management priorities. Landscape units situated in upper-mountain or multi-basin zones together contributed only 2.9% of the regional gullied area, confirming that gully erosion in the Tashkent region is concentrated almost exclusively within the four principal river basins.

This basin-differentiated pattern has direct management implications. The Chirchiq basin, despite its large area and comparatively low within-basin density, contributes nearly 30% of the region's total gullied land in absolute terms, warranting basin-wide, extensive conservation planning. In contrast, the Gijigen and Syrdarya basins — smaller in area but exhibiting the highest within-basin densities — require targeted, intensive intervention within a comparatively confined geographic footprint. This basin-differentiated pattern directly addresses the third research gap identified in the Introduction: the previously weak link between gully erosion mapping and basin-level management planning.

Distribution by landscape unit and elevation

The ten most severely affected landscape units (Table 2; Fig. 3) were distributed across three of the four basins — Ohangaron (4 units), Gijigen (3 units), Syrdarya (2 units), and Chirchiq (1 unit) — with gully shares ranging from 15.9% to 40.9%. The single most affected unit, located on the right bank of the Syrdarya River (elevation 280–310 m), showed gullies covering 40.9% of its 107.2 km² area. Notably, several of the most severely affected units were relatively small in absolute terms (e.g., unit 3–17, 2.44 km²; unit 4–11, 2.82 km²), underscoring that landscape size is not a determinant of relative degradation severity.

Across the full set of 102 gully-bearing landscape sub-units, a weak but statistically significant negative correlation was found between elevation and gully share ($r = -0.231$, $p = 0.020$). Figure 3 clarifies why this

linear coefficient understates the true spatial pattern: gully-bearing units are concentrated at low-to-moderate elevations (below approximately 600 m), where both the highest individual gully shares (up to 40.9%) and the greatest scatter in values occur, while units above roughly 800 m show consistently low and narrowly distributed gully shares (mostly below 5%). This reflects a threshold-like decline in gully activity above the foothill zone rather than a gradual, linear one. When the foothill zone (300–600 m a.s.l.) — the elevation range most frequently associated with irrigation-driven erosion in the descriptive analysis — was compared against all other elevations, mean gully share was higher within the foothill zone (6.38% vs. 4.86%), although this difference did not reach statistical significance (Welch's $t = 1.00$, $p = 0.323$), reflecting the high within-group variability visible in Fig. 4 and documented in Table S1. The non-significance of this comparison should not be read as evidence against a foothill effect; rather, as Fig. 4 shows, the effect is better characterized as an elevated ceiling on gully severity within the foothill zone (individual units reaching 30–40%) rather than a uniformly elevated mean, a distinction a simple two-group mean comparison cannot fully capture.

This elevation pattern contrasts with findings from the Mediterranean and East Asia, where lowland areas are typically identified as the most erosion-prone zones (Casalí et al., 1999; Chaplot et al., 2005). In the Tashkent region, the combination of steep foothill slopes, erodible soils, and intensive irrigated agriculture appears to displace the zone of maximum instability upslope relative to these previously studied regions. This elevation-dependent decline is also consistent with mountainous-catchment studies identifying weakly aggregated, barren high-elevation soils as disproportionately erosion-prone (David Raj et al., 2024), further supporting the interpretation that relief and land use jointly govern erosion intensity across elevation gradients. This finding extends the discussion initiated by Bryan (2000), Kirkby and Bracken (2009), and Valentin et al. (2005) on the role of hillslope hydrology and land use in gully initiation, suggesting that elevation-dependent land-use intensity, rather than elevation itself, may be the more direct driver — a hypothesis that future work incorporating land-use classification at the sub-unit level could test directly.

Independence from landscape size

No significant relationship was found between landscape unit area and gully share ($r = 0.016$, $p = 0.874$). This indicates that the intensity of gully degradation, expressed as a proportion of local area, operates independently of landscape size — small landscape units are statistically as likely to exhibit severe relative degradation as large ones (Table 2, units 3–17 and 4–11). By contrast, absolute gullied area (km^2) was moderately and significantly correlated with landscape unit area ($r = 0.400$, $p < 0.001$), as expected for an extensive-quantity measure: larger units simply have more surface area over which a given gully density can accumulate, without that density itself increasing.

The overall gully coverage found in this study (2.30% of the Tashkent region) is broadly consistent with anthropogenically driven gully erosion rates reported across irrigated semi-arid landscapes elsewhere (Hooke, 2000; Montgomery, 2007; Boardman & Poesen, 2006; Maetens et al., 2012; Vanacker et al., 2014; García-Ruiz et al., 2015; Vanmaercke et al., 2015; Tarolli & Sofia, 2016; Goudie & Viles, 2016;

Vanwalleghem et al., 2017), while the sharply higher, spatially concentrated values found within specific landscape units (up to 40.9%; Table 2; Fig. 3) align with global observations that aggregate regional statistics can substantially understate the severity of localized degradation (Castillo & Gómez, 2016; Vanmaercke et al., 2021). This distinction between absolute and relative gully coverage is directly confirmed by the statistical independence between landscape size and gully share found in this study: mitigation priorities based solely on absolute gullied area risk overlooking small but severely degraded landscape units. This semi-arid regional pattern parallels basin-scale assessments elsewhere, where combined rainfall and vegetation controls, together with irrigation practices, similarly shape erosion severity in semi-arid river basins (Kaliraj et al., 2025).

Relationship to the companion hazard-modeling study

These findings complement the DEM-based Weighted Overlay hazard model previously developed and validated for this region (Sharipov & Samatova, 2025), which demonstrated that relief-based factors (slope, flow accumulation, aspect) captured 78–82% of mapped gullies within its high-hazard class. The present landscape-scale analysis extends that work by showing where, within the region, this hazard is realized most severely — namely, within specific foothill landscape units of the Ohangaron, Gijigen, and Syrdarya basins (Table 2; Fig. 3) — and by basin (Fig. 2), information not resolved by the hazard model alone. Together, the two studies suggest a two-tier planning approach: the relief-based hazard model of Sharipov and Samatova (2025) for rapid, region-wide screening, and the present landscape/basin inventory for prioritizing specific management units within high-hazard zones.

Limitations

Several limitations should be acknowledged. First, field verification was restricted to cross-sectional profile measurements at three representative gully sites, a small fraction of the 748 digitized features; while these measurements supported the reliability of the visual-interpretation criteria used, broader ground-truthing — ideally a stratified random sample across basins and elevation zones — remains a priority for future work. Second, a subset of landscape units (jointly accounting for approximately 5% of the study area) could not be unambiguously assigned to a single hydrographic basin, either because they span multiple basins or lie within unclassified upper-mountain zones; these were reported separately (Table 1) rather than force-assigned, and their exclusion does not affect the region-wide gully-area total, which is based on direct polygon digitization rather than basin summation. Third, the foothill-zone comparison, while directionally consistent with the descriptive elevation pattern shown in Fig. 4, did not reach statistical significance, reflecting substantial within-zone variability; this should be interpreted as suggestive rather than conclusive evidence of an elevation threshold effect.

Notwithstanding these limitations, this study provides the first landscape-scale, basin-differentiated empirical inventory of gully erosion for the Tashkent region — addressing a documented data gap for Central Asia (Poesen, 2017) — and demonstrates, through direct statistical testing rather than description alone, that relative gully severity is independent of landscape size while remaining strongly

basin- and elevation-dependent. This dual finding provides a quantitative basis for prioritizing both basin-wide and unit-specific conservation measures in irrigated foothill environments more broadly.

Conclusions

This study provides the first landscape-scale, GIS-based inventory of gully erosion in the Tashkent region (Fig. 1), based on 748 digitized gully features covering 345.4 km² (2.30%) of the 14,995.7 km² study area. Although this regional figure is modest, individual landscape units reached gully shares of up to 40.9%, and this severity was shown to be statistically independent of landscape size — confirming that small landscape units can be as critically degraded as large ones. Gully distribution differed markedly by river basin: the Gijigen and Chirchiq basins together accounted for over 60% of the region's total gullied area, while the Gijigen and Syrdarya basins exhibited the highest within-basin densities. A weak but significant negative correlation between elevation and gully share, together with a higher, though not statistically significant, mean gully share within the 300–600 m foothill zone, points to irrigation-driven foothill instability as a defining feature of gully erosion in this semi-arid region — distinguishing it from patterns reported in lowland-dominated erosion studies elsewhere.

Together with the previously validated DEM-based hazard model for this region, these findings support a two-tier approach to erosion management: relief-based hazard screening at the regional scale, followed by basin- and landscape-unit-specific conservation planning informed by the empirical distribution reported here. Future research should prioritize expanded field-based validation of the gully inventory across a stratified sample of basins and elevation zones, incorporation of land-use classification at the sub-unit level to test whether irrigation intensity — rather than elevation per se — drives the observed foothill concentration, and temporal monitoring using multi-date remote sensing to assess rates of gully expansion under ongoing land-use change.

Declarations

Competing interests:

The authors have no relevant financial or non-financial interests to disclose.

Ethics approval:

Not applicable. This study did not involve human participants, human data, or animals.

Consent to participate:

Not applicable.

Consent to publish:

Not applicable.

Statement:

All authors have read, understood, and have complied as applicable with the statement on "Ethical responsibilities of Authors" as found in the Instructions for Authors.

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Author Contribution

Sh.M. Sharipov: Conceptualization, Methodology, Supervision.N.R. Samatova: Writing, Data curation, Formal analysis, Investigation.Sh.I. Mukhtorova: Writing – review and editing.M.R. Gudalov: Analysis of tables and diagrams.I.E. Karimov: Map compilation and cartographic layout.

Data Availability

https://zenodo.org/records/23310546

References

1. Akgün, A. & Türk, N. Mapping erosion susceptibility by a multivariate statistical method: A case study from Ayvalık region, NW Turkey. *Comput. Geosci.* **37** (9), 1515–1524. https://doi.org/10.1016/j.cageo.2010.09.006 (2011).
2. Ayalew, L. & Yamagishi, H. The application of GIS-based logistic regression for landslide susceptibility mapping in the Kakuda–Yahiko Mountains, Central Japan. *Geomorphology* **65** (1–2), 15–31. https://doi.org/10.1016/j.geomorph.2004.06.010 (2005).
3. Boardman, J. & Poesen, J. (eds) *Soil erosion in Europe* (Wiley, 2006).
4. Bryan, R. B. Soil erodibility and processes of water erosion on hillslopes. *Geomorphology* **32** (3–4), 385–415. https://doi.org/10.1016/S0169-555X(99)00105-1 (2000).
5. Burkard, M. B. & Kostaschuk, R. A. Patterns and controls of gully growth along the shoreline of Lake Huron. *Earth. Surf. Proc. Land.* **22** (10), 901–911 (1997).
6. Casalí, J., López, J. J. & Giráldez, J. V. Ephemeral gully erosion in southern Navarra (Spain). *Catena* **36** (1–2), 65–84. https://doi.org/10.1016/S0341-8162(99)00013-2 (1999).

7. Castillo, C. & Gómez, J. A. A century of gully erosion research: Urgency, complexity and study approaches. *Earth Sci. Rev.* **160**, 300–319. https://doi.org/10.1016/j.earscirev.2016.07.009 (2016).
8. Chaplot, V., Giboire, G., Marchand, P. & Valentin, C. Dynamic modelling for linear erosion initiation and development under climate and land-use changes in northern Laos. *Catena* **63** (2–3), 318–328. https://doi.org/10.1016/j.catena.2005.06.008 (2005).
9. Conoscenti, C. et al. Gully erosion susceptibility assessment by means of GIS-based logistic regression: A case of Sicily (Italy). *Geomorphology* **204**, 399–411. https://doi.org/10.1016/j.geomorph.2013.08.021 (2013).
10. David Raj, A., Kumar, S., Sooryamol, K. R., George, K. & J Soil erodibility mapping using remote sensing and in situ soil data with random forest model in a mountainous catchment of Indian Himalayas. *Environ. Monit. Assess.* **196**, 1032. https://doi.org/10.1007/s10661-024-13173-1 (2024).
11. García-Ruiz, J. M. et al. A meta-analysis of soil erosion rates across the world. *Geomorphology* **239**, 160–173. https://doi.org/10.1016/j.geomorph.2015.03.008 (2015).
12. Golosov, V. et al. Mapping and spatial-temporal assessment of gully density in the Middle Volga region, Russia. *Earth. Surf. Proc. Land.* **43** (13), 2818–2834. https://doi.org/10.1002/esp.4435 (2018).
13. Goudie, A. S. & Viles, H. A. *Geomorphology in the Anthropocene* (Cambridge University Press, 2016).
14. Hooke, R. L. On the history of humans as geomorphic agents. *Geology* **28**, 843–846 (2000).
15. Kaliraj, S., Anoop Krishnan, K., Suresh, D., Kasivisvanathan, K. S. & Chandrasekar, N. Evaluating soil erosion patterns and potential impacts of rainfall and vegetation index in the semi-arid river basin of southern India. *Environ. Monit. Assess.* **197**, 848. https://doi.org/10.1007/s10661-025-14277-y (2025).
16. Kirkby, M. J. & Bracken, L. J. Gully processes and gully dynamics. *Earth. Surf. Proc. Land.* **34** (14), 1841–1851. https://doi.org/10.1002/esp.1866 (2009).
17. Laraib, S. et al. Assessment of gully influencing factors and susceptibility using remote sensing-based frequency ratio method in Sunshui River Basin, Southwest China. *Environ. Monit. Assess.* **196**, 731. https://doi.org/10.1007/s10661-024-12889-4 (2024).
18. Maetens, W., Poesen, J. & Vanmaercke, M. How effective are soil conservation techniques in reducing plot runoff and soil loss in Europe and the Mediterranean? *Earth Sci. Rev.* **115**, 21–31. https://doi.org/10.1016/j.earscirev.2012.08.003 (2012).
19. Montanarella, L. et al. World's soils are under threat. *SOIL* **2** (1), 79–82. https://doi.org/10.5194/soil-2-79-2016 (2016).
20. Montgomery, D. R. Soil erosion and agricultural sustainability. Proceedings of the National Academy of Sciences, 104(33), 13268–13272. (2007). https://doi.org/10.1073/pnas.0611508104
21. Oh, H. J. & Pradhan, B. Application of a neuro-fuzzy model to landslide-susceptibility mapping for shallow landslides in a tropical hilly area. *Comput. Geosci.* **37** (9), 1264–1276. https://doi.org/10.1016/j.cageo.2010.10.012 (2011).

22. Poesen, J. Soil erosion in the Anthropocene: Research needs. *Earth. Surf. Proc. Land.* **43** (1), 64–84. https://doi.org/10.1002/esp.4250 (2017).
23. Razavi-Termeh, S. V., Sadeghi-Niaraki, A. & Choi, S. M. Gully erosion susceptibility mapping using artificial intelligence and statistical models. *Geomatics Nat. Hazards Risk*. **11** (1), 821–845. https://doi.org/10.1080/19475705.2020.1753824 (2020).
24. Real, L. S. C., Crestana, S., Ferreira, R. R. M. & Rodrigues, V. G. S. Evaluation of gully development over several years using GIS and fractal analysis: a case study of the Palmital watershed, Minas Gerais (Brazil). *Environ. Monit. Assess.* **192**, 434. https://doi.org/10.1007/s10661-020-08362-7 (2020).
25. Sharipov, S. M. Issues of preserving landscape diversity and improving the geoecological situation of the Tashkent region [Doctoral dissertation]. Tashkent. (2022).
26. Sharipov, S. M. & Samatova, N. R. Soil erosion risk in Tashkent region: DEM and GIS analysis. *FarDU Ilmiy Xabarlar — Sci. J. Fergana State Univ.* **31** (6), 254–261 (2025).
27. Tarolli, P. & Sofia, G. Human topographic signatures and derived geomorphic processes across landscapes. *Geomorphology* **255**, 140–161. https://doi.org/10.1016/j.geomorph.2015.12.007 (2016).
28. Valentin, C., Poesen, J. & Li, Y. Gully erosion: Impacts, factors and control. *Catena* **63** (2–3), 132–153. https://doi.org/10.1016/j.catena.2005.06.001 (2005).
29. Vanacker, V., Bellin, N., Molina, A. & Kubik, P. W. Erosion regulation as a function of human disturbances to vegetation cover: A conceptual model. *Landscape Ecol.* **29** (2), 293–309. https://doi.org/10.1007/s10980-013-9964-5 (2014).
30. Vanmaercke, M. et al. Measuring, modelling and managing gully erosion at large scales: A state of the art. *Earth Sci. Rev.* **218**, 103637. https://doi.org/10.1016/j.earscirev.2021.103637 (2021).
31. Vanmaercke, M., Poesen, J., Govers, G. & Verstraeten, G. Quantifying human impacts on catchment sediment yield: A continental approach. *Glob. Planet Change*. **130**, 22–36. https://doi.org/10.1016/j.gloplacha.2015.04.001 (2015).
32. Vanwalleghem, T. et al. Impact of historical land use and soil management change on soil erosion and agricultural sustainability during the Anthropocene. *Anthropocene* **17**, 13–29. https://doi.org/10.1016/j.ancene.2017.01.002 (2017).

Figures

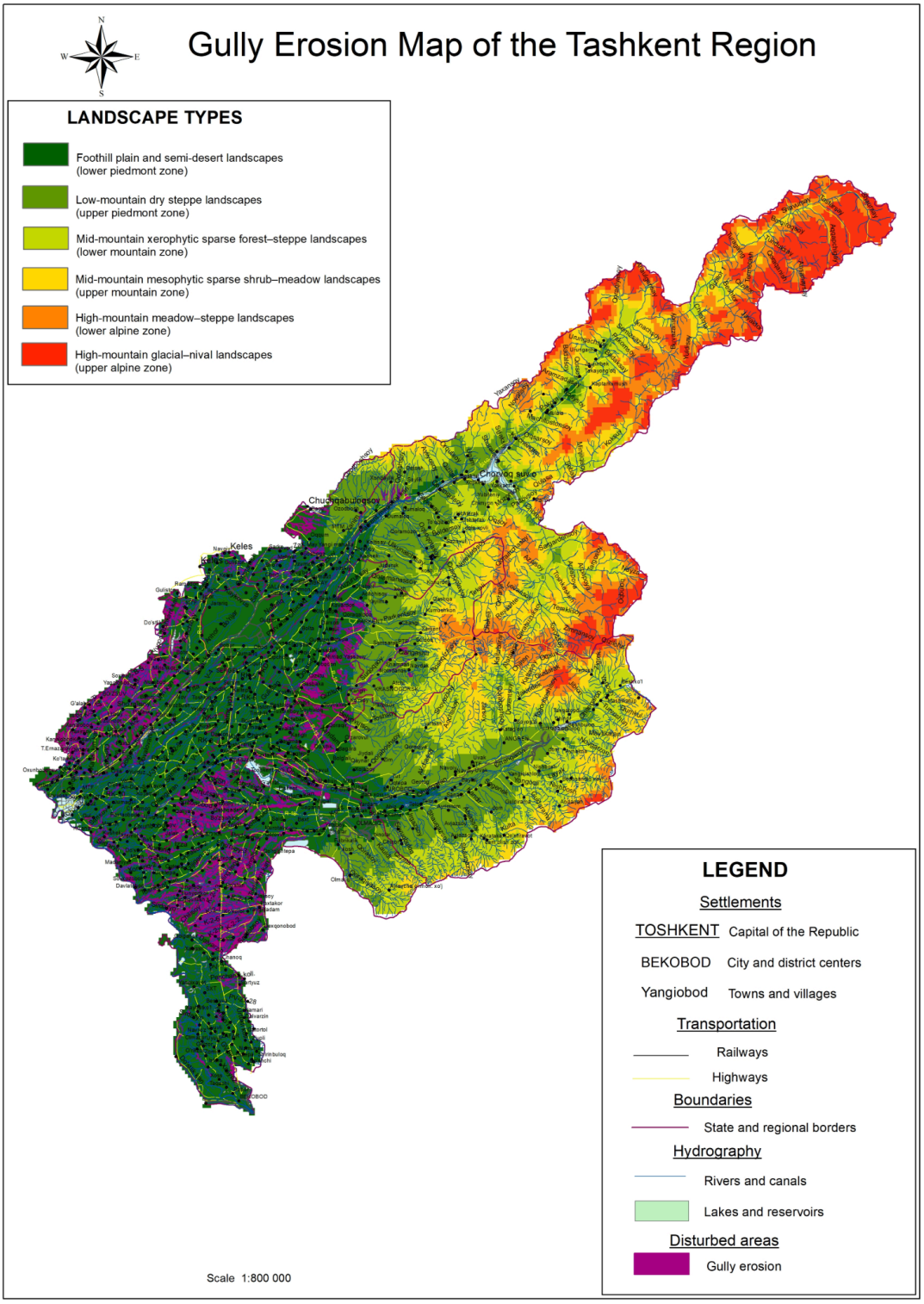


Figure 1

Gully erosion map of the Tashkent region, showing landscape types (piedmont to high-mountain zones) and mapped disturbed/gullied areas (magenta) across the four main river basins. Scale 1:800,000.

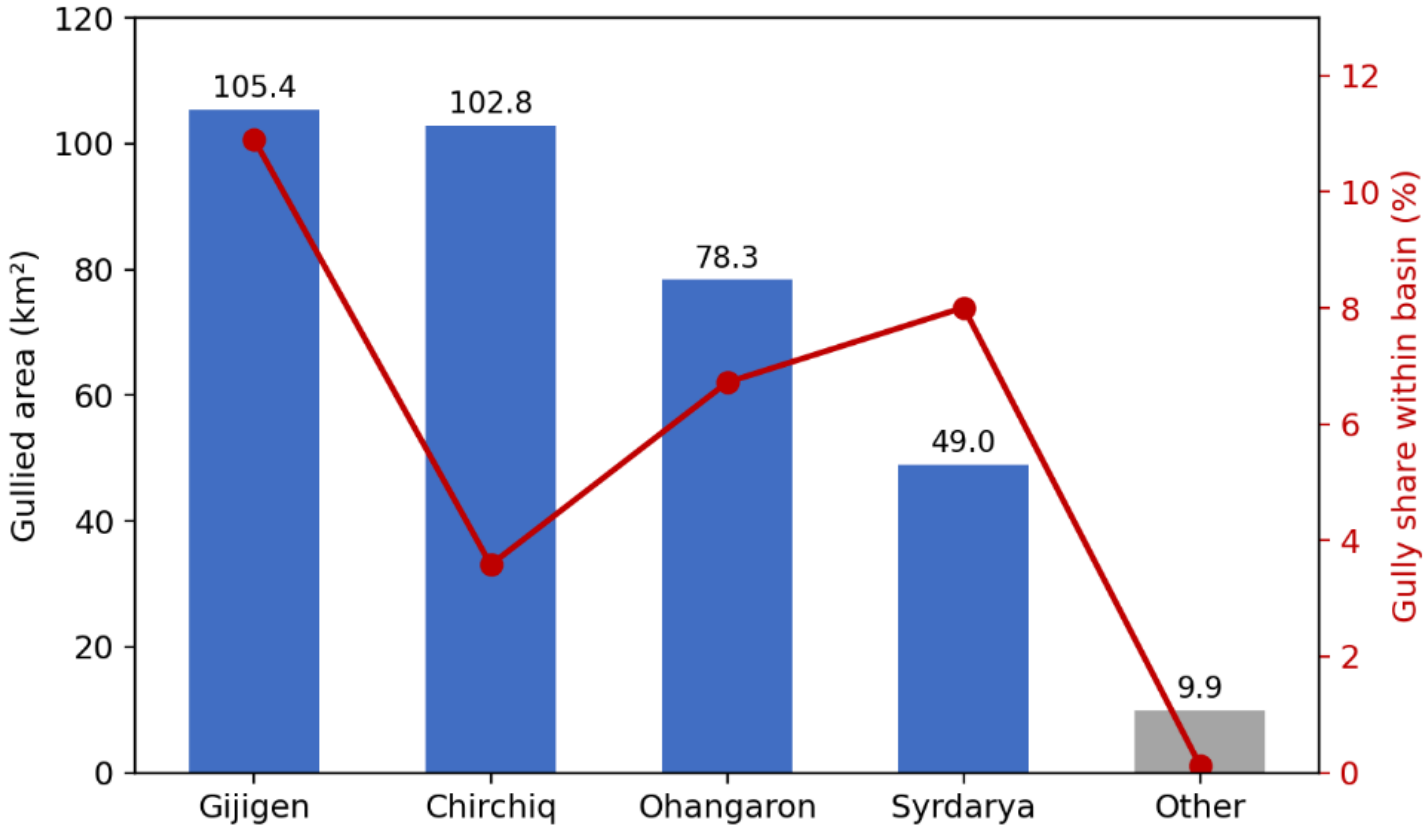


Figure 2

Gullied area (bars, left axis) and within-basin gully share (red line, right axis) for the four main river basins and the unclassified/multi-basin category. Absolute area and relative density follow different rankings across basins.

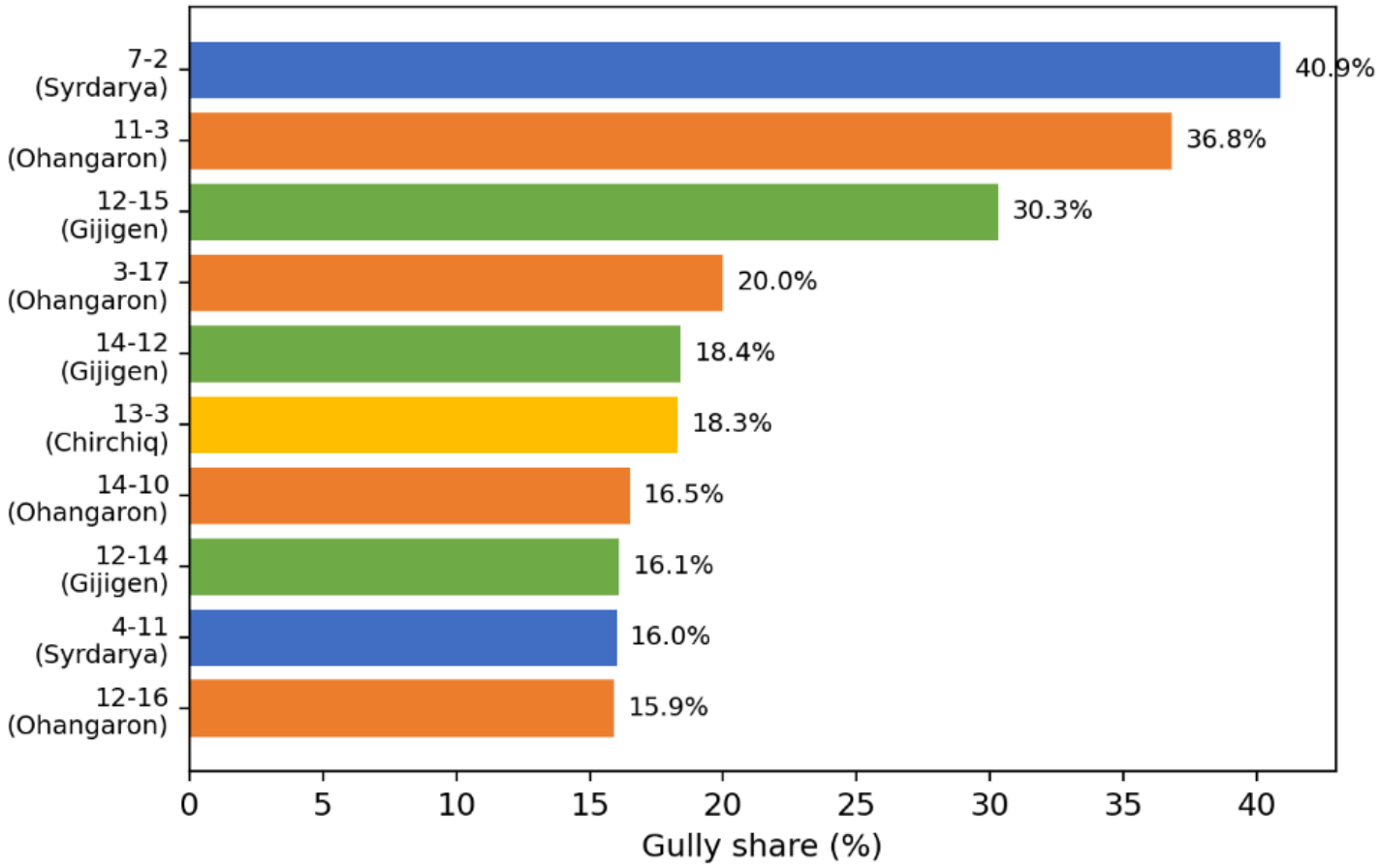


Figure 3

Gully share (%) for the ten most severely affected landscape units, coloured by river basin (blue = Syrdarya, orange = Ohangaron, green = Gijigen, yellow = Chirchiq).

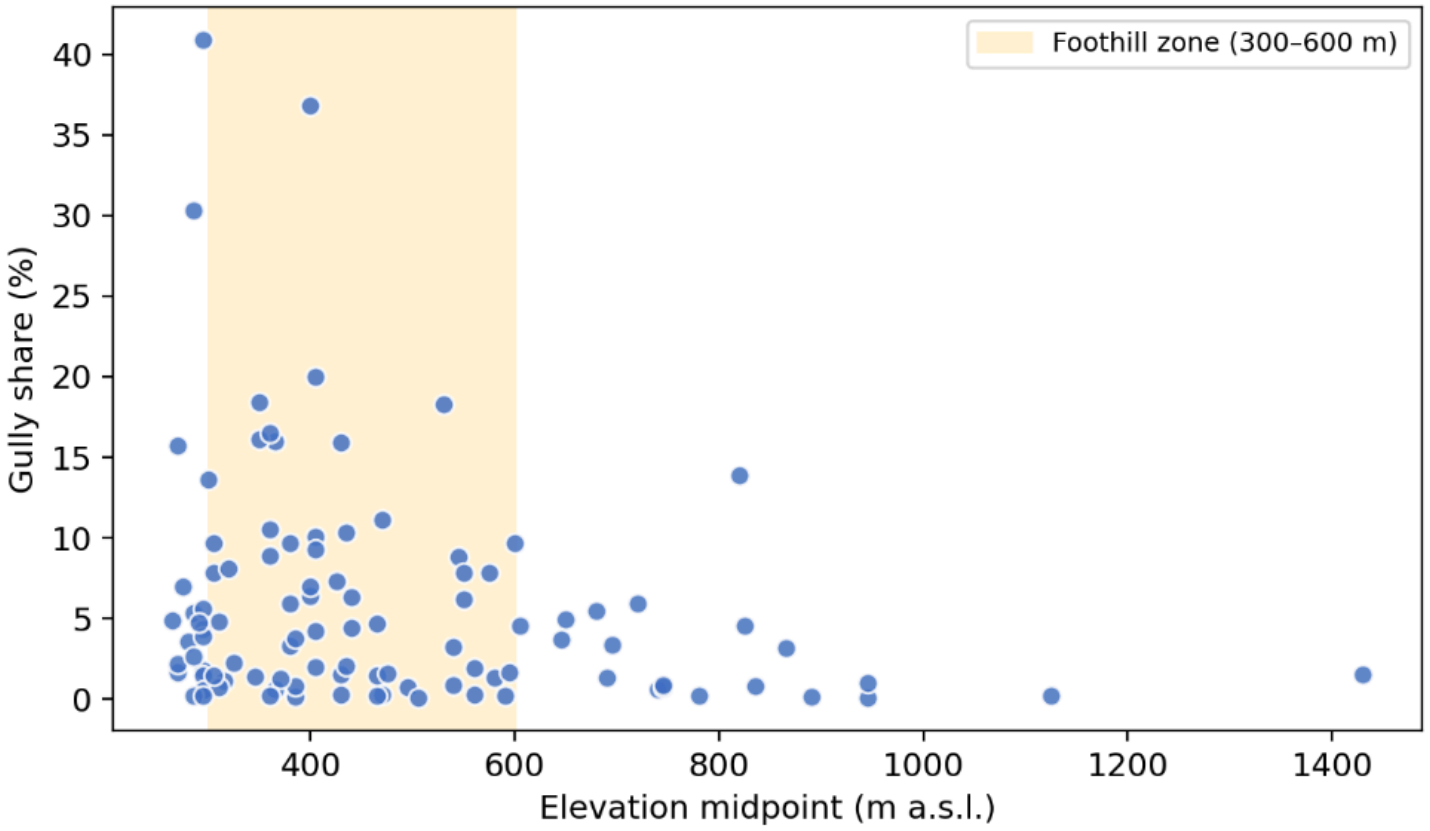


Figure 4

Gully share (%) versus elevation midpoint for all 102 gully-bearing landscape sub-units. The shaded band marks the 300-600 m foothill zone; the highest and most variable gully shares occur below approximately 600 m, with a marked decline at higher elevations.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Table.S1.xlsx