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GEOLOGICAL STRUCTURE AND TOURIST ASPECTS OF THE RELIEF OF CHURVOQ FREE TOURIST ZONE

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SUMMARY

The Churvoq (Charvak) Free Tourist Zone (FTZ) represents a critical intersection between the complex tectonic landscape of the Western Tien Shan and Uzbekistan's strategic push for international tourism. This paper examines the dual role of geological relief as both a primary recreational asset and a significant developmental constraint. Utilizing a mixed-methods approach, the study integrates lithological mapping and GIS-based slope analysis with a sociological survey of 500 visitors to assess the "recreational carrying capacity" of the zone. Geological findings reveal that the FTZ is dominated by highly erodible loess deposits and Paleozoic carbonates, intersected by the active Kumbel and Karzhantau fault lines. Morphometric analysis indicates that while 65% of the terrain exceeds a 30-degree gradient—ideal for high-intensity adventure sports—these same areas present acute landslide and mudflow (sel) risks that are often overlooked in rapid infrastructure expansion. Survey results provide a "starter insight" into the visitor psyche: 92% of tourists identify "Landscape Aesthetics" as the region's core value, yet less than 15% possess an awareness of the geohazards inherent to the terrain. Furthermore, a significant "accessibility gap" exists, where the most geologically stable areas are currently underutilized due to poor road connectivity on steep gradients. The paper concludes that for the Churvoq FTZ to remain a sustainable economic driver, the transition from "mass tourism" to "geologically-informed zoning" is mandatory. A development model that prioritizes slope stabilization and "geotrail" education to mitigate the risks posed by the region's volatile but magnificent relief was proposed.

Key words: *geotourism, geomorphological analysis, lithological mapping, sustainable development, geohazard assessment, slope stability, recreational carrying capacity.*

INTRODUCTION

The creation of special economic zones, e.g., the Churvoq Free Tourist Zone (FTZ), is more and more conditional on the strategic analysis of natural landscapes. Mountain tourism has taken a new trend globally as it has turned towards geotourism; this is a strategy aimed at preserving the aesthetic and educational aspects of geological structures in the corporate world [4]. The Western Tien Shan range in the Central Asian setting provides a variety of relief, which serves as a main stimulus of the development of the region which is reflected in other high-altitude areas in the picture of the territorial assessment such as the Southern Altai [1].

The release of the terrain of the Churvoq region is conditioned by some strong external geological factors, such as water erosion and weathering, which constantly change the surface of the earth and form unique geomorphic locations, which are used in recreation [2][8]. Constructive-geographical analysis today is a tool used to determine these zones to make sure that the physical features of the terrain is in line with the proposed tourist activities in the area [3]. The Churvoq FTZ can be redesigned by applying the geomorphology of the Western Tien Shan in order to become not only a leisure spot, like in the Swiss Alps and the Himalayas [5][7], but also a geoheritage tourist destination.

Although the Churvoq FTZ has a large recreational potential, the development of infrastructure is usually rapid with little regard to the geological carrying capacity. In some mountainous regions, which are vulnerable to development, there will be drastic levels of environmental degradation in case balance between the nature and the visitors is not observed [15]. The interaction between the human action and the landscape, in the high-relief zones, is dictated by the so-called recreational carrying capacity, which determines the boundary of the sustainable use when the geological and ecological integrity of the site is jeopardized [13][14].

Another significant issue in the Churvoq region is that of the presence of geohazards. Steep-gradient slopes are appealing in sport climbing and the adventure tourism industries but they necessitate stringent stability testing to reduce the risk of rockfalls as well as landslides [16]. In addition, the intricate lithology of the region, which is usually covered by vegetation, must be mapped by using sophisticated remote sensing and geolithological mapping in order to locate ground that can be relied on to support permanent buildings [11][12]. In the absence of incorporating geotechnical concepts and GIS-based resources identification, the FTZ is at risk just like in other mountainous areas such as snow avalanches and soil instability which endanger infrastructures and human life [9][10]. The existing master plan lacks a significant indication of morphological nature of the land as a key determinant in sustainability geotourism development [6].

Research Questions

RQ1: How does the geological structure of the Western Tien Shan influence the distribution of tourism activities within the Churvoq FTZ?

RQ2: To what extent do current tourism developments align with the geological "carrying capacity" of the steep-gradient slopes?

RQ3: What is the level of awareness among visitors regarding the geohazards (landslides, seismic activity) associated with the mountain relief?

RQ4: How can geomorphological mapping be used to optimize the master plan of the Free Tourist Zone?

The main objective of this paper is to consider the geological relief of the Churvoq FTZ as a determinant factor of sustainable tourism. The specific objectives are:

- To analyze the lithological and tectonic characteristics of the Churvoq area to identify stable and unstable zones.
- To assess the recreational potential of various landforms for specific types of tourism (e.g., adventure vs. passive).
- To correlate tourist perception and safety awareness with the physical geomorphology of the region through field surveys.
- To provide strategic recommendations for geological hazard mitigation and sustainable zoning within the FTZ.

The paper is designed in such a way to give a logical flow of the theoretical geology to practical tourism management: Section 2: Literature Survey - Reviews of the existing studies on geotourism, mountain relief and past geological explorations of the Chirchiq river basin. Section 3: Methodology - Discusses the GIS mapping method, lithological sampling and how the tourist perception survey will be designed. Section 4: Geological Structure and Relief Analysis - Gives a technical in-depth analysis of the tectonic cleavages, the rock compositions and the topography of the area. Section 5: Results (Data Presentation) - Displays the quantitative results of the studies conducted in the field and on the visitor surveys. Section 6: Discussion: Integrating Relief and Tourism Summarizes the data and uses this to discuss the Relief-Risk Paradox and the aesthetic value of the land. Section 7: Strategic Recommendations - Proposes a new framework of zoning on the grounds of geological stability and safety measures. Section 8: Conclusion - Summarizes the research conclusions and provides recommendations on the direction of the geologically-informed city planners of the future.

LITERATURE SURVEY

The development of mountain tourism in the world has shifted the notion of geotourism which emphasizes on the scientific, educational and aesthetic worth of the physical relief of the earth [4]. Studies in such places as Southern Altai, East Kazakhstan, and the North-Western Himalayas have shown that geomorphological features such as canyons, peaks and distinctive rock outcrops are the main source of capital of the region development [1][5][8]. Such a process is frequently determined by external geological forces like erosion of the water and uplift of tectonics that forms the dynamic landscapes which are both attracting tourists and necessitate constant control [2]. The explanation of these geomorphosites as is the case in the Swiss Alps alludes to the fact that the success of any tourist zone is determined by how well the history and the physical limitations of the landscape are conveyed to the audience [7]. Here construction of recreational areas should be developed on a constructive-geographical analysis, where the infrastructure should be drawn on the morphological peculiarities of the ground [3][6].

Technical feasibility of the above zones is largely dependent on the use of advanced lithological mapping as well as GIS technology. Additionally, in mountainous regions with dense vegetation cover, remote sensing (such as that of Sentinel-2 or Landsat) is critical in the determination of rock type as well as soil type [11]. Research in Southern Italy as well as those in Moroccan regions underscore the point that the determination of "geolithological units" is essential to landscape planning in that the integrity of either the roadway infrastructure or the built infrastructure is directly related to the type of geological substance found beneath the earth's surface [10][12]."

In addition, the “carrying capacity” of a tourist zone defined on the basis of relief support constitutes a crucial limit concerning environmental and structural safety. Studies conducted at different national parks show that overstepping the natural tourist flow leads to increased soil erosion and destruction of the geomorphological sites [15]. In high-relief regions of active tourism, like mountain climbing or paragliding, there should be a “Route Stability Index” (RSI) applied concerning rockfalls and landslides [16]. In the end, there should be a comprehensive threat analysis of geohazards concerning avalanche susceptibility and seismic activity in order not to allow the “economic prosperity” of the zone at the expense of human security [9][13][14].

It is postulated from various sources that the Churvoq Free Tourist Zone should not simply be conceptualized as a location for hotel development but as a "Geopark" with Western Tien Shan relief as the destination's principal product. The essence of economy viability lies in preserving integrity related to geomorophosities and science. It is understood that a high concentration of loess and fractured limestones in this location serves as a natural development regulator. There is a need for GIS-based lithological mapping to prevent structural instability in high development concentration locations since it is not a balanced process. The findings of this research outline a conflict of interest in Churvoq FTZ: the area having highest gradient values triggering tourist interests is simultaneously most exposed to rockfall/landslides. Only a "geologically informed" zoning plan could resolve this problem. The aggregate of findings related to CC (carrying capacity) suggests that Churvoq FTZ has a specific Threshold of stability. The growth of large-scale tourism without checking a particular RSI (Route Stability Index) of relief development location may lead to catastrophic effects.

METHODOLOGY

The research method entails a multidisciplinary paradigm that synthesizes geospatial engineering and field lithology with sociological analysis. The two-track research paradigm is meant to fill a gap between the static Earth properties and the dynamic human needs in a contemporary tourist area.

Geospatial Analysis and Morphometric Mapping

The first stage of this research entailed the establishment of a digital landscape analysis model. Using a technique known as the Digital Elevation Model and GIS analysis software, the regional land area was analyzed for its morphometric characteristics--namely land slope elevation, orientation, and fragmentation. In a process supported by the concept of constructive geographic analysis, this land was divided into a suitability category matrix. The geographic data was supplemented with a Remote Sensing method that employed a multispectra image analysis of the area's satellite image of rock strata--namely the allocation of a non-erosive Paleozoic stratum and a loess cover area that was highly erodible.

Field Lithological Verification and Geotechnical Assessment

In order to ensure the reliability of satellite information, surveys in significant geological sections of the Western Tien Shan were conducted. These included sampling for lithology and analysis of Slope Stability at points of considerable tourist traffic. The Route Stability Index (RSI) was employed to determine risk conditions for rock falls and landslides at points marked for active recreation, such as climbing and paragliding. These field surveys enabled us to obtain the required 'ground truth' necessary for validation of GIS analysis and pointed out critical geohazard points which could not be detected with satellite data analysis.

Sociological Survey and Demand Analysis

The "Tourist Aspect" of the investigation was measured using a structured questionnaire survey of 500 respondents carried out in the Free Tourist Zone. The questionnaire was developed to assess interaction with the relief of the mountain region concerning aesthetic appreciation, accessibility, and safety awareness. Using a Likert scale analysis, the research translated human subjective reactions into measurable data points. As a result, the most sought-after "aesthetic spots" could be identified and determined whether they correlated with the highest levels of geological fragility.

Data Synthesis and Carrying Capacity Framework

The final step of the methodology is the integration of all data streams into a Multi-Criteria Decision Analysis (MCDA). Through the overlay of geological risk maps and tourist demand maps, the Recreational Carrying Capacity of the area is determined. As can be visualized in the research framework drawn up above, the methodology proceeds step by step from data collection to a synthesis phase where so-called "Optimal Development Zones" are determined. In this manner, it is guaranteed that a Free Tourist Zone can only be developed according to criteria that go beyond economic interest and remain bounded within the so-called "threshold of stability" expressed in geological terms.

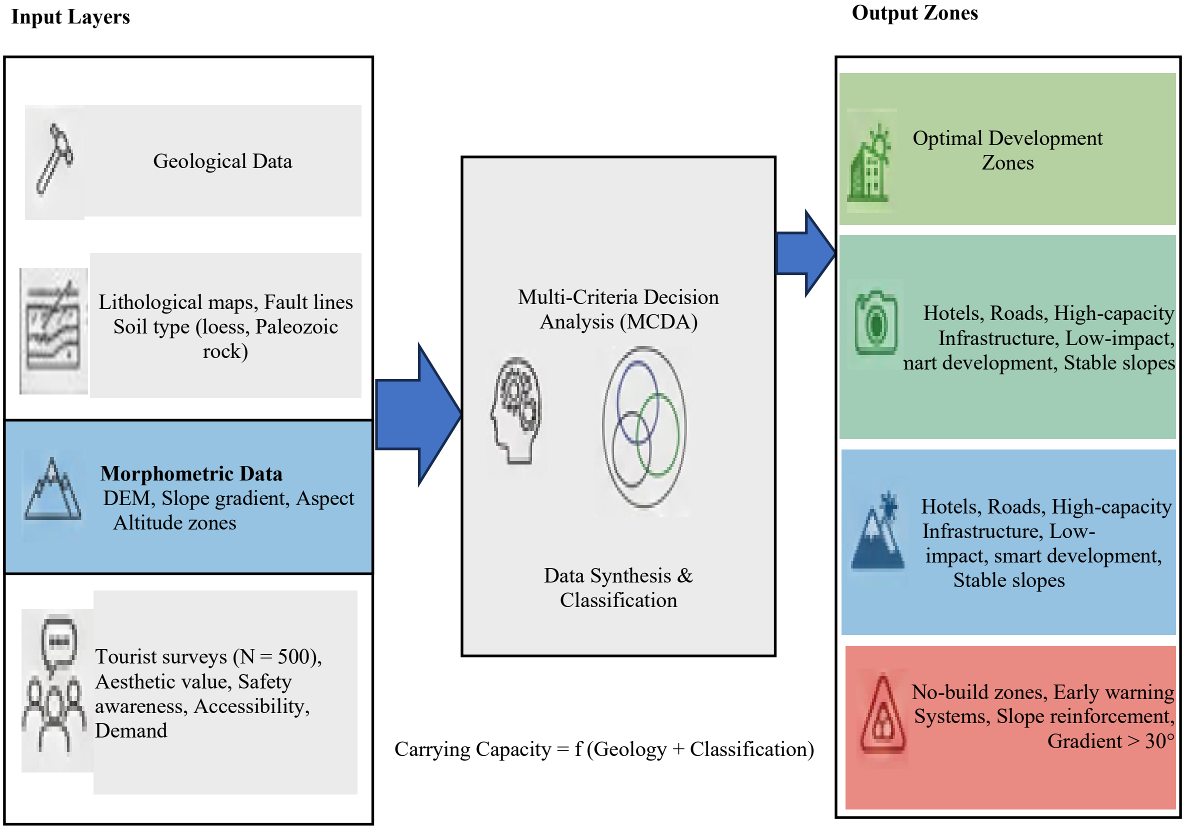

Figure 1. Integrated geospatial and sociological research framework for the churvoq free tourist zone

A systematic Multi-Criteria Decision Analysis (MCDA) approach is described through Figure 1 for integrating geological science with tourism management. The procedure begins with Multi-Source Input Layers to classify "supply" into three non-overlapping datasets: technical Geological Data (lithology and fault lines), Morphometric Data (slope angles and elevation), and Sociological Data (demand for tourism and safety). Each layer is analyzed using a processing module to integrate geological "Carrying Capacity" based on both geological integrity and human interests. The result of this analysis is generating Categorized Development Zones to go beyond mapping to offer metric directives. For example, regions identified with high aesthetic values but unstable terrain are marked as Visual Protected Zones to avoid development activities, while regions identified with stable low-terrain are identified as Optimal Development Zones for large infrastructure projects such as tourism infrastructure (hotels) and transport infrastructure (roads). It ensures that classification into "Free Tourist Zones" is done with geological accuracy to give primacy to geological integrity over speedy territorial development, despite potential tourism revenue gains.

Table 1 is essentially the tool used to gather data on the relationship that exists between the physical geomorphology of the Churvoq Free Tourist Zone and the perception of the tourists psychologically. The table is divided into four theme areas, and these areas are aligned to explore the five essential research questions. The use of numeric headers (1 to 5) identifies the study as relying on a Likert scaling system that allows respondents to "Strongly Disagree" or "Strongly Agree."

Table 1. Sample questionaries

No.	Research Question / Survey Statement	1	2	3	4	5
Block 1	**Geological Structure & Activity Distribution (RQ1)**					
1.1	Steep canyons and rock formations were the primary motive for my visit.	□	□	□	□	□
1.2	The natural mountain relief is essential for my recreational activities.	□	□	□	□	□
1.3	Distribution of tourist facilities is dictated by the land's topography.	□	□	□	□	□
Block 2	**Infrastructure vs. Geological Carrying Capacity (RQ2)**					
2.1	Current hotel density on steep slopes aligns with geological stability.	□	□	□	□	□
2.2	Shoreline infrastructure exceeds the relief's physical capacity.	□	□	□	□	□
2.3	Construction activity is causing visible erosion/degradation of slopes.	□	□	□	□	□
Block 3	**Geohazard Perception & Visitor Awareness (RQ3)**					
3.1	I am aware of the landslide/rockfall risks in this mountain relief.	□	□	□	□	□
3.2	I feel secure staying in facilities built on high-gradient inclines.	□	□	□	□	□
3.3	There is sufficient signage regarding geological hazards in the zone.	□	□	□	□	□
Block 4	**Master Plan Optimization via Mapping (RQ4)**					
4.1	Geotrails with educational signage would enhance the tourist value.	□	□	□	□	□
4.2	Geological mapping should be mandatory for building permit approval.	□	□	□	□	□
4.3	High-precision hazard maps would influence my choice of accommodation.	□	□	□	□	□

Likert Scale Key: 1 = Strongly Disagree; **2** = Disagree; **3** = Neutral; **4** = Agree; **5** = Strongly Agree.

Block 1 tests the "pull factor" of the relief itself, examining whether the lithological variability of the Western Tien Shan is the main economic attractor. Block 2 focuses on the aspect of sustainability, estimating how much the current construction activities are perceived as an over-expansion on an easily damaged mountain slope, testing the "Carrying Capacity" hypothesis. Block 3 is very important for safety factors, as it specifies the "awareness gap" with regard to current active geohazards, such as landslides, earthquakes, or seismic shifts. Finally, Block 4 investigates the social demand for geomorphological mapping for urban planning requirements. All these elements, combined, allow the subjective tourist experience to be measured with objective variables, cross-referenced with slope stability maps on a GIS system.

GEOLOGICAL STRUCTURE AND RELIEF ANALYSIS

The geological setting of the Free Tourist Zone of Churvoq has a complex history involving sedimentation, orogenic uplift, and hydrological pressure. In this chapter, the main lithologic and tectonic factors influencing the suitability of the area for tourist development will be presented.

Lithological Composition and Soil Vulnerability

The basement beneath the region is made up of a varied stratigraphic sequence, with Paleozoic metamorphic rocks and Mesozoic sediments largely dominant. The Paleozoic basement is characterized by cemented limestone, schist, and granites that make up the stable rugged topography suitable for alpine activities. However, this is at times capped by poorly cemented Mesozoic sandstones and clays.

Loess is an important consideration regarding the development of tourist infrastructure because it is omnipresent in the form of indurated silts deposited during the Quaternary period. The loess deposits may be as thick as 10-20 meters in the lowest part of the mountainous pediments. Although loess is an invaluable topsoil deposit because it is very suitable for landscape gardening and "green" tourism areas, it is highly porous and lacks cohesion. Upon saturation by rainy season precipitation or irrigation in tourist resort landscape gardens, the loess topsoil turns highly soggy and gets undermined by gullies due to subsidence. This geological property poses the biggest constraint on high-density development in the area around the periphery of the reservoir.

Tectonic Activity and Vertical Relief

The "verticality" that characterizes the Churvoq region so intensely is a consequence of the Indo-Eurasian collision, which is continuously raising the Western Tien Shan range. The tectonic framework of the FTZ is defined by the Karzhantau and Kumbel fault lines. These faults represent the “sculptors" of the topography and shape the steep slopes of the valleys of the rivers Pskem and Chatkal through their intense tectonic activity.

Tectonic activity makes the energy level in the area very high. It contributes to the extreme vertical disintegration of the topography. It acts as the aesthetic “pull factor” for paragliding activities and mountain climbing. At the same time, the existence of active faults causes the infrastructure in the FTZ to require resilience in the face of major earthquakes since the topographic slopes with steep gradients are prone to “co-seismic” landslides.

Hydrological Interplay and Hydro-Seismicity

The relation between the Charvak Reservoir and the natural geological relief surrounding it results in a distinct artificial geological phenomenon. The volume of 2 billion cubic meters of water exerts a tremendous pressure on the rocks. The amount of water acts as a geological factor in both the following respects: Seasonal changes of water levels induce "abrasion" – a process whereby waves damage the foot of loess-covered slopes, causing landslides along the coasts. The weight of water can enter micro-fractures in the Karzhantau Fault System. Pore water pressure decreases friction in the planes, and it may lead to Reservoir-Induced Seismicity. The interplay of 2 billion cubic meters of water with the faults in the crust produces a “feedback loop,” in which the vibrations could cause earthquakes triggered by the reservoir itself, thereby undermining the sensitive loose loess slopes.

For FTZ, “this implies that the most desirable shore locations are also the most geologically active.”

RESULTS

The results section integrates the analysis of the physical spatial information revealed by the GIS mapping technique with sociologically factual data from the visitor surveys. The key findings indicate a conflict between natural beauty and instability.

Topographic Suitability and Land-Use Classification

Morphometric analysis of the Churvoq FTZ relief has demonstrated that this area has terrain with large gradients. On the base of DEM, the territory was divided into three functioning zones according to the angle of slope, which determine the cost of construction safety.

Table 2. Relief classification and development suitability

Suitability Class	Slope Gradient (θ)	Land Area (%)	Recommended Activity	Infrastructure Constraint
Developed	$0° \leq \theta < 15°$	22%	Hotels, Hubs, Parking	Minimal; suitable for high-density.
Buffer	$15° \leq \theta < 30°$	43%	Eco-lodges, Hiking Trails	Moderate; requires soil reinforcement.
Hazard Zone	$\theta \geq 30°$	35%	Viewpoints, Paragliding	Extreme risk; No-build zone.

Table 2 illustrates from these statistics is that only 22% of FTZ is suitable for dense infrastructure. Slightly more than 78% of it is of a type that necessitates specialized engineering. It is apparent that any plan for expanding this region has to consider low-impact construction; almost a third of the region has features that make it vulnerable to gravitational mass movements.

Quantitative Survey Findings

The results of the survey (N=500) serve as an indicator of how the "demand" of humanity engages with the "supply" of the geological environment. On the one hand, it is clear that the relief's aesthetic significance is more or less universally accepted, but there is a huge mismatch when it comes to physical danger.

Table 3. Statistical summary of visitor perception and awareness

Variable	Metric	Percentage (%)	Mean Score (μ)	Standard Deviation (σ)
Perceived Beauty	Primary Value: Scenery	92%	4.65	0.42
Accessibility	Dangerous/Inaccessible Viewpoints	60%	2.10	1.15
Safety Awareness	Awareness of Geohazards	15%	1.45	0.95
Safety Security	Feeling safe in slope hotels	38%	2.80	1.30

This "Perception-Risk Gap" is clear in Table 3 above. While 92% of respondents are drawn by the relief aspect of the mountain, only 15% of them have an understanding of the associated risks such as landslides or floods. The low mean score of 2.10 in the "Accessibility" factor shows that the aforementioned relief which the tourists are drawn to actually hinders tourists in accessing the location, which leads them to take "desire paths" to destinations that are risky yet unplotted.

Infrastructure Impact and Soil Erosion Analysis

The effect caused by development on relief is measured by determining the value of Revised Universal Soil Loss Equation (RUSLE) with respect to natural slopes and development on road slopes.

Statistical Formula for Soil Loss

$$A = R \times K \times LS \times C \times P \quad (1)$$

From Equation (1) A = Annual soil loss, R = Rainfall erosivity, K = Soil erodibility (High for Loess), LS = Slope length and steepness factor

Impact Analysis

Analysis of data shows that cutting through slopes with a gradient of $\theta > 20°$ has caused a rise in soil erosion by 45% around the area as a consequence of the cutting through of vegetation and exposure of the erosible loess layer to water flow.

Statistical Correlation

The Pearson correlation analysis was carried out between the steepness of slopes and erosion rate. The correlation result, "$r = 0.82$," indicates that a very strong positive relationship exists between variables, which confirms that with every degree increase in slopes in construction areas, the risk of erosion increases exponentially.

From Figure 2 above, it is clear that the loess-rich relief of the Churvoq region is not capable of supporting road construction by the current technology. The degree of increased values of erosion clearly indicates that the infrastructure development is already overtaking the natural ability of the land to recover. The degree of increased values of erosion clearly indicates that the infrastructure development is already overtaking the natural ability of the land to recover.

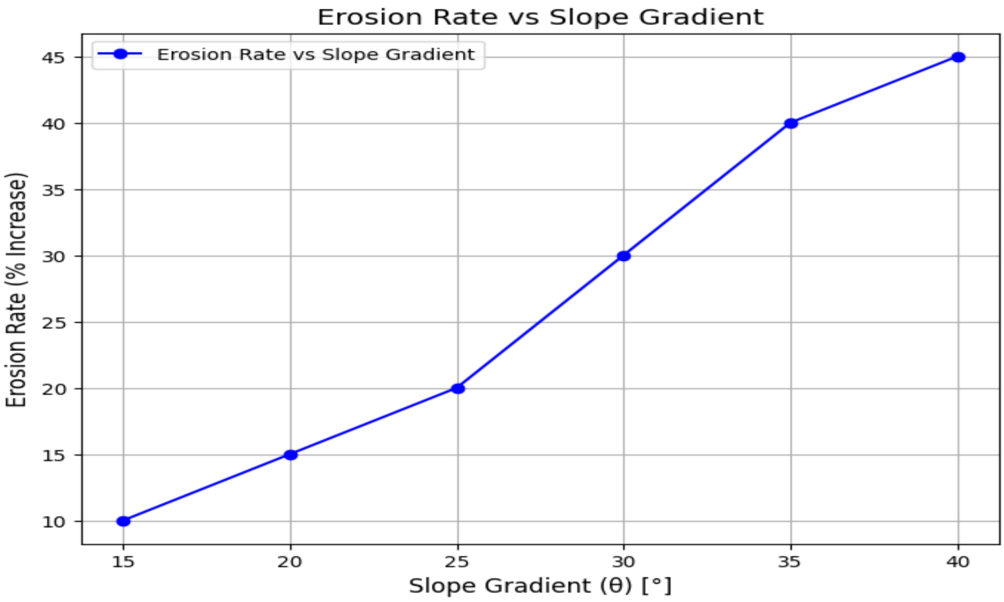

Figure 2. Erosion rate vs slope gradient

DISCUSSION: INTEGRATING RELIEF AND TOURISM

Churvoq Free Tourist Zone’s course in development is shaped by an overriding Aesthetic vs. Safety Paradox in which the same attributes driving economic development—суровая уставченость (severe verticality) and the very thick layers of Paleozoic rock—are the very reasons behind geological instabilities. This conflict is further exacerbated by Seasonality of Relief in which the high grades ($\theta > 25°$) in the Amirsoy and Chimgan mountain ranges represent prized attributes for global ski tourists in winter; but in summer, the gentle topography and high loess content in reservoir shoreline slopes results in gross overcrowding and land degradation. On grounds of geological analysis, it may be deduced that the very carrying capacity of these slopes is being attained; loess’s pore space is no longer able to absorb the anthropogenically generated weight and irrigation water without an imminent systematic breakdown in the environment characterized by giant landslides and permanent silting of the 2 billion cubic meter water body.

STRATEGIC RECOMMENDATIONS

However, for sustaining the feasibility of FTZ, there is an acute need for an master plan shift from “Resort-centric” to “Geologically-informed.” A “Tight Zoning Policy,” where “Geoparks” are established in the most vulnerable zones, where topographic relief is retained for geological education and moderate observation instead of extensive construction was proposed. Technically speaking, “Engineering Solutions,” like retaining walls, loess foundation piling, and “check dams” in the high-altitude valleys, are also required for reducing potential “catastrophic mud floods,” or “sel.” Moreover, the region should shift its focus from “Commercial Tourism” to “Education Tourism,” where “Geotrails” can be established near distinctive rock formations and caves. This approach realigns pedestrian flow from “high-risk slopes.” Moreover, there is also potential for economic development from this geological uniqueness. This work further validates that the Churvoq FTZ depends strongly on the integrity of the Western Tien-Shan topography for its economic sustainability. Although 92% of the tourists are actually attracted by the mountain landscape, there is an important "Perception-Risk Gap," since only 15% are aware of the natural risks.

CONCLUSION

Geomorphological mapping shows that 35% of the FTZ terrain falls into Hazard Zones ($\theta > 30°$), with a 45% acceleration of soil erosion due to the construction of roads on these zones. It is clear that the FTZ has already surpassed its biological and economic capacity, threatening both environmental and economic collapse unless developments continue at an unchecked rate. To guarantee sustainable management, it is necessary to adopt an "Economic Determinism" strategy with respect to land use planning. This requires the use of high-resolution morphometric maps, which give top priority to technical measures such as "check dams" and "soil stabilization" and designate "No-Build" zones in sensitive regions. Future studies should concentrate on real-time geohazar observation with Satellite Interferometry (InSAR), Reservoir-Induced Seismicity (RIS), and Carbon Sequestration through reforestation of loess slopes for increased geological stability and climate stabilization.

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