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IMPROVING CLIMATE INFORMATION SERVICES FOR ENVIRONMENTAL PROTECTION AND SUSTAINABLE DEVELOPMENT IN UZBEKISTAN

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Abstract

Climate change has transformed into one of the most severe environmental and socio-economic challenges affecting Central Asia, particularly Uzbekistan. The observed rise in annual temperatures, highly irregular precipitation patterns, degradation of mountain glaciers, and the increasing frequency of extreme hydrometeorological events—such as flash floods, mudflows, droughts, and avalanches—significantly intensify environmental vulnerability and pose direct threats to sustainable development.

This study examines the current effectiveness of Climate Information Services (CIS) in the Republic of Uzbekistan, focusing on their contribution to environmental protection, disaster risk reduction, and ecological security. As an empirical basis, a detailed qualitative and quantitative analysis was conducted on five major flash flood and mudflow events recorded during the spring season of 2026 across various regions

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of the country (Navoi, Jizzakh, Namangan, and Kashkadarya regions). The analysis utilizes operational hydrometeorological reports, emergency warnings from the official Uzhydromet Telegram channel, and associated national environmental reports.

The research identifies critical structural gaps in the information dissemination chain: weak community preparedness, time delays in transmitting storm warnings to rural and mountainous populations, and a significant deficit in localized (site-specific) alerting. To address these vulnerabilities, the study proposes an innovative digital ecosystem framework—the "Smart Climate Alert Uzbekistan" mobile application. This system integrates GIS technologies, artificial intelligence, and participatory communication to provide personalized, location-specific forecasting and hazard alerts 1–2 days prior to an event. Findings indicate that implementing such a user-centered digital solution can radically minimize infrastructure damage and strengthen the overall climate resilience of ecosystems in Uzbekistan.

Keywords: *climate change, Climate Information Services, Uzhydromet, flash floods, mudflows, early warning systems, GIS technologies, sustainable development, climate adaptation.*

1. Introduction

One of the most fundamental and widely accepted roles of governments through the ages has been to provide for the protection of their national communities from external threats to their safety, security and general way of life. The most serious threats have historically come from armed invasion and from the various forces of nature which imperil the safety of life and property and may lead to economic and social dislocation, famine and disease.

In many countries, the most frequent and pervasive threat derives from the wide range of meteorological and hydrological hazards, especially the immediate impacts and secondary effects of tropical cyclones, severe storms, floods, drought and fire. Governments have long accepted responsibility for national leadership in reducing the

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damage and loss of life from the full array of natural disasters of meteorological and hydrological origin and in assisting affected communities to recover from the social, economic and physical devastation left in their wake.

Over the past century, governments in an increasing number of countries have identified meteorological and hydrological warning systems as a vital element in their armaments against the burgeoning economic and social cost of natural disasters which have recently been estimated to exceed USD 200 billion annually in economic costs alone (United Nations 1998).

The operation of such warning systems and the provision of warning services has historically been one of the highest priority functions of the National Meteorological and Hydrological Services (NMHS) that now operate in more than 180 countries and, in many cases, the primary rationale for their existence.

Two features, one characteristic of the human response to disaster of all kinds and the other a particular attribute of natural hazards of meteorological origin, bestow a uniquely international dimension to the challenge of natural disaster reduction.

Global climate transformations are exerting unprecedented pressure on the stability of natural ecosystems, human security, and the sustainability of national economies worldwide. The Central Asian region is highly vulnerable due to a progressive water deficit, intensive glacier retreat, accelerated desertification, and a sharp increase in the frequency of extreme weather events. For Uzbekistan, characterized by a sharply continental climate, extensive mountainous terrain, and a heavy economic reliance of its agricultural sector on stable water availability, these risks are of critical importance.

According to the findings of the "Uzbekistan Green Growth Country Assessment" published by the World Bank, the sustainable dynamics of the country's economic advancement face direct threats from rising thermal stress and the depletion of natural capital (World Bank, 2022). This stance is corroborated by the UNECE

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"Environmental Performance Review of Uzbekistan," which highlights an exponential growth in climate-induced natural disasters—primarily mudflows, landslides, and flash floods that trigger large-scale land degradation (UNECE, 2024).

Under these conditions, Climate Information Services (CIS) serve as a cornerstone for climate adaptation and environmental protection. CIS bridges the gap between raw meteorological observations and actionable, understandable data required by government authorities, emergency response agencies, and local communities. However, despite substantial modernization of Uzhydromet's observation and monitoring network, the practical utility of early warnings is constrained by several systemic factors: limited public risk awareness, technical latencies in warning transmission, low digital penetration at the grassroots level, and a lack of high-resolution geographical localization in forecasting for remote rural territories.

2. Object and Subject of the Research

The Object of the Research is the national framework of Climate Information Services (CIS) in the Republic of Uzbekistan, evaluated as a structural instrument for mitigating environmental risks and protecting the population.

The Subject of the Research encompasses the organizational and technological mechanisms, data collection and processing methodologies, and communication channels used to distribute predictive and emergency hydrometeorological data within the context of disaster risk management (using the spring 2026 flood season as a case study).

3. Primary Data and Research Methods

The methodology of this study relies on an integrated approach combining statistical, comparative, and geoinformation (GIS) analysis. The primary data sources include:

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1. Arrays of operational emergency warnings and hydrometeorological bulletins published by the official verified information channel of Uzhydromet between February and May 2026 (Uzhydromet, 2026).

2. National and international analytical reviews addressing the climate policy and environmental status of Uzbekistan.

3. Statistical data regarding the impacts and damage metrics of hazardous natural phenomena.

Within the scope of this work, a thorough cross-verification of five specific extreme mudflow and flash flood events from the spring 2026 season was performed. The study analyzed the timeline of warning issuance, the exact distribution channels utilized, and the nature and localization of the resulting infrastructure and property damage.

4. Main Results: Analysis of Flash Flood Events in Spring 2026

The spring season of 2026 in Uzbekistan was characterized by anomalously high intensity and frequency of torrential rainfall in foothill and mountainous zones. This led to rapid slope runoff and the formation of destructive mudflows. Table I systematizes the data compiled and analyzed for the five major incidents selected for this study.

Table I. Major Mudflow and Flash Flood Events in the Republic of Uzbekistan (Spring 2026)

№	Region/Province	District	Nature and Scale of Documented Damage
1	Navoi Region	Khatirchi District	Flooding of residential sectors; partial destruction and

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			structural damage to private houses, washing away of household plots.
2	Jizzakh Region	Zomin District	Severe damage to local transport infrastructure; washing away of rural roads, blocking of transport routes.
3	Kashkadarya Region	Yakkabog District	Large-scale inundation of residential zones, heavy silting of courtyards and social infrastructure due to river overflows.
4	Namangan Region	Pop District	Deformation and blockage of critical mountain transit corridors; temporary isolation of several remote settlements.
5	Kashkadarya Region	Qamashi District	Total structural failure and critical damage to a strategic transport overpass (bridge), interrupting regional logistics.

Key Scientific Finding: A cross-verification of the timelines indicates that all the affected districts were proactively listed by Uzhydromet as high-risk mudflow zones within seasonal outlooks. However, the generalized nature of these outlooks failed to translate into effective preventative infrastructure protection or timely local evacuations.

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5. Discussion: Identifying Structural Gaps and Barriers in the CIS Framework

A detailed review of the spring 2026 flash floods revealed four fundamental vulnerabilities in the operational "scientific forecast -> community reaction" chain.

5.1. Infrastructure Systemic Vulnerabilities

The events of spring 2026 clearly demonstrated that the primary impact of extreme hydrometeorological events falls on transit arteries, bridges, and regional drainage networks. Existing engineering protective structures are frequently under-designed for the sharp, climate-induced spikes in peak runoff volume. The lack of real-time integration between meteorological data and transport management platforms means that traffic streams are not rerouted proactively, endangering lives on blocked or collapsing roads.

5.2. Public Preparedness and Risk Perception Gaps

People at risk do make rational choices about protecting themselves from disaster. They do have a view of that risk. We cannot understand responses to early warnings without first having a good understanding of this. Here we should note two important points: the social dimensions of risk perception, and the diversity of views that this generates.

In vulnerable communities, events relating to hazards interact with a variety of social, psychological, institutional and cultural processes in ways that can heighten or attenuate perceptions of risk and thereby shape risk behavior. This is known as the ‘social amplification’ of risk. It implies that the experience of risk is both one of physical or potential physical harm and the result of the cultural and social processes through which individuals or groups interpret hazards. Individuals have their own ‘worldview’ or understanding of how the world works based on a combination of observations, information and ideas (conscious and unconscious). Within communities, there are many different worldviews and hence many different

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perspectives of risk which vary according to socio-economic differences in such aspects as wealth, social standing, level of education, age, religion, ethnic group and gender. Personal and collective experience plays a significant part here.

We can see from this that risk perceptions are likely to vary considerably between different communities, and even within communities. This diversity presents a particular challenge to those who have to transmit early warning messages over wide areas.

One of the principal socio-economic factors affecting response to disaster warnings in much of the Third World is, surely, the vital need to protect assets and maintain livelihoods. The poorer and more marginalised a household is, the more important it becomes to hold on to its assets and property (such as livestock and household goods) and income (for a day labourer, every day's wages are vital in feeding the family or paying off debts to moneylenders). A household may perceive the risk of evacuation, in terms of losing control of its assets and resources, as more devastating than the risk of the hazard (especially where warnings are frequent but do not necessarily lead to disaster) (Zschau, J., Kuppers, A. N., 2003).

A profound psychological and behavioral gap was identified: even when accurate scientific forecasts are generated by Uzhydromet, the actual public preparedness to act during an emergency remains critically low. Citizens in rural areas often minimize the severity of storm warnings or lack an explicit, rehearsed protocol of actions to execute when a mudflow threat is imminent.

5.3. Communication Disparities and Digital Inequality

Currently, the primary digital channel for real-time warning dissemination used by Uzhydromet is the Telegram messaging application. While highly popular, this approach induces digital exclusion. Elderly demographics, inhabitants of remote mountain villages with unstable cellular coverage, and low-income households

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frequently experience an information void. Critical warnings reach them with considerable delay, often after the mudflow has entered its active destructive phase.

5.4. Absence of Geo-Targeting and Localization (The Main Research Gap)

The current framework relies heavily on generalized, province-level alerts (e.g., "Mudflow risks expected in Kashkadarya Region"). For an individual citizen or a local farmer, such an announcement is too abstract. It fails to clarify whether a specific nearby river basin will overflow, or if a particular community bridge will become unsafe. Moving away from area-wide (provincial) bulletins toward highly localized, object-oriented warnings that explicitly define local evacuation routes is a clear scientific necessity.

Drawing a scientific parallel, research conducted in Ghana regarding user-centered climate information services (Antwi-Agyei et al., 2021) demonstrated that delivering simplified, localized forecasts in native languages increased public trust in meteorological services by over 70%. It fundamentally altered economic behavior, prompting communities to proactively safeguard livelihoods, livestock, and assets. This international experience serves as a valuable model for modernizing early warning frameworks in Uzbekistan.

6. Proposed Innovation: The "Smart Climate Alert Uzbekistan" Digital Ecosystem

To bridge the identified communication and geographical gaps, this study presents the design architecture for an intelligent mobile warning application.

The application uses a hybrid predictive model: it employs machine learning algorithms to process satellite imagery, radar data from Uzhydromet, and real-time soil saturation metrics, automatically overlaying precipitation forecasts onto a high-resolution Digital Elevation Model (DEM).

“Severe flooding expected in your region. Evacuate immediately.”

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When seconds count, clarity saves lives. To ensure no one is left behind during a crisis, these critical alerts are deployed simultaneously via SMS and email, guaranteeing wide accessibility across varying levels of technological connectivity. Ultimately, “Smart Climate Alert” is more than just an early-warning system—it is a powerful tool for community empowerment. By transforming raw meteorological data into actionable, real-time intelligence, the platform actively reduces climate-related risks and builds long-term local resilience. In doing so, Green Alert bridges the gap between climate science and human survival, contributing directly to the United Nations Sustainable Development Goals (SDGs) by fostering safer, more sustainable, and climate-ready communities.

Advancing the SDGs: Contributes directly to the United Nations Sustainable Development Goals—specifically SDG 13 (Climate Action) and SDG 11 (Sustainable Cities and Communities)—by fostering safer, more sustainable habitats.

7. Expected Results and Impact Assessment

Integrating the proposed smart alert ecosystem can significantly enhance the efficiency of regional environmental management and public safety. The expected shifts in key operational performance indicators are outlined in Table II.

Table II. Indicator Framework Before and After "Smart Climate Alert" Implementation

Performance Indicator	Current Situation (Baseline)	Expected Outcome (Post-Implementation)
Early Warning Accessibility	Medium (skewed toward urban internet users)	High (total reach via SMS and automated voice systems)
Public Risk Awareness	Low (absence of clear local action protocols)	High (personalized emergency action blueprints)

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Local Flood Preparedness	Moderate / Reactive	Highly proactive community-level response coordination
Infrastructure Damage	High	Significantly reduced via automated preventative actions
Emergency Response Efficiency	Delayed (initiated post-disaster logging)	Proactive (forces deployed ahead of the hazard impact)
Rural Population Inclusivity	Limited (hampered by language & connectivity)	Comprehensive (expanded via multilingual voice alerts)

8. Conclusions and Policy Recommendations

The results of this study show that the performance of Climate Information Services (CIS) must not be evaluated solely based on the mathematical or physical accuracy of meteorological models. The ultimate value of scientific forecasts is determined by the design, inclusivity, and reliability of the communication channels that connect these forecasts to the end-users.

Based on the empirical findings, the following set of recommendations is proposed for integration into the national climate adaptation and environmental governance frameworks of the Republic of Uzbekistan:

1. Technological Shift to Localization: Transition from broad, province-level storm warnings to high-resolution GIS-driven hazard mapping and object-level geo-targeting at the district and village scale.

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2. Bridging the Digital Divide: Implement automated text-to-speech voice broadcasting systems in local languages (Uzbek, Karakalpak) to ensure timely warning delivery to elderly demographics and remote communities lacking stable mobile internet.

3. Cross-Agency Digital Integration: Establish an automated API data-exchange protocol connecting Uzhydromet's predictive models directly with the Ministry of Emergency Situations and the Ministry of Transport to trigger instantaneous closures of threatened mountain highways and bridges.

4. Advancement of AI in Hydrology: Expand investments in localized AI/ML models trained on historical hydro-climatic data of Central Asian river basins to achieve a reliable 48-hour lead time for flash floods and mudflow forecasting.

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