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Innovative Scientific and Practical Approaches to Biodiversity Conservation in Uzbekistan: Digital Ecology and Nature-Based Solutions for Sustainable Development

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Annotation: Biodiversity in Uzbekistan, encompassing deserts, steppes, riparian forests, wetlands, and mountain ecosystems, is increasingly threatened by climate change, water scarcity, land degradation, and unsustainable land use. This study evaluates an integrated conservation framework that combines digital ecology tools (remote sensing, GIS, artificial intelligence, and predictive modeling) with nature-based solutions (NbS), including habitat restoration, ecological corridors, wetland rehabilitation, and community participation. Between 2022 and 2025, twelve pilot sites across five ecological regions were monitored. Spatial analysis identified 174 biodiversity hotspots, 38 critical habitats outside protected areas, and 22 high-risk degradation zones. AI-assisted monitoring achieved 93% accuracy across 45 target species. NbS implementation resulted in a 28–44% increase in vegetation cover, a 22% improvement in soil moisture, and the return of endangered species in 67% of restored sites. Predictive models indicate that without intervention, 24% of habitats may lose suitability by 2040, while integrated digital-NbS strategies could preserve over 80%. The results confirm that combining digital technologies with NbS provides an effective, scalable, and climate-resilient approach to biodiversity conservation in Uzbekistan.

Keywords: biodiversity conservation, digital ecology, GIS, artificial intelligence, nature-based solutions, habitat restoration, Uzbekistan.

1. INTRODUCTION

Biodiversity provides essential ecosystem services, including water regulation, soil fertility, climate stabilization, and food security. Uzbekistan hosts diverse ecosystems ranging from arid deserts to riparian *tugai* forests and mountain steppes. However, decades of intensive agriculture, water mismanagement, climate change, overgrazing, and habitat fragmentation have significantly reduced ecosystem resilience and species diversity.

Traditional conservation approaches based on protected areas and periodic field surveys are insufficient to address rapidly changing environmental conditions. Advances in digital ecology and the global adoption of nature-based solutions (NbS) offer new opportunities for adaptive, data-driven, and cost-effective conservation. This study aims to assess the effectiveness of an integrated digital-NbS framework for biodiversity conservation in Uzbekistan.

Objectives:

Identify biodiversity hotspots and degradation risks using GIS and remote sensing

Apply AI-based species monitoring for long-term ecological assessment

Evaluate NbS interventions in degraded ecosystems

Model future habitat suitability under climate change scenarios

Provide practical recommendations for national conservation strategies

2. MATERIALS AND METHODS.

2.1 Study Areas. Twelve pilot sites were selected across five ecological regions: Aral Sea wetland remnants, Amu Darya and Syr Darya tugai forests, Kyzylkum Desert and Ustyurt Plateau, Tien Shan foothills, and steppe-semi-desert transition zones. Sites represent varying climatic conditions, land-use pressures, and restoration potential.

2.2 GIS and Remote Sensing Analysis. Satellite imagery from Sentinel-2, Landsat-8, and MODIS was used to analyze vegetation health (NDVI), wetland dynamics (NDWI), land-use change, and habitat fragmentation. Hotspot and risk-zone mapping supported prioritization of conservation interventions.

2.3 AI-Based Ecological Monitoring. A convolutional neural network was trained on camera-trap data to detect 45 target species. Monitoring data provided information on species presence, abundance trends, and illegal activities such as grazing and logging.

2.4 Predictive Modeling. Habitat suitability was modeled using MaxEnt and Random Forest algorithms under mid- and high-emission climate scenarios. Hydrological modeling was applied to wetland sites to assess water retention under NbS interventions.

2.5 Nature-Based Solutions Implementation. NbS measures included riparian reforestation, wetland rehydration, ecological corridor creation, controlled grazing, and community-based restoration programs. Ecological indicators were monitored before and after interventions.

2.6 Data Analysis. Statistical analyses compared pre- and post-intervention conditions using diversity indices, vegetation metrics, soil parameters, and connectivity indices.

3. RESULTS

Spatial analysis identified 174 biodiversity hotspots, with 21.8% located outside protected areas. AI-based monitoring achieved 93% detection accuracy and recorded endangered species in 67% of restored sites. NbS interventions increased vegetation cover by up to 44%, improved soil moisture by 22%, and enhanced habitat connectivity by 37%. Climate modeling predicted that integrated digital-NbS strategies could preserve more than 80% of critical habitats by 2040.

4. DISCUSSION.

The findings demonstrate that digital ecology significantly enhances biodiversity monitoring and conservation planning, while NbS delivers measurable ecological and socio-economic benefits. The synergy between technology and ecosystem restoration improves climate resilience, reduces costs, and strengthens community stewardship. These results align with global conservation trends while addressing regional knowledge gaps in Central Asia.

5. CONCLUSION

Integrating digital ecology tools with nature-based solutions provides an effective and scalable approach to biodiversity conservation in Uzbekistan. The study confirms that proactive, data-driven strategies can restore degraded ecosystems, protect biodiversity under climate change, and support sustainable development. Establishing national digital conservation infrastructure and expanding NbS implementation are critical for long-term ecological security.

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