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FROM RIVERS TO RED BOOK: HOW CLIMATE CHANGE RESHAPES UZBEKISTAN'S ECOSYSTEMS, BIODIVERSITY, AND HUMAN WELL-BEING

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Abstract

Uzbekistan sits at the climatic crossroads of Central Asia, where arid and semi-arid landscapes and heavy dependence on the Amudarya and Sirdarya rivers heighten sensitivity to warming and water scarcity. Heat extremes raise ecological and physiological stress, while hydrological shifts threaten riverine wetlands and irrigated food systems that rely on seasonal flows and groundwater recharge. Regional assessments anticipate that, by mid-century, Amudarya and Sirdarya flows could decline by roughly 5–15%, increasing the risk of water deficits across sectors [2,4].

This article examines how climate change is reshaping Uzbekistan's ecosystems, biodiversity, and human well-being through linked pathways: heat and drought stress, habitat shrinkage, land degradation and desertification, and dust and air-quality deterioration. It summarizes conservation stakes, including the Red Book (2019), which lists 314 plant species and 206 animal species requiring protection [1]. A focused case study of the Aral Sea highlights how large-scale irrigation diversion drove ecological collapse and how climate warming can further constrain recovery [6].

The article concludes with evidence-based options that align adaptation with conservation—water-smart irrigation, protection and restoration of wetlands and

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tuqay forests, biodiversity monitoring, and heat–dust health preparedness—framed as integrated “nature–water–food–health” governance [4,5,7].

Keywords: Climate change; biodiversity; water scarcity; Amudarya; Sirdarya; Aral Sea; tuqay; heat stress; Uzbekistan; Central Asia.

Introduction

Biodiversity—the variation within species (genetic diversity), among species, and across ecosystems—underpins the stability and productivity of natural systems. In Uzbekistan, biodiversity supports services that remain largely invisible until they fail: soil formation and nutrient cycling at steppe and desert margins, pollination for orchards and vegetable crops, natural regulation of pests and diseases, filtration and retention of water in wetlands, and the microclimatic buffering provided by riparian vegetation along rivers and canals. These ecosystem services are not “extras”; they are part of the operating system for food security, disaster risk reduction, and public health.

Uzbekistan’s ecological fabric spans deserts (including the Kyzylkum), mountain systems (Western Tien Shan and Pamir-Alai foothills), steppe and grassland mosaics, wetlands and river deltas, and tuqay riparian forests. Each system is shaped by a limiting factor—most often water—and each responds differently to warming, precipitation variability, and land-use change. What makes this landscape scientifically compelling is that many of its ecosystems already operate close to physiological and hydrological thresholds; modest shifts in temperature and water availability can tip them into rapid change.

Climate change is increasingly understood as a “threat multiplier”: it rarely acts alone, but it intensifies pre-existing pressures such as water overuse, land conversion, pollution, and habitat fragmentation. As temperatures rise, evaporation increases and drought risk grows, amplifying competition between agricultural demand, ecosystem water needs, and urban–industrial consumption

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[3,4]. At the same time, extreme heat poses direct risks to human health, raising the likelihood of heat stress and heatstroke and compounding the health burden for vulnerable groups [7].

This article synthesizes evidence relevant to Uzbekistan and adjacent Central Asian basins to answer a core question: through what mechanisms does climate change reshape biodiversity, and how do these ecological changes reverberate through food systems and human well-being? Section C explains why Uzbekistan is highly sensitive, emphasizing climatic continentality and river dependence. Section D outlines the ecological baseline and conservation stakes, including nationally listed threatened species. Sections E and F analyze mechanisms and the Aral Sea case study. Sections G and H connect biodiversity change to agricultural resilience and health risks, and Sections I–K assess future trajectories and evidence-based solutions.

Context: Why Uzbekistan is Highly Sensitive

C1. Climate and geography drivers

Uzbekistan is dominated by lowland plains and deserts, with high mountains and foothills framing the east and southeast. This geography produces a sharply continental climate: hot summers, cold winters, large diurnal temperature ranges, and substantial year-to-year variability. Precipitation is limited in many regions and is concentrated in cooler months, while the hottest months coincide. with peak evaporative demand. As a result, ecological productivity concentrates where water is concentrated: along rivers, in irrigated oases, around wetlands, and in the mountain-to-plain transition zones where springs and seasonal streams sustain vegetation.

The country's hydrological dependence is amplified by the transboundary nature of its main rivers. The Amudarya and Sirdarya rise outside Uzbekistan, and their flows reflect upstream climate dynamics (including snowpack and glacier change) as well as upstream water management. National and regional

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assessments note that glacier retreat can initially increase meltwater but tends to reduce long-term water security as ice reserves shrink [2,3]. In practical terms, Uzbekistan must manage a downstream exposure: it experiences the combined effects of climate-driven supply changes and allocation decisions made across the basin.

C2. Water stress and future pressure

Water stress is therefore not a future abstraction; it is a defining constraint of development and conservation. Large irrigated areas support national food supply and rural incomes, yet irrigation networks can be aging and loss-prone, and many ecosystems - especially river deltas and tuqay forests - depend on minimum environmental flows and periodic flooding to regenerate [4]. When water is allocated narrowly for production in dry years, ecological functions are often the first to be reduced, triggering habitat contraction, rising salinity in wetlands, and declining groundwater tables that weaken riparian forests.

A consistent finding across syntheses is that climate warming is likely to intensify this pressure. A national state-of-environment synthesis anticipates that by mid-century the flow of the Amudarya and Sirdarya could decrease by about 5-15%, increasing the risk of water deficits [2]. World Bank analyses similarly project declining water resources and emphasize that rising heat will increase irrigation demand even as supplies become less reliable [4]. The resulting scarcity will not be uniform: it is likely to be most acute during hot, dry years when multiple sectors demand more water at the same time.

These sensitivities matter for biodiversity because many of Uzbekistan's ecosystems are synchronized to water dynamics. Tuqay forests rely on shallow groundwater and episodic inundation for seedling establishment; wetlands depend on seasonal inflows that regulate salinity and nutrient availability; and desert and steppe communities depend on rare precipitation pulses whose timing shapes flowering, seed set, and forage availability. In other words, the same

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physical variables that govern water allocation also govern species persistence, making biodiversity a frontline indicator of climate-water risk.

Conceptual synthesis

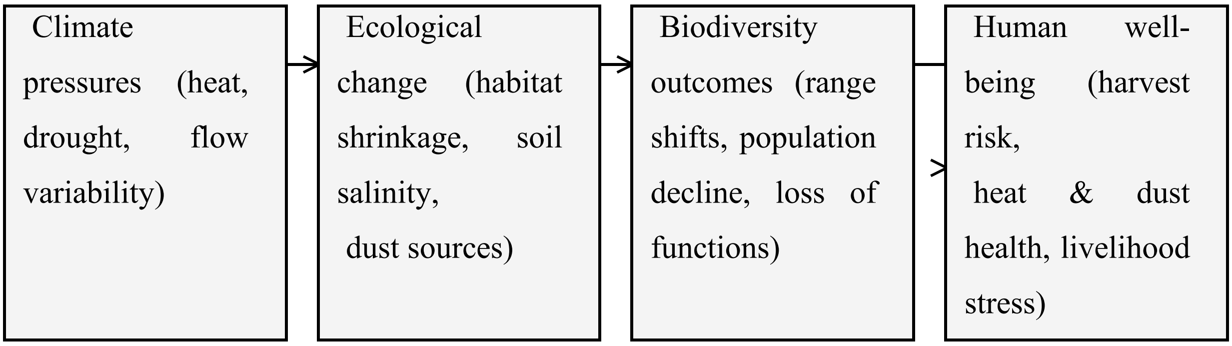

Figure 1. Simplified pathways linking climate pressures to biodiversity outcomes and human well-being.

Feedbacks via water demand and land use

Biodiversity Baseline and What Is at Stake

D1. Key ecosystems in Uzbekistan

Uzbekistan's biodiversity is best understood as a gradient from mountains to lowlands. Mountain and foothill zones in the east and southeast host high plant endemism and provide climatic refugia that may become increasingly important as lowland summers become hotter and drier. Steppe and grassland mosaics support rangeland livelihoods and migratory pathways, while desert ecosystems (including the Kyzylkum) contain species adapted to extreme heat and scarce water. In the lowlands, wetlands, river deltas, and riparian habitats concentrate biological productivity and species interactions, providing crucial ecosystem services where water and people intersect.

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Among these systems, tuqay forests deserve special attention because they function as linear biodiversity corridors across otherwise water-limited landscapes. Tuqay vegetation - often dominated by poplar, willow, tamarisk, and associated understory species - stabilizes banks, shades channels, and creates habitat heterogeneity that supports birds, small mammals, and invertebrates. Evidence from regional studies links tuqay degradation to altered river flow regimes, falling groundwater tables, and salinization, which can weaken tree water uptake and reduce regeneration success [9].

Several characteristics make these ecosystems particularly climate-sensitive. First, many species already operate near thermal or hydrological tolerance limits, especially in deserts and saline wetlands. Second, linear habitats (riparian forests, canals, and wetland chains) concentrate biodiversity but also concentrate risk: when flows decline or salinity rises, habitat loss propagates along entire corridors. Third, the spatial distribution of protected areas and key biodiversity areas is uneven relative to future climate exposure, meaning that conservation effectiveness will increasingly depend on ecological connectivity and flexible management.

D2. Conservation status and the Red Book

Conservation status provides a structured lens for what is at stake. Uzbekistan maintains a national Red Book (Red Data Book) that lists species considered rare, threatened, or otherwise requiring special protection. The 2019 edition lists 314 plant species and 206 animal species, signaling conservation concern across taxa and ecosystems [1]. While national categories are not identical to international systems, they commonly distinguish species that are rare (with small populations or restricted ranges), endangered (facing elevated extinction risk), and those believed to be disappearing or locally lost.

The Red Book matters not simply as a catalog, but as an organizing instrument for policy and monitoring. Listing can trigger legal protections, guide protected-

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area planning, and prioritize research and funding for recovery actions. Importantly, Red Book species can act as sentinels: because they are sensitive to habitat fragmentation, water stress, or temperature thresholds, their trends often reveal broader ecological change before it becomes visible in aggregated ecosystem indicators. In this sense, conservation status is also a diagnostic tool for climate-risk management.

Protected areas and biodiversity initiatives in Uzbekistan - ranging from mountain reserves to biosphere and desert-forest projects - can therefore be viewed as part of a climate adaptation portfolio. Mountain parks and reserves can safeguard elevational gradients and microclimates; wetland protection can buffer against extremes by storing water and moderating dust; and tuqay restoration can provide multiple co-benefits (bank stability, shade, habitat, and local cooling). However, these benefits are contingent on water allocation and land-use decisions at the basin scale, reinforcing the need to treat biodiversity policy as water policy.

Table 1. Climate pressures, ecological changes, and implications for biodiversity and people (illustrative synthesis).

Climate pressure	Ecological change	Biodiversity outcomes	Human implications
Heat extremes & drought	Higher evapotranspiration; phenology shifts; heat stress	Range shifts; lower survival and reproduction; loss of specialists	Heat illness risk; higher water demand; productivity loss [7]
Reduced river flows & variability	Wetland contraction; higher salinity; lower groundwater tables	Wetland habitat loss; tuqai degradation; corridor fragmentation	Irrigation deficits; livelihood stress; water competition [2,4]
Land degradation & salinization	Vegetation loss; soil erosion; salt accumulation	Functional diversity decline; simplified communities	Yield instability; dust sources; higher restoration costs
Dust & air-quality deterioration	Exposure of saline surfaces; particle transport; deposition	Plant stress; soil chemistry shifts; aquatic stress	Respiratory burden; compounding heat risk [5,7]

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Mechanisms: How Climate Change Reduces Biodiversity

Organizing logic: Pressure → Ecological change → Biodiversity outcome.

E1. Heat and drought stress

Heat and drought stress sit at the center of climate-biodiversity pathways in Uzbekistan. Rising mean temperatures increase evapotranspiration, meaning that ecosystems require more water to maintain the same physiological function. For plants, this can translate into reduced photosynthesis, earlier senescence, and higher mortality during multi-year droughts. For animals, it can reduce foraging time, shift activity toward cooler hours, and alter reproduction. While many dryland species are adapted to hardship, the combination of higher baseline heat and longer dry spells can push populations beyond tolerance limits, especially in fragmented habitats.

Crucially, extreme heat changes ecological timing. In mountain foothills, shifts in snowmelt timing can alter the onset of spring growth, affecting flowering windows and the synchrony between plants and pollinators. In drylands, rare precipitation pulses can trigger brief productivity booms; if heat arrives earlier, these booms may shorten, reducing seed production and forage availability. Such phenological shifts often become visible first in species with narrow ecological niches or in habitats with limited microclimatic refuge.

Heat also interacts with human systems in ways that feed back to biodiversity. When heat stress rises, water demand increases and labor productivity can fall, creating incentives to intensify irrigation, expand into new land, or modify cropping patterns [4,7]. If adaptation focuses narrowly on production without ecological safeguards, the cumulative effect can be higher pressure on remaining natural habitats.

E2. Water scarcity and habitat shrinkage

Water scarcity and habitat shrinkage translate climate signals into ecological outcomes. In river basins, lower or more variable flows can reduce the area and

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duration of wetland inundation, raise salinity in terminal lakes, and reduce channel connectivity that fish and amphibians need for breeding. Riparian habitats can contract to narrow strips, losing structural complexity and microclimatic buffering. In Uzbekistan, these processes are most visible in deltaic and floodplain landscapes where biodiversity is concentrated but depends on a small fraction of total land area.

Reduced flows also undermine tuqay forests through groundwater pathways. Where groundwater tables fall beyond the rooting depth of key species, drought stress increases even if rainfall is unchanged. Salinization compounds this problem by lowering plant water potential, effectively making water less available even when it is present. The ecological outcome is not merely fewer trees; it is a functional shift from diverse, multi-layered riparian forest to simplified shrublands, with cascading effects on nesting sites, prey availability, and corridor connectivity [9].

These habitat changes, in turn, affect species persistence and movement. Wetlands serve as stepping-stones for migratory birds across Central Asia; when they shrink, migration routes can fragment. Similarly, riparian corridors enable dispersal across deserts; when they degrade, populations can become isolated, increasing local extinction risk, especially for species already listed as threatened in the Red Book [1].

E3. Land degradation and desertification

Land degradation and desertification are often described as slow processes, but in water-limited landscapes they can accelerate abruptly once thresholds are crossed. Higher temperatures and more frequent drought can reduce vegetation cover, exposing soils to wind erosion. When protective plant cover is lost, the surface heats more strongly and retains less moisture, further limiting regrowth. This feedback loop - hotter and drier conditions leading to soil degradation,

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leading to less vegetation, leading to higher local temperatures - is a classic pathway by which climate change can amplify land degradation.

In Uzbekistan, the interaction between irrigation and land degradation is especially important. Irrigation enables high productivity but can raise groundwater and concentrate salts if drainage is insufficient. Under hotter conditions, evaporation from soils and canals can intensify salinity risks. Salinization can push agricultural fields toward lower yields, and it can also alter adjacent natural habitats by changing soil chemistry and water availability. Where farms respond to yield loss by expanding cropland or grazing into semi-natural habitats, the pressure on biodiversity can increase even if climate trends are unchanged.

From a biodiversity perspective, degraded lands often shift species composition toward tolerant generalists while losing specialists. This reduces functional diversity - the diversity of roles organisms play-which can weaken ecosystem resilience. In turn, weakened resilience makes ecosystems less able to recover after drought, fire, or pest outbreaks, creating a self-reinforcing pathway of decline.

E4. Dust and air-quality impacts

Dust and air-quality impacts form a bridge between biodiversity change and human well-being. When vegetation cover declines and saline surfaces expand, strong winds can lift fine particles and salts into the atmosphere. In the Aral Sea region, the exposure of former seabed has created a new dust source whose impacts extend beyond immediate surroundings. UNICEF assessments emphasize that many regions in Uzbekistan face combined exposure to climate and environment-related hazards, including extreme heat, water scarcity, and sand and dust storms [5].

Ecologically, dust deposition can affect plant physiology by blocking leaf surfaces and reducing photosynthetic efficiency, and it can alter soil properties when salts accumulate. Dust also interacts with water quality: sediments can

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affect wetlands and shallow lakes, and increased salinity can stress aquatic communities. The outcome is a coupled stressor regime in which heat, drought, land degradation, and dust reinforce one another.

For public health, dust and extreme heat can act synergistically: high temperatures exacerbate dehydration and cardiovascular strain, while particulate pollution burdens the respiratory system [7]. This coupling is not peripheral; it shapes the social feasibility of conservation and adaptation, because communities facing frequent dust events and heat stress must prioritize immediate health and livelihood needs. Reducing dust sources through vegetation restoration and sustainable water management therefore offers a dual dividend: it supports biodiversity and reduces direct health risks.

Case Study: The Aral Sea and Irrigation

The Aral Sea provides a defining case study for how water management and climate dynamics can converge to reshape biodiversity. In the mid-twentieth century, large-scale irrigation expansion diverted substantial portions of the Amudarya and Syrdarya to support agricultural production, particularly water-intensive crops. NASA Earth Observatory summaries describe how dams, canals, and other infrastructure redirected river flows that once replenished the Aral Sea, initiating a multi-decade contraction of the water body [6]. The result was not simply a smaller lake, but a transformation of an aquatic ecosystem into a fragmented set of increasingly saline basins.

As the sea shrank, ecological thresholds were crossed. Rising salinity and pollution undermined native fish communities, contributing to the collapse of commercial fisheries and associated livelihoods. Wetlands and reed beds that depended on deltaic inflows contracted, reducing breeding habitat for birds and other wildlife. Exposed seabed became a new desert - the Aralkum - whose saline and contaminated sediments can be mobilized by wind, increasing dust exposure and degrading nearby vegetation. These outcomes illustrate an important

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principle: when hydrological inputs are reduced, the ecological response is often nonlinear, with abrupt shifts in community composition and ecosystem function. Climate change amplifies this story rather than replacing it. NASA documentation of the Aral Sea's post-2000 fluctuations highlights how drought and variability in Amudarya inflows influenced year-to-year water extent [6]. In a warming climate, higher evapotranspiration increases water demand while reducing the effective supply that reaches deltas and terminal basins. Regional assessments that project declining river flows by mid-century imply that the environmental "margin" available for delta restoration and wetland maintenance may shrink unless efficiency gains and basin-scale coordination improve [2,4].

The Aral case also cautions against single-sector optimization. Irrigation transformed desert landscapes into productive fields, yet the externalized ecological costs - wetland loss, biodiversity decline, and dust hazards - were borne by communities and ecosystems downstream. A central lesson for Uzbekistan is therefore governance-based: sustaining biodiversity and human well-being under climate change requires water allocation frameworks that explicitly protect environmental flows, reduce losses in irrigation systems, and treat ecosystem health as a form of infrastructure rather than an optional luxury.

In Uzbekistan, the downstream region of Karakalpakstan illustrates the human-biodiversity interface of such collapse. Reduced wetland habitat can diminish grazing and fishing resources, while more frequent dust events can increase health burdens and constrain outdoor work, including agriculture. UNICEF's hazard mapping highlights that sand and dust storms are a major climate-and-environment hazard affecting children, and the Aral Sea crisis is explicitly linked to desertification and dust pollution [5]....

The region has not been without responses. Measures to stabilize exposed seabed through afforestation and soil-binding vegetation (for example, saxaul planting) are intended to reduce dust emissions while creating new habitat niches. Such interventions can deliver tangible benefits, but they do not substitute for basin-

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wide water governance. They function best as part of a portfolio that includes irrigation modernization, improved drainage to reduce salinization, protected environmental flows for deltas...

Strikingly, the Aral Sea narrative is not only a retrospective caution; it is a forward-looking stress test for climate adaptation. As climate-driven scarcity intensifies, allocation choices become sharper: each cubic meter saved through efficiency gains can either expand production, sustain ecosystems, or reduce public health risks. The analytical value of the Aral Sea is that it makes these trade-offs visible, measurable, and therefore governable.

Agriculture and Biodiversity: A Two-Way Relationship

Agriculture and biodiversity are linked in both directions: climate change affects harvests, and responses in the agricultural sector shape habitats and species persistence. Uzbekistan's irrigated agriculture is a cornerstone of rural livelihoods, yet it is climate-sensitive because it depends on reliable water deliveries during the hottest months. The World Bank's country profile for Uzbekistan notes that projected warming and water shortages are expected to reduce yields of major crops, with additional ...

Biodiversity supports agriculture in ways that conventional accounting often misses. Pollinators increase yield and quality in orchards and horticulture; soil organisms maintain fertility and structure; and diverse landscapes can suppress pest outbreaks by supporting predators and parasitoids. These services depend on habitat connectivity, clean water, and microclimatic buffering. When riparian strips and wetland mosaics are degraded, or when pesticide use intensifies without integrated pest management, ...

A key risk under climate stress is maladaptive expansion. If yields fall due to heat, salinity, or water rationing, producers and local authorities may compensate by converting additional land to agriculture, often targeting the same ecologically valuable areas that retain moisture - floodplains, wetlands, and tuqay corridors.

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Such conversion can accelerate biodiversity loss and undermine the ecosystem services that agriculture depends on. For this reason, adaptation strategies should be evaluated not o...

Conversely, climate-smart practices can generate co-benefits. Improving irrigation efficiency and scheduling can reduce pressure on rivers and groundwater, creating space for environmental flows that sustain wetlands and riparian forests [4]. Soil conservation and salinity management can maintain productivity without expansion. Landscape-scale approaches - such as maintaining buffer strips along channels, protecting wetlands that regulate water quality, and conserving pollinator habitat - offer a practical w...

Uzbekistan's historical reliance on water-intensive cropping in arid landscapes makes the water-energy-food nexus especially salient. In hot years, irrigation demand rises just as river inflows may fall. If this gap is managed through groundwater pumping, the short-term benefit can be long-term depletion and higher salinity risk, with consequences for both farms and adjacent natural habitats. If it is managed through rationing, farms may prioritize a subset of fields, and marginal lands may be abandoned...

Notably, agriculture also offers one of the fastest levers for reducing pressure on biodiversity under climate change. Shifts toward less water-intensive crops, improved conveyance efficiency, and digital water accounting can reduce the system-wide footprint. The scientific point is not that a single technology will "solve" scarcity, but that cumulative savings can be converted into resilience: part to stabilize yields, part to maintain environmental flows, and part to reduce conflicts. When designed wit...

Human Health Dimension

Climate change affects health through direct exposure pathways and through ecological and economic intermediaries. In Uzbekistan, two exposures stand out for their immediacy: extreme heat and dust. The World Health Organization

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emphasizes that heat stress is a leading cause of weather-related mortality and can exacerbate cardiovascular and respiratory disease, increase accident risk, and lead to heatstroke, which is a medical emergency [7]. Heat impacts are especially relevant for outdoor workers, inc...

Heat also has visible dermatological and physiological manifestations. Higher ambient temperatures and solar exposure can increase the risk of sunburn, heat rash, dehydration-related skin irritation, and worsening of some inflammatory conditions. While these outcomes depend on individual behavior and access to cooling, they illustrate an important point for environmental science: climate change expresses itself on the body surface as well as in ecosystems. When nights remain warm and humidity rises, t...

Dust exposure provides a second, compounding hazard. UNICEF's assessment highlights sand and dust storms as a key hazard affecting children across Uzbekistan and links the Aral Sea's shrinkage to desertification and dust pollution [5]. Fine particulate matter and salt-laden dust can irritate airways, worsen asthma and other respiratory conditions, and increase vulnerability during heat events. The intersection of dust and heat matters for biodiversity as well: when dust reduces vegetation health and...

Finally, climate change can influence infectious disease dynamics, particularly for vector-borne diseases. Temperature and precipitation patterns affect vector development rates, survival, and seasonal activity, while drought and water storage practices can alter breeding habitats. A clinical review in the New England Journal of Medicine summarizes evidence that warming and changing rainfall are affecting the occurrence of vector-borne diseases in multiple regions [8]. For Uzbekistan, the practical im...

From a policy perspective, health impacts reinforce the value of ecosystem-based adaptation. Heat action plans, early warning systems, occupational protections, and access to cooling reduce acute risk [7]. At the same time, measures that protect wetlands and riparian vegetation can moderate local microclimates,

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improve air quality, and reduce dust sources, delivering preventative benefits. This integrated view - treating biodiversity conservation as part of health resilience - strengthens the...

Future Outlook

If current trends continue, Uzbekistan is likely to face a tighter coupling of heat extremes and water scarcity. Climate projections summarized in national and international assessments point toward continued warming, higher evaporative demand, and a greater likelihood of drought and low-flow years [3,4]. In river basins, this implies that scarcity will be experienced not only as lower mean supply, but also as higher variability - more frequent years when ecological and agricultural needs peak precisely...

Hydrologically, one plausible stressor is declining river flows. A state-of-environment synthesis anticipates that Amudarya and Sirdarya flows could decrease by about 5-15% by mid-century [2], while World Bank work emphasizes that heat stress will increase demand and that scarcity could rise markedly without efficiency gains [4]. The policy implication is that allocation rules will be tested more frequently: drought years will become the new normal reference point rather than an exception.

For biodiversity, the likely trajectory is a shift in species distributions and community composition. Lowland habitats may lose moisture-dependent species and gain more drought-tolerant generalists; wetlands may contract and become more saline; and tuqay forests may fragment if groundwater declines and floods become rarer. Mountain systems may provide partial refugia, but only if corridors and protected gradients allow species movement. The conservation implication is that Red Book listings will likely...

For human well-being, the combination of heat, dust, and water stress can increase health burdens and economic risk. Extreme heat reduces labor capacity

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and can raise demand for cooling and water [7]. Dust events can intensify respiratory impacts, particularly for children and other vulnerable groups [5]. Importantly, these risks are not deterministic: they depend on whether governance converts climate signals into crisis or into managed adaptation. The next section therefore focuses on interventions ...

Solutions and Recommendations

Without immediate action, climate change is likely to deepen biodiversity loss and raise the costs of protecting health and harvests. However, a coherent response is available if interventions are designed as a portfolio that aligns adaptation with conservation. A robust framing for Uzbekistan is an integrated "nature-water-food-health" strategy in which water efficiency gains, habitat protection, and health preparedness are treated as mutually reinforcing rather than competing goals.

Water-smart irrigation and allocation. Irrigation modernization is a priority because it reduces pressure on the same rivers and aquifers that sustain biodiversity. Measures include drip or sprinkler systems where feasible, canal lining and leakage control, improved drainage to limit salinization, and scheduling based on crop water requirements and weather information. World Bank assessments emphasize that scarcity will increase under warming and that efficiency and better allocation are central levers [4...

Environmental flow protection should be embedded in allocation rules. Even modest, well-timed releases can sustain key ecological functions: wetland inundation for breeding, groundwater recharge for tuqay forests, and salinity control in terminal basins. Integrating environmental flows into basin planning shifts conservation from a discretionary activity to a core water-management requirement [4].

Protect and restore climate-resilient habitats. Conservation priorities should focus on habitats that deliver high ecosystem-service and biodiversity value per unit

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water. Wetlands and riparian corridors often meet this criterion because they support disproportionate biodiversity and provide cooling, filtration, and dust reduction. Restoration should be designed around hydrology: planting without securing groundwater and flood regimes is unlikely to be durable. Tuqay restoration, for instance, should be paired with groundwater protection and managed flooding where possible [9].

Monitoring and evidence for decision-making. Robust biodiversity monitoring reduces uncertainty and improves prioritization. Updating Red Book assessments and linking them to systematic surveys can reveal where climate stress is translating into population decline [1]. Remote sensing can track wetland extent, vegetation cover, and dust-source dynamics, while community science can complement formal monitoring by increasing spatial coverage. The goal is not data for its own sake, but actionable indicator...

Health protection and risk communication. Heat and dust are immediate hazards with well-established prevention measures. Heat action plans, occupational protections, and public guidance on hydration, cooling, and recognition of heat illness are recommended by public health authorities [7].

UNICEF's hazard analysis provides a basis for targeting protection to vulnerable regions and populations, including children [5]. Preparedness should also include dust-storm alerts, indoor air-quality measures for ...

Governance: aligning incentives across sectors. The effectiveness of technical measures depends on governance. Integrated planning should evaluate policies for cross-sector impacts: a water allocation decision is simultaneously an agricultural decision, a biodiversity decision, and a public health decision. Transparent water accounting, incentives for efficiency, and enforcement against habitat conversion in floodplains can reduce maladaptation. Regional cooperation in transboundary basins is also necessary to reconcile upstream and downstream needs under changing flow regimes [4].

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Research, capacity, and finance. Finally, sustaining progress requires institutional capacity and durable financing. Research priorities include quantifying environmental flow requirements for key wetlands and tuqay forests, assessing climate refugia in mountain systems, and evaluating the effectiveness of dust-reduction and restoration programs. Capacity building - from water managers to health workers and protected-area staff - improves the translation of monitoring data into decisions. Financing mechanisms can reward efficiency and ecosystem services, helping ensure that conservation is not treated as an optional add-on but as a foundation for resilience.

Conclusion

Uzbekistan's biodiversity and human well-being are being reshaped by a common set of physical drivers: rising heat, tightening water scarcity, and land degradation that can amplify dust exposure. These drivers do not operate in isolation. They interact across ecosystems and sectors, converting climate signals into habitat change, agricultural risk, and health burdens. The Red Book's threatened species listings underscore that conservation is not a niche concern but a national resilience indicator [1]....

If current trends continue, the country is likely to face more frequent years in which heat extremes and low water availability coincide, shrinking wetlands and weakening tuqay corridors while raising the costs of maintaining harvest stability and protecting health [2-4]. Yet the Aral Sea case demonstrates that outcomes are shaped by governance: allocation choices, infrastructure performance, and the willingness to protect environmental functions determine whether scarcity becomes crisis or managed ris...

Without immediate action, biodiversity loss and climate-related health risks will become harder and more expensive to reverse. The priority is not a single "silver bullet" but an integrated portfolio: water-smart irrigation and transparent allocation, legally protected environmental flows, targeted restoration of

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wetlands and riparian forests, evidence-based biodiversity monitoring, and heat-and-dust health preparedness [4,5,7]. Implemented together, these measures can help Uzbekistan navigate climate...

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