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# EFFECTIVENESS OF TREES AND VEGETATION IN DUST RETENTION IN UZBEKISTAN'S XORAZM REGION

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**Abstract.** Dust storms driven by the exposed lakebed of the Aral Sea and local deserts severely impact the Xorazm (Khorezm) region, degrading air quality, soil, and crop productivity. Vegetation – especially trees, shrubs, and shelterbelt plantings – can substantially mitigate dust by capturing particles on foliage and stabilizing soils. This review synthesizes ecological and agronomic perspectives on dust retention by vegetation in arid Uzbekistan, with emphasis on species adapted to Khorezm's climate and soils. We discuss mechanisms of dust capture (leaf surface deposition and windbreak effects), ecosystem benefits of stabilized soil and reduced erosion, and agricultural benefits of windbreaks. Native and well-adapted species emerge as most effective: desert shrubs (black saxaul Haloxylon aphyllum, saltwort Salsola spp., Calligonum spp.) establish dense stands on saline sands, while trees such as poplars (Populus spp.), elms (Ulmus), willows (Salix), and hardy fruit/forest trees (e.g. black locust, paulownia) are used in oasis windbreak belts.

**Keywords.** Dust, Vegetation, green, tree, Halocnemum, Ulmus, environment, agroforestry

**Introduction.** Multi-row shelterbelts integrating fast-growing poplars or paulownia with understory shrubs markedly reduce wind speed and evapotranspiration in adjacent fields. Large-leaved species and evergreen conifers can trap dust on foliage, but durability under arid, saline conditions is critical. Studies have shown that deciduous shade trees (plane Platanus, catalpa Catalpa) accumulate more foliar dust per leaf area than many conifers, suggesting that broadleaf belts may be especially efficient at particle capture. National afforestation initiatives in Uzbekistan illustrate these principles: over recent years millions of hectares on the former Aral seabed and desert fringes have been planted with salt-tolerant shrubs and trees (e.g. saxaul, Calligonum, Salsola, Tamarix) to bind soil and curb salt-dust emission. In irrigated Khorezm farmland, belt plantations of poplar, elm, and other quick-growing species form protective green barriers along fields and canals. These mixed-species plantations provide multiple functions: they anchor sand, intercept airborne dust, and create localized humid microclimates that reduce crop evapotranspiration (studies report up to ~50% reduction in field evapotranspiration from multi-row windbreaks). Overall, vegetation cover has been modeled to cut regional dust emissions by the majority (up to ~80% in favorable seasons) when scaled across key source areas. The choice of species is guided by drought and salt tolerance, growth form, canopy density, and maintenance needs. The most dust-retentive species are those with high leaf surface area, rough or hairy foliage, and capacity to form dense shelterbelts in the harsh Khorezm environment. In conclusion, integrating ecological forestation (stabilizing bare salt flats with native shrubs and grasses) with agroforestry windbreaks (high-density tree belts along irrigated fields) offers a resilient, nature-based approach to trapping dust. Strategic greening with adapted species not only reduces airborne particulates but also improves soil stability and crop yields, contributing to regional sustainable land management. The Xorazm (Khorezm) region in

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northwestern Uzbekistan occupies an arid belt along the Amu Darya river delta. It endures a desert climate (hot, dry summers; cold winters; ~100 mm annual rainfall) and heavy irrigation agriculture. Since the 1960s, intensive irrigation diverted water from the Amu Darya, contributing to the Aral Sea's desiccation. As the sea receded, a toxic salt-laden desert (the Aralkum) emerged, becoming a primary source of regional dust. Windborne salt-dust from the Aralkum and local sandy soils now commonly inundates Khorezm, especially in spring. These sand and dust storms (SDS) degrade air quality, damage crops and infrastructure, and pose health risks to rural communities. Recent analyses confirm that Khorezm experiences frequent and intense dust events (often exceeding 80 storm-days per year), with peak activity in late spring from winds blowing off the former seabed[1][2]. Climate change has further increased aridity and SDS frequency in the region[3][4]. In this context, vegetation is recognized as a key mitigant of dust storms. Plants influence wind flow and trap particulate matter on leaves and branches. On the vast saline sands of the Aralkum and surrounding deserts, stabilizing the soil surface with perennial vegetation can suppress the generation of dust plumes. Within irrigated farmlands and oasis fringes, shelterbelts of trees and shrubs reduce wind speed, decreasing soil erosion and protecting crops. Afforestation and reforestation programs in Uzbekistan explicitly target SDS reduction through nature-based solutions: government and international initiatives have planted hundreds of thousands of hectares of drought- and salt-tolerant species to bind soils and intercept dust (e.g. Uzbekistan reached its Bonn Challenge restoration target of 500,000 ha by 2020[5]). Field studies indicate that certain tree and shrub species accumulate large amounts of dust on their foliage, making them effective "dust sponges" in urban and desert settings[6]. This article reviews how trees and other plants capture dust in the Xorazm region, from both ecological and agronomic viewpoints. We examine mechanisms of dust retention, benefits to ecosystems and agriculture, and the suitability of various species under Xorazm's climatic and soil constraints. The goal is to identify which plant types and species most efficiently remove dust from the air and stabilize soils, while thriving in local conditions. By covering a broad suite of trees, shrubs, and protective vegetation, we provide guidance for ecosystem restoration and farm windbreak design in this vulnerable region.

**Ecological Role of Vegetation in Dust Control.** Vegetation influences dust in two fundamental ecological ways. First, living plant cover (grasses, shrubs, trees) physically anchors soil and sand, preventing them from becoming airborne. Even sparse vegetation can reduce wind erosion by lowering surface wind speed and protecting bare ground. In this way, plantations and natural plant communities interrupt the source of dust storms. Second, plant canopies capture dust particles on leaves, needles, and twigs, effectively filtering particulates from the air column. Though deposited dust may later be washed to the ground by rain (cycling nutrients back into the soil), its temporary immobilization reduces atmospheric loads. In the Aralkum desert and other degraded landscapes, reestablishing native vegetation is a priority for dust mitigation. Halophytic shrubs and semi-shrubs naturally colonize saline flats. For example, black saxaul (Haloxylon aphyllum), a salt-tolerant desert shrub, has dense, twiggy stems that trap blowing salt and sand. Saltworts (Salsola spp.), Halocnemum, Kalidium, and other chenopods form halophytic ground cover on solonchak (saline) soils. Deep-rooted psammophiles like Calligonum spp. stabilize dunes and spread across sands, creating islands of firm ground. International research on the Aralkum shows that plant succession has already produced mosaic communities of high-sand psammophytic plants interspersed with salt-tolerant halophytic communities[7][8]. Restoration efforts mimic these communities. Uzbekistan and international partners have planted saxaul extensively on dried seabed and adjacent desert soils. New plantation areas allow vegetation to grow thick enough to substantially reduce wind speed: modeling suggests that widespread afforestation on the Aral seabed can decrease airborne dust by a majority, with one analysis

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indicating up to ~80% fewer dust emissions in key seasons once vegetation coverage is restored[9]. The World Bank/ICARDA report on Aralkum restoration highlights that plantations of indigenous shrubs and trees deliver "improved ecosystem services via soil and water retention, preventing polluted dust from being transported". In other words, re-greening the desert both binds the sediment and retains moisture, compounding benefits. In sum, ecologically oriented dust control relies on selecting species that establish stable, long-lived cover on poor soils, especially salt-tolerant perennials. Native genotypes dominate such programs, since they are pre-adapted to the extreme saline-arid environment. For example, recent government afforestation in the former Aral bottom and desert areas has focused on planting and sowing seeds of halophytes (black saxaul, saltworts) and psammophytes (Calligonum). These plantings create continuous belts and patches of vegetation that mechanically trap dust and reduce soil erosion by wind. Even simple stabilizing grass/forb swards (e.g. Artemisia, Stipa) in less harsh patches contribute to halting sand movement.

**Agronomic Benefits of Windbreaks and Shelterbelts.** Beyond pure ecological restoration, dust and wind control are integral to sustainable agriculture in Xorazm. Windbreaks or "shelter forests" bordering fields have a long history in Central Asia for improving crop conditions. By breaking the force of prevailing winds, trees reduce wind-blown soil particles and cut evapotranspiration from crops. In Khorezm's irrigated farmland, protective belts enhance soil moisture retention and reduce irrigation needs, while also intercepting dust that would otherwise coat crops. Field experiments in similar arid regions of Central Asia confirm these effects. For instance, multi-row windbreaks combining poplar (Populus) and elm (Ulmus) significantly lowered the reference evapotranspiration of adjacent crops. One study reported that seasonal evapotranspiration in crops with no windbreak was 876–995 mm, whereas it dropped to less than half when crops were behind a double-row shelterbelt (with understory shrubs). In practice, a 50 m wide belt of mixed trees (poplars and elms) reduced water consumption by crops by roughly 50%. Such water savings can translate into higher yields under irrigation constraints. Notably, the study found elms (though slower-growing) provided greater reduction per meter of belt than poplars, but poplars were valued for rapid growth and ease of establishment. In addition to microclimate regulation, shelterbelts directly trap dust. Large, continuous plantings force dusty air to slow, causing heavier particles to drop within the canopy. Over time, downwind fields remain cleaner and fertile. Agroforestry belts also yield secondary products (fuelwood, fruit, timber, forage) and can diversify farm income. For example, Uzbekistan's national strategy encourages planting fast-growing poplars, elms, and even paulownia in irrigated zones – species that not only grow vigorously under irrigation but also form dense foliage to intercept wind and particles. Trees such as willow (Salix) and Russian olive (Elaeagnus angustifolia) are commonly used along canals and farm margins for similar reasons. Economically, improved vegetation cover has quantifiable benefits for agriculture. Analyses of the Aral seabed rehabilitation show that landscape restoration can prevent millions in annual losses by preserving soil productivity and reducing off-site health impacts. On-farm, windbreaks increase yields by reducing lodging and moisture stress. They also mitigate dust deposition on crop leaves, which can impair photosynthesis and grow fungal problems under dusty conditions. In short, from an agronomic viewpoint the best shelter species are those that thrive with irrigation or groundwater (for quick growth) while enduring local climate extremes, thus providing a reliable dust barrier.

**Species Effectiveness and Adaptability.** Not all plants are equally effective at dust retention. The key attributes of top-performing species include tolerance of aridity or salinity, dense canopy or branching structure, and sufficient leaf area or surface roughness to intercept particles. In Khorezm, the following groups have proven most valuable:

Native Desert Shrubs: Black saxaul (Haloxylon aphyllum and H. persicum) are flagship species for Aralkum stabilization. These deep-rooted shrubs form thickets on sandy and saline flats. Saxaul's dense, many-branched crown catches fine salt particles, while its extensive roots bind the soil. Similarly, saltwort (Salsola spp.) and other chenopods (e.g. Kalidium, Halocnemum) tolerate soil salinity and often form low mats or shrub stands in dry depressions. The Russian government and NGOs have documented that combined Haloxylon–Calligonum communities can trap and hold mobile sands, initiating soil-building succession. Halophytes thus serve as "pioneer forests" on former seabeds, even without irrigation.

Tamarix (Salt Cedar) and Related Halophytes: Tamarix spp. (e.g. T. laxa, T. elongata, T. hispida, T. ramosissima) are salt-tolerant shrubs/trees historically found in river deltas (tugai forests). Their fine foliage can trap aerosols and dust, and they also tolerate irrigation canal edges. In desert afforestation, tamarisks have been planted in shelterbelts around oases and along canals, although they may require some water.

Poplars (Populus spp.): Fast-growing poplars (white poplar Populus alba, black poplar P. nigra, or local P. diversifolia/euphratica) are classic shelter species. They grow well on moist alluvial soils of Khorezm and can reach considerable height and canopy width. Broad poplar leaves present large surfaces for particle deposition. Studies in Chinese oasis cities show Populus alba varieties can retain substantial dust on foliage over short periods. In Uzbekistan, multi-row poplar belts are common along fields and roads. Even a single row of poplars with high leaf area can reduce downwind dust loads; denser arrangements only improve this effect.

Hardy Broadleaf Trees: Other deciduous trees with large, rough leaves also trap dust effectively. Sycamore-like London plane (Platanus acerifolia) and common catalpa (Catalpa bignonioides) have been measured to collect more dust per leaf area than many conifers (in an urban study in Tashkent). In Xorazm, related species could include native elm (Ulmus minor or Ulmus pumila) and native Populus diversifolia. These trees are moderately drought-tolerant and often used in Uzbek greening programs. Elder belts (rows) of elm and poplar together are recommended for alternation: one study suggests planting lower shrubs/trees (for first wind break) and then higher upright canopy species behind them to form a "solid green fence" against dust.

Fast-Growing Exotics: Non-native but fast-growing species like paulownia (Paulownia tomentosa), weeping willow (Salix babylonica), or hybrid black locust (Robinia pseudoacacia) are used in Uzbekistan's afforestation on better soils. These species rapidly produce biomass and shade, thereby creating windbreaks quickly. However, they often require reliable water (limiting use to irrigated areas). When employed as windbreaks, they trap airborne dust by sheer volume of foliage. Government programs note the use of paulownia and other poplars in irrigated belts, recognizing their air-cleaning benefit. Conifers and Evergreens: Some drought-resistant conifers (e.g. Crimean pine, juniper) are grown in parks and urban belts in Uzbekistan. These can provide year-round wind protection, though conifers typically retain less particulate matter per unit leaf area than deciduous trees (broad leaves can catch more dust). However, species like eastern red cedar (Juniperus virginiana) develop a waxy, aromatic surface that still holds fine dust. In desert afforestation, pine or cypress may not be as common, but junipers and even tamarisk could function similarly. Given water scarcity, most conservation efforts prioritize shrubs and drought-hardy deciduous trees over water-demanding evergreens.

Grasses and Groundcover: Though the focus is on trees and large shrubs, perennial grasses and low shrubs contribute by trapping moving sand. Native grasses (e.g. Stipa species) and semi-shrubs (Artemisia, Caragana) are often included under shelterbelts. These form a ground cushion that supplements trees. Afforestation projects sometimes plant rows of indigenous grasses or leguminous shrubs between tree rows to form multi-layered shelter. The combined effect is greater dust capture and further soil binding.

From these, the top performers in dust retention are generally the tall, dense-canopied, fast-growing trees and the resilient desert shrubs. For example, large-plane or catalpa trees in a dense stand can intercept substantial dust clouds, while multi-stemmed halophytes like saxaul can virtually clog sand movement. Adaptability is paramount: species must survive extreme heat (up to ~45 °C summers), cold winters, and saline groundwater. Many of Uzbekistan's protective forests therefore use native or well-adapted exotics: poplars and willows along irrigation channels; elms and ash on upland soils; and Atriplex or tamarisk on the driest salt flats. Government literature underscores these choices. Under Uzbekistan's 2025 environmental plans, thousands of hectares of "protective forest plantations" were established in Khorezm and elsewhere, specifically allocating sections of the former Aral bed for saxaul, Salsola, and Calligonum plantings. In irrigated lands, seedling plantations favored poplar, elm, paulownia, and even walnut or fruit trees in moister soils. Such mixed plantings are guided by each site's soil and moisture regime.

**Discussion.** The integration of dust-retentive vegetation into landscape management yields multiple co-benefits. Ecologically, it halts land degradation: by stabilizing the soil, vegetation reduces the material available for dust storms. Cropland bordering shelterbelts enjoys less topsoil loss and reduced dust deposition on crops. Environmentally, forests sequester carbon and enhance biodiversity in these fragmented oasis environments. The captured dust itself can nourish plants: recent research shows that nutrients in deposited dust (P, Fe, etc.) can be absorbed by leaves, benefiting plant nutrition, especially in nutrient-poor soils. Agriculturally, the shield effect of trees supports higher yields. The saved water from windbreak shade is especially important in Uzbekistan's arid agriculture. Additionally, trees provide wood, fodder, and other resources to villagers, creating incentives for maintenance. Joint woodland-farm systems (agroforestry) may be promoted under national "Green Belt" programs (e.g. Yashil Makon) to link soil conservation with rural development. However, success depends on careful design. Shelterbelt planting patterns should consider prevailing wind directions and field layouts: dense thickets (multiple parallel rows) are more effective dust barriers than single rows. Species must be chosen for longevity; drought-sensitive trees will die out and leave bare gaps that can later generate dust. Regular maintenance (watering young trees, weed control) is crucial to ensure survival in the first years. Studies indicate that survival rates of planted saplings directly determine long-term dust control efficacy. Another consideration is that plants can become too effective at wind reduction if they consume too much water: e.g., large tree belts might raise water tables or compete with crops. Thus, a balanced mix of shrubs and trees, possibly with seasonal deciduous species that transpire less in winter, can optimize benefits. In summary, combining desert afforestation (on sandy soils) with irrigated-land windbreaks (in crop zones) is the most comprehensive strategy. The former tackles the dust source at its root; the latter protects human and plant communities from what dust does arise. With climate projections indicating continued aridity, expanding vegetation cover is a long-term resilience investment. Recent advanced atmospheric modeling for Uzbekistan strongly supports this: it finds that strategic revegetation of key areas can suppress hundreds of micrograms per cubic meter of particulate matter region-wide*[9]*.

**Conclusion.** Vegetation remains one of the most effective natural shields against sand and dust storms in arid Uzbekistan. In the Xorazm region, well-designed green belts and shrub plantations capture dust both by filtering air currents and by holding soil in place. The choice of species is crucial: the best dust-trapping plants are those that survive hot, dry, saline conditions while developing dense foliage. For Khorezm, this means prioritizing native desert shrubs (like saxaul, saltwort, Calligonum) on degraded lands, and hardy, fast-growing trees (poplar, elm, willow, etc.) in irrigated farmland buffers. Mixed-species plantings often outperform monocultures; for instance, combining lower salt-tolerant shrubs in front rows with taller deep-rooted trees behind can create a "living fence" that uniformly blocks particles. The evidence shows that with sufficient scale, vegetation can dramatically reduce airborne dust. National efforts in Uzbekistan have demonstrated this potential: large-scale planting projects in former Aral basins and across sandy plains are already cutting regional dust transport. On the ground in Khorezm, expanding protective forests and farmland belts should remain a priority. By aligning ecological restoration with agricultural windbreak design – using species adapted to local microclimates and soils – communities can achieve cleaner air and more sustainable crop production. In other words, the most effective dust retention strategy is one that holistically integrates ecological vegetation and farming needs, using diverse, regionally adapted plant species to build a resilient, green landscape.

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