Albedo Enhancement: Localized Climate Change Adaptation with Substantial Co-Benefits

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Introduction

Pursuing localized albedo (surface reflectivity) enhancement can be an important component of regional climate change adaptation. Increasing surface reflectivity to reduce absorption of solar radiation can partially offset the local warming effects of increased atmospheric greenhouse gas concentrations while also improving public health and conserving water resources.

This paper highlights the potential efficacy, costs, and risks of localized albedo enhancement for urban centers, deserts, farmlands, and water bodies. Current research suggests that urban and farmland albedo enhancements are particularly effective in moderating greenhouse gas emissions and local climate change that provide additional localized benefits, thereby incentivizing communities to pursue them.

Albedo Enhancement Strategies

Scientists have studied several intriguing climate intervention (geoengineering) strategies for enhancing the planetary albedo as a means of counteracting global climate change. While these are potentially effective and will possibly be necessary to prevent a climate catastrophe, significant research into each approach is needed. Governance mechanisms also remain a significant challenge.

There is considerable knowledge about how local temperatures and other climate features are affected by the local albedo. This understanding makes clear that increasing the local albedo can affect the local weather and humidity, leading to generally beneficial outcomes. These outcomes are dependent on both their unique characteristics and how they are implemented. The following subsections describe a few examples.

Urban Albedo Enhancement

Painting surfaces such as roofs and pavements white or otherwise adding a reflective coating can be an effective way to increase the albedo of urban areas. Doing so has been demonstrated to reduce the urban heat island effect, which leads to cities experiencing temperatures above those of surrounding areas due to the heat-absorbing characteristics of buildings and infrastructure along with
reductions in air circulation and evaporative cooling due to sparse greenery.\(^1\) As more people are projected to move into cities in the coming decades,\(^2\) urban albedo enhancement seems likely to be a particularly important adaptation strategy for cities to pursue.

While there is considerable potential for reducing the absorption of solar radiation, estimates vary as to how much albedo could realistically be increased and over what percentage of urban surfaces. An experiment conducted in western Athens found that brightening of asphalt and concrete pavements reduced ambient temperature by 7.5 degrees and 6.1 degrees Celsius respectively.\(^3\)

Such large reductions in temperature would dramatically improve the living environment for urban residents. Among all types of extreme weather events, heat stress is a leading cause of mortality\(^4\) and is projected to become even more intense as a result of global warming.\(^5\) A recent *Scientific American* article provides a moving description of how heat waves have become a major source of human health risks, especially in urban areas,\(^6\) and these risks have been increasing over the last decade. Effective approaches for reducing temperatures in densely populated areas are thus becoming more critical.

Because higher temperatures speed up chemical reactions, urban albedo enhancement would also reduce the concentrations of photochemically generated ozone (smog).\(^7\) As improved air quality is known to reduce rates of respiratory diseases and other ailments, urban albedo enhancement would contribute to improved human health.

Energy consumption is projected to increase significantly in urban areas as air conditioning becomes more widely available. Urban temperatures can sometimes become so dangerously high that air conditioning is a life-saving as well as comfort-enhancing technology. Increased use of cooling systems, however, can lead to both warmer outdoor temperatures and more air pollution due to the waste heat from the running of the systems themselves and from the electric generating facilities.\(^8\) Urban albedo enhancement could help moderate these effects by reducing city temperatures in a way that does not require a cooling system. A study conducted in Andalusia, Spain found that the widespread implementation of cool roofs would lower carbon dioxide emissions by
135,000 metric tons annually as a result of the reduced energy use,\(^9\) equivalent to removing almost 29,000 passenger vehicles from the road for an entire year.\(^{10}\)

A recent study in Los Angeles County analyzed the energy savings of modestly increasing roof albedo, finding that this could produce savings from reduced energy use of 23% to 40%,\(^8\) making cool roofs a financially attractive option. Others have found that, as a result of their energy savings, cool roofs pay for themselves within five to seven years.\(^{11}\)

Energy savings and improved comfort from installation of cool roofs are even more significant in the low-performance, outdated, and inefficient buildings\(^8\) that are often found in low-income areas where residents are likely to suffer most during extreme heat. Subsidizing albedo enhancement projects in these areas, thereby overcoming the inability to cover upfront costs, could thus have beneficial public health outcomes.

_Agricultural Albedo Enhancement_

Choices of plants in vegetated areas can also affect the local albedo. Crops absorb electromagnetic radiation both inside and outside the photosynthetically active region (PAR), or the window of radiation that actually contributes to growth.\(^{12}\) The radiation absorbed outside this window contributes nothing to productivity but still heats the plants and soil, leading to higher evaporative losses and earlier water stress.

Biologists and engineers have considered a variety of approaches to decreasing water usage and reflecting away more non-PAR radiation. This may involve adjusting leaf canopy structure or genetically modifying plants’ cuticles, hairs, or glaucousness.\(^{12,13}\)

It is estimated that crop albedo could be increased by as much as a third without reducing plant productivity.\(^{13}\) This could have significant regional effects by reducing temperatures on the hottest days.\(^{14}\) The *Scientific American* article mentioned earlier also noted that 80% of the billions of hours of labor lost due to dangerously high temperatures are in agriculture.\(^6\) It therefore seems plausible that increasing crop albedo to moderate local temperatures could reduce health risks and lost work hours, substantially improving agricultural market efficiency.
In addition, crops are harvested and re-planted so frequently that implementing such changes could be relatively quick. The main tenets of climate effective land management are currently conservation tillage and improved irrigation techniques, but crop albedo enhancement also merits being included as a plausible approach.

*Albedo Enhancement of Water Bodies*

Just as air jets in bathtubs and spas create bubbles that make the water more reflective, microbubbles injected into water bodies such as water reservoirs, aqueducts, streams and ponds have the potential to reduce the absorption of solar energy, thus cooling the waters and leading to less evaporation. Freshwater is a vital resource under increasing strain from agricultural production and climate change. The increasing frequency of droughts and heat waves, along with escalating pollution of freshwater sources, is leading to stricter and stricter rules governing water use. A recent study based on data from a NASA satellite identified nineteen hotspots that may face catastrophic water scarcity in coming years. Given this growing concern, the potential to alleviate pressure on freshwater sources merits further investigation.

*Current Applications*

Use of the suggested albedo enhancement techniques does not require international or national approvals. Cities, states, and businesses can take the lead on these adaptive strategies. Urban, crop, and water albedo enhancement investigated here provide localized adaptation benefits, improving livelihoods and conserving precious resources.

Some cities are already implementing the urban strategies outlined here, albeit on a small scale. In April of 2018, Los Angeles started using CoolSeal, a white coating, on roads and pavement to reduce urban heat island effect. Mayor Eric Garcetti says this is part of the city’s plan to bring greenhouse gas emissions 45% below 1990 levels by 2025.

State and municipal governments seem to have the authority to take actions to incentivize albedo enhancement measures and encourage their widespread implementation. Just as California has recently approved a regulation that all newly built homes must install solar panels or purchase
solar power from developers, similar governance frameworks could be used to promote albedo enhancement measures by, for example, requiring that newly built buildings and homes and newly paved streets be highly reflective. The co-benefits of albedo enhancement measures could also be bolstered and legitimized through information campaigns that point out the potential benefits of energy savings and more comfortable daytime temperatures. By doing so, use of reflective materials in urban environments could gradually become the new norm, displacing the widespread use of heat-absorbing dark pavements and roofs. Promoting the widespread use of reflective crops would likely require a different path, less focused on consumers and instead oriented toward the agricultural industry and farmers, encouraging expansion of the definition of climate effective land management to include reflective crops.

**Evaluating Albedo Enhancement Options**

Urban and farmland albedo enhancement are compelling forms of local- to regional-scale climate change adaptation if used to complement overall efforts to reduce the increasing atmospheric concentrations of CO₂ and other greenhouse gases. In large population centers, reflective roofs and pavements, if widespread, offer the potential to moderate peak daytime temperatures, lessen the use of cooling systems, and reduce greenhouse gas emissions. In agricultural areas, use of more reflective crops could lower water use and regional temperatures while reducing the amount of work hours lost to extreme heat.

Cost-benefit studies are needed to better understand the potential for these approaches to strengthen regional climate adaptation plans. Further research into the potential for microbubble injection into localized water bodies is needed to determine the role that this strategy could play in helping to conserve freshwater resources. As governments move to establish, formulate, and take actions to meet the time-sensitive emissions reductions goals that can moderate the consequences of climate change for their communities, albedo enhancement would seem to offer a compelling opportunity to bolster localized efforts.

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Notes


