COMMENTARY

Reassessing the climate mitigation potential of Chinese ecological restoration: The undiscovered potential of urban

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Since 1998, China has embarked on numerous ecological restoration projects (ERPs) to mitigate global climate change and the ecological consequences of intensive human activities. These efforts have culminated in China accounting for 25% of the global increase in green areas over the past twenty years. Sultan Jaber, President of COP28, acknowledged, "China has made significant contributions to the global climate change response."

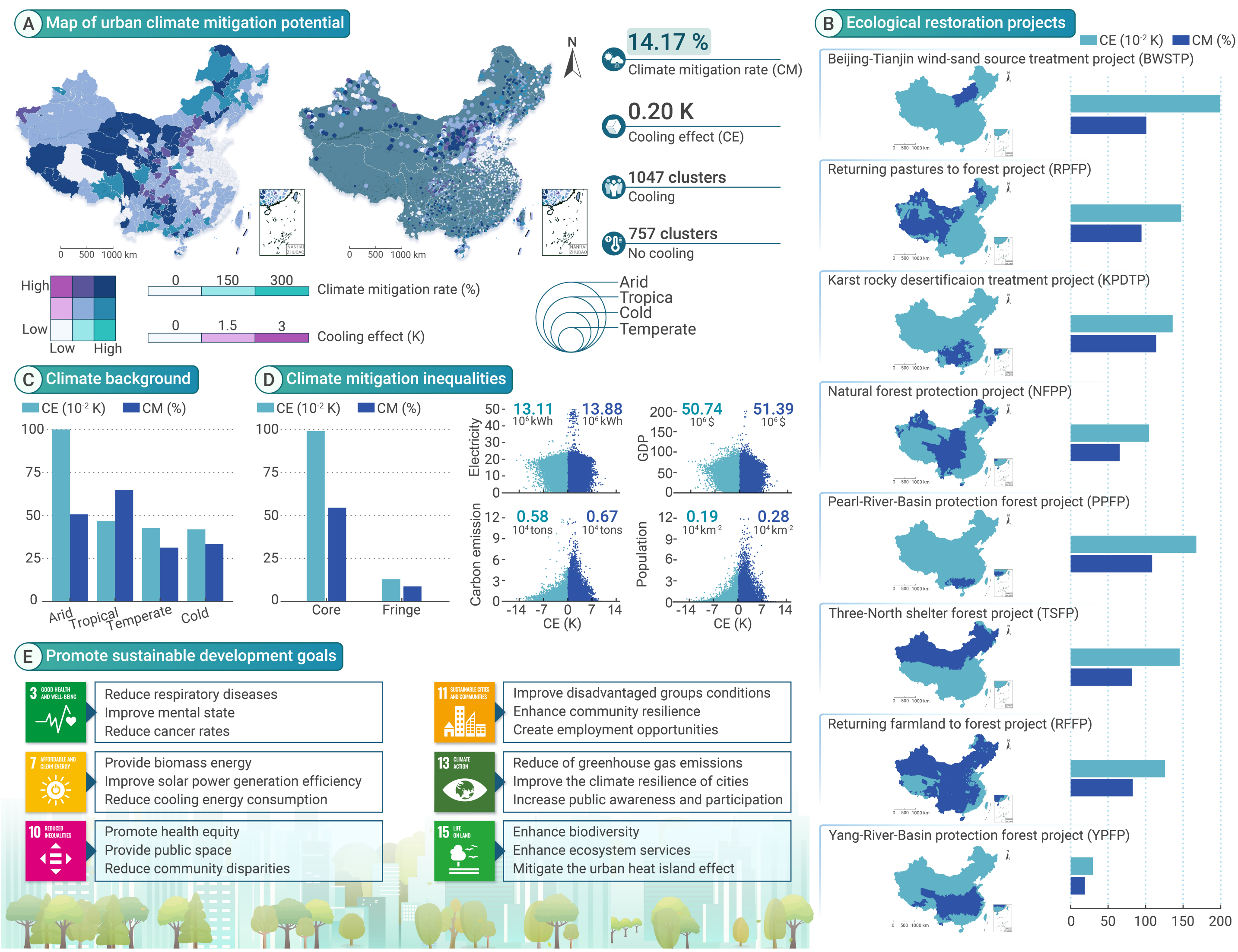

Figure 1. Undiscovered climate mitigation potential from urban areas of Chinese ecological restoration projects (ERPs) (A) Urban climate mitigation potential map of ERPs. (B) Ranking of urban climate mitigation potential of different ERPs. "Returning Forest to Pastures (Farming)" is not included in this study. (C) Ranking of urban climate mitigation potential under different climate backgrounds. (D) Urban climate mitigation potential exposes inequalities. The grey and purple numbers in the figure represent the average value of the metric for all pixels in the cooling and non-cooling backgrounds, respectively. (E) Impact of ERPs on sustainable development goals. Note: The urban core is defined by the urban boundary data from the year 2000, whereas the urban expansion area encompasses the regions that extended beyond this boundary from 2000 to 2018. And ecological restoration project boundary data was obtained from the National Ecological Science Data Centre. Please refer to https://zenodo.org/records/10416851.

However, there remains a contentious debate regarding the necessity and optimal locations for tree planting to maximize climate benefits.

Recently, Shani Rohatyn et al.[1] discovered that the climate mitigation potential of ecological restoration in arid regions is limited. Rohatyn determined that incorporating considerations of albedo significantly diminishes the anticipated cooling impact of dryland afforestation, thereby halving, the expected climate mitigation potential. While attempting to integrate the biogeochemical effects of vegetation (carbon indicators) with biogeophysical effects to enhance the precision of evaluating ecological restoration's climate mitigation potential, their approach equated carbon sequestration with climate change mitigation, which does not adequately reflect the climate mitigation potential of afforestation. This significantly underscores the ongoing debate regarding the net climate impact of vegetation greening in hot regions. The reason for this controversy is that in certain areas, notably urban ones, the cooling effect derived from carbon sequestration is markedly less influential than that from shading and evaporation. Moreover, quantifying the climate mitigation potential of afforestation based on the net cumulative carbon sequestration of the entire arid zone tends to obscure regional climate mitigation hotspots, including urban areas. Although ERPs are still at an exploratory stage, key questions like "Where, how much, and how?" remaining unanswered. Currently, more than 50% of global ecological restoration efforts are concentrated in drylands, and the conclusions of Shani Rohatyn et al.[1] may distract attention from the task of ecological restoration.

Urban environments are 'natural laboratories' for studying global climate change mitigation, especially in China. China's urban expansion has constituted 46% of global urban growth in the past two decades. Alterations in subsurface properties have significantly shifted the land surface's energy balance, leading to various ecological and environmental issues.[2] ERPs offer a nature-based solutions to these issues. Investigating the climate mitigation capacity of ecological restoration in urban areas of China is essential for determining critical and high-priority zones for its implementation. Here, we executed a nation-scale investigation to quantify the urban cooling effect and the climate mitigation efficacy of long-term greening trends resulting from ecological restoration by examining1721nationwide urban clusters[2] utilizing a high-resolution dataset spanning from 2001 to 2018.

NATIONAL URBAN CLIMATE MITIGATION POTENTIAL

Utilizing multi-source remote sensing data and reanalysis data, we identified the most sensitive indicator of surface temperature for each city. Employing this indicator, alongside the Normalized Difference Vegetation Index (NDVI), we simulated the surface temperature trend under a hypothetical no-greening scenario for each city. By subtracting this simulated trend from the trend remotely observed, we quantified the climate mitigation potential of pixel-by-pixel ERPs for each city. The urban greening trend resulting from ERPs has yielded a cooling effect of 0.2K in Chinese urbans over the past two decades. This has subsequently reduced their warming trend by 14.17% (Figure 1A). Such findings imply that prioritizing urbans for ecological restoration efforts in real-time could enhance climate benefits. Specifically, cities with significant urban cooling were predominantly situated in southwest China, the Loess Plateau, Qinghai, and Tibet. Conversely, the eastern coast of China, characterized by a lower density of ERPs, has seen a cooling effect and climate mitigation potential that are effectively negligible. At the cluster scale, ecological restoration has led to cooling effects in over 57% of urban clusters. It is noteworthy that there is a distinct spatial synergy between the cooling effect and climate mitigation potential.

ECOLOGICAL RESTORATION PROJECTS AND CLIMATE BACKGROUND

Over the past two decades, China has implemented nine significant ecological restoration projects, eight of which have encompassed urban areas, spanning approximately three-quarters of the country's landmass (Figure 1B). These projects have notably contributed to mitigating urban warming. Notably, the Beijing-Tianjin Wind-Sand Source Treatment Project yielded the most substantial urban cooling effect, at 1.69K, and a climate mitigation potential of 85.93%. This was closely followed by the Returning Pastures to Forest Project, achieving a cooling effect of 1.55K and an exceptional climate mitigation potential of 100.72%. These findings underscore the pivotal role of China's extensive ecological restoration efforts in the global response to climate change, providing compelling evidence amidst recent debates on the subject.[3,4]

Contrary to Shani Rohatyn et al.,[1] the most substantial urban cooling effect, measuring 1.0K, coupled with 50.63% climate mitigation potential (Figure 1C), was observed in the arid zone. This was narrowly surpassed by the tropical zone, which exhibited a cooling effect of 0.47K and a climate mitigation potential of 64.80%. These findings indicate that ERPs yield more pronounced benefits in urban climate amelioration in warmer regions.

ECOLOGICAL RESTORATION PROJECTS FOR SUSTAINABLE GOALS

China's ERPs serve as a compelling model for urbans worldwide seeking effective strategies to address climate change and expedite progress toward sustainable urban development (Figure 1E). These projects play a pivotal role in fostering urban greenery, not only facilitating the absorption of harmful airborne pollutants and reducing cooling energy consumption but also providing recreational spaces such as green parks. Consequently, these endeavors contribute to a decline in respiratory ailments and an enhancement of overall mental well-being among residents. In turn, this aligns with the objectives outlined in SDG3, aiming to ensure a healthy living environment and further supports SDG13, focused on proactive measures against climate change. Moreover, advanced urban vegetation management offers more than just ample biomass energy and enhances cooling, thereby boosting the efficiency of solar power generation (a 1-K cooling effect results in a 0.5% increase in power generation efficiency). This holds promise for advancing the attainment of SDG7. Additionally, beyond their urban climate mitigation advantages, ecological restoration initiatives have proven instrumental in preserving biodiversity, remediating soil, and rejuvenating urban water bodies. Consequently, they make significant contributions toward achieving SDG15, aimed at promoting sustainable terrestrial ecosystems.

Nevertheless, it is imperative to acknowledge that significant disparities persist in the exposure of urbans and residents across various regions to the climate advantages derived from ecological restoration efforts (Figure 1D). Notably, restoration efforts in urban cores have achieved a cooling effect of 1.01K and a climate mitigation potential of 56.08%, figures that are 7.2 and 5.6 times greater, respectively, than those in urban fringes. Furthermore, areas with higher incomes, increased resource consumption, and greater greenhouse gas emissions disproportionately benefit from the cooling effects of ecological restoration. This is predominantly because these areas, typically in the urban's heart, are concentrations of more affluent, educated populations who prioritize and have greater means to achieve a higher quality living environment. These disparities pose substantial obstacles to the fulfillment of SDG10 and SDG11. Consequently, we urge policymakers to address urban warming with a strategy that equally emphasizes social equity, aiming to foster inclusive, resilient, safe, and sustainable cities.[5]

Despite our development of an ambitious blueprint for mitigating climate change, the full realization of urban climate mitigation benefits stemming from ERPs remains unrealized. In light of this, it is necessary for China to reaffirm its commitment to urban ecological restoration by including urbans in the planning of ecological restoration initiatives when developing or revising relevant regulations.

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DECLARATION OF INTERESTS

The authors declare no competing interests.