

Identifying forestation priority areas in China for multi-objective optimization towards future through history

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Abstract [Objective] Identifying what kind of spatiotemporal optimization patterns of forestation can achieve the greatest carbon sink or habitat quality improvement benefits or both of them in the future across the nation. **[Method]** Overview, we identified future forestation priority areas for multi-objective optimization by evaluating the benefits of historical forestation programs across China, which means where the historical forestation benefits are higher, the future forestation should be given priority. This optimization process from history to the future was combined by a machine learning model, which accounts for the effects of climate, geography, forest structure, natural disturbances and human activities on outcomes of forestation to find where landscapes are likely to provide the greatest individual criterion or multicriteria forestation benefits under present state. We considered that carbon sequestration (CS) and regional land surface temperature (RLST) are the proxies of mitigating climate warming, and mean patch area (MPA) is the proxy of habitat quality improvement of forestation. The combinations of CS and MPA (CS_MPA), CS and RLST (CS_RLST), and MPA, CS and RLST together (MCR) with equal weight mean three multicriteria driven by the targets of climate warming mitigation, carbon sequestration and habitat quality improvement, and both climate warming mitigation and habitat quality improvement, respectively. Specifically to do so, we: (1) evaluated past long-term (2000-2020) forestation benefits per unit forestation area for mean patch area (MPA), carbon sequestration (CS) and regional land surface temperature (RLST); (2) established three multicriteria: CS_MPA, CS_RLST, and MCR to show overall benefits; (3) implemented a machine learning model named Gradient Boosting Machine (GBM) to accounts for the driving mechanism of spatiotemporal varieties of forestation benefits and to further predict the gains potential of future forestation under present state; (4) Optimized the spatial allocation of potential forestation areas (the portion of the study area not fully covered by continuous forests, urban areas, cropland, water bodies, permanent snow and ice) based on projected potential benefits of future forestation. All variables, including forest maps, forestation benefits and impact factors are aggregated their respective resolution into the 10 km window level. **[Result]** The six forestation indicators driven by different forestation goals and 24488 target landscapes constituted the objects for evaluating the historical forestation benefits. The largest and most concentrated mean patch area (MPA) benefits was mainly located in the Changbai Mountains and the Qinling Mountains. The Yunnan-Kweichow Plateau, as well as along the east-west line between the Qinling Mountains and the middle-lower reaches of the Yangtze River were the most conspicuous areas for carbon sequestration (CS). The regional land surface temperature (RLST) benefits showed the opposite trend in boreal forests and temperate regions. The forestation benefits across space and spatial patterns for individual criterion varied markedly, which indicated considerable trade-offs and synergies among these individual gains; The result of Gradient Boosting Machine (GBM) showed that initial forest coverage is the most important factor, and the marginal effect showed that with the increase of forest coverage, forestation benefit increases slowly at first, then rapidly, and finally tends to be stable; 28,910 landscapes with forest coverage greater than 1% were targeted for potential future forestation. Based on our assessment of the history to predict the future we found that the Greater and Lesser Hinggan Mountains, and Loess Plateau had considerable trade-offs among mean patch area (MPA), carbon sequestration (CS), regional land surface temperature (RLST) targets. The Southwestern regions had the highest overall benefits and the lowest trade-offs, where about 80% of landscapes were in the top 55% of national priorities. Uniform forestation required the utilization of 15% or 30% of the potential forestation areas to obtain the equal

MPA and CS, or RLST gains achieved by forestation in 5% of the priority areas. Multicriteria optimization solutions showed that balancing for both MPA and CS benefits simultaneously would deliver 97% of the maximum MPA benefits and 90% of the maximum for CS benefits and balancing for both RLST and CS benefits simultaneously would deliver 80% of the maximum RLST benefits under forestation 20% of potential total forestation areas. If forestation is only considered in cost-effective areas, China is expected to end large-scale forestation campaigns 5 to 15 years ahead of 2060. **[Conclusion]** Our work goes beyond the assessment of area-based target to highlight that area alone is an ineffective metric for ensuring expected habitat quality improvement or climate mitigation outcomes due to the individual criterion benefits of forestation vary markedly across space. The marginal curve of forest coverage to forestation benefits emphasizes that reforestation has greater benefits than direct afforestation generally. The findings of applying a multicriteria approach to joint habitat quality improvement and climate change mitigation underscore the synergies that arise from bridging the targets rather than pursuing them separately. The result of the outcomes of priority areas for forestation highlights that the importance of spatial priority allocation of forestation tasks and pointed that the Southwest should be a priority for forest expansion.