Optimal pathways for green infrastructure toward climate resilience

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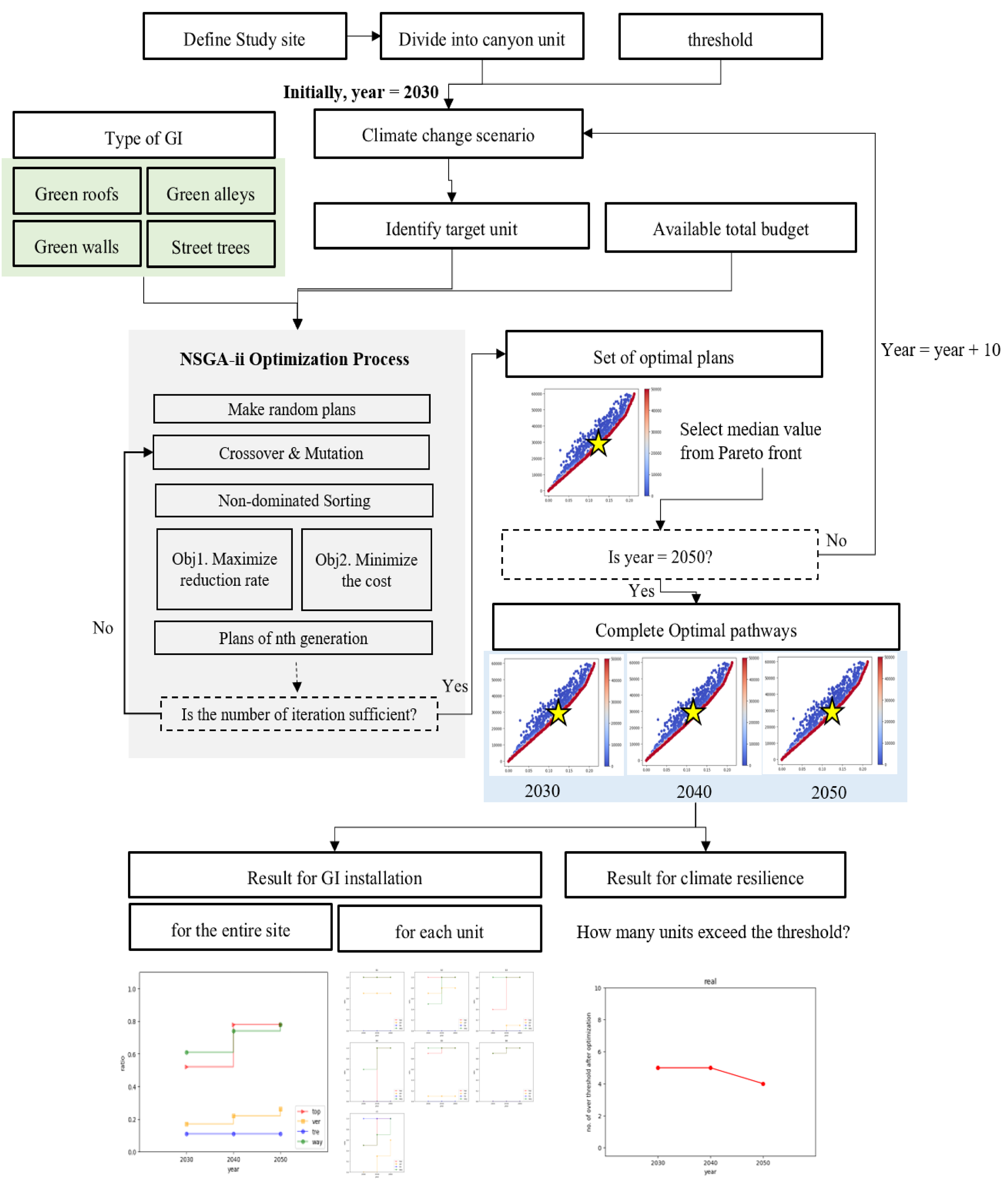
Background

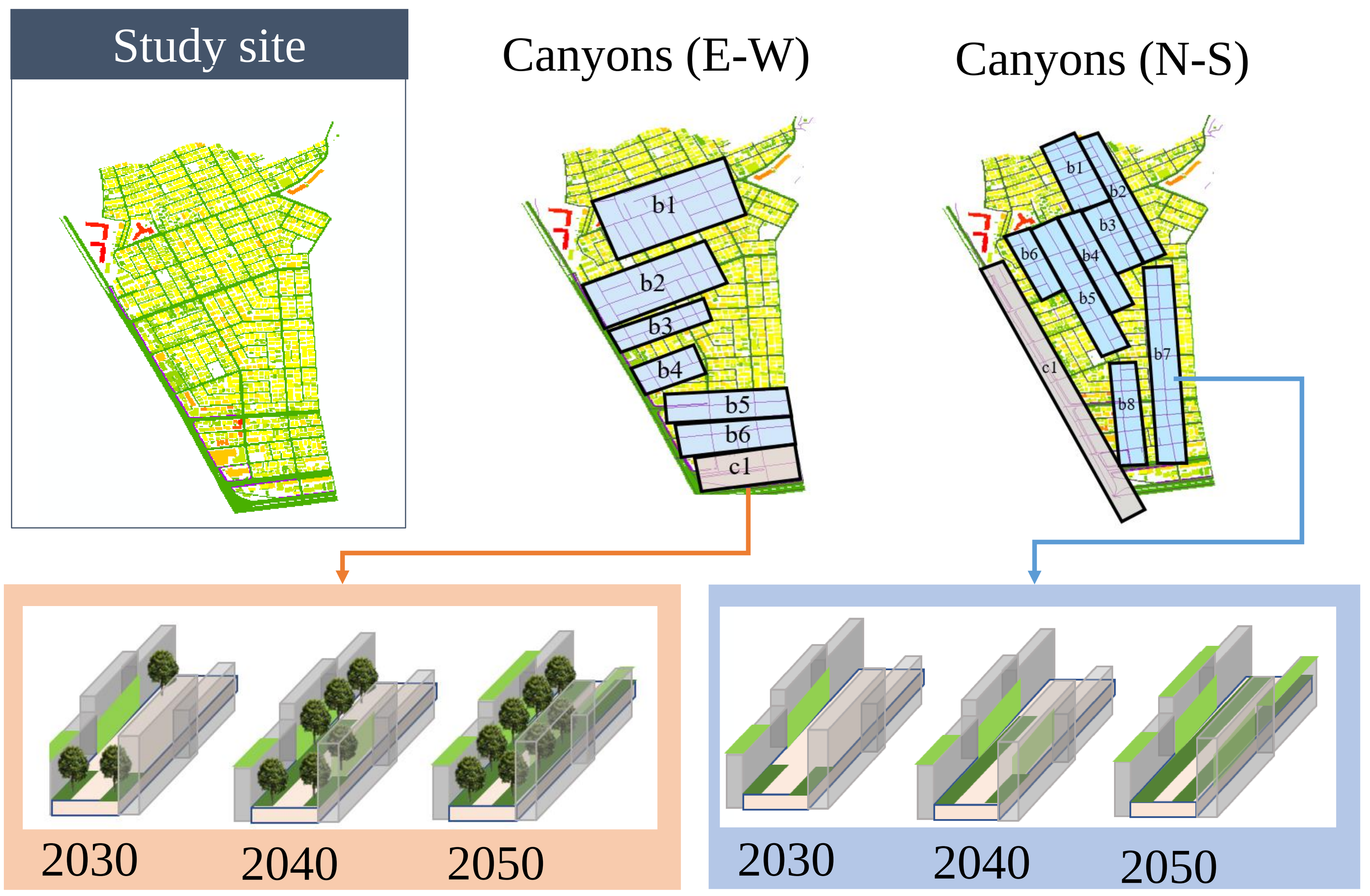
Climate change is leading to a global increase in average temperatures, which exacerbates the adverse effects on urban areas with high population density and extensive infrastructure. Effective planning requires judicious allocation of resources from the outset, ensuring that limited budgets are used as efficiently as possible. This study aims to create resilient pathways that can adapt to heatwaves considering future climate change using green infrastructures (GI). A "threshold" value was set to quantify heatwave damage. As the number of areas exceeding the threshold decreases, the local government's capacity to independently manage risks increases, thus securing climate resilience. Optimal pathways aid in identifying high-risk areas, proposing spatial arrangements, and budgeting for GI, thus supporting resilient urban planning and policy development.

Research flow

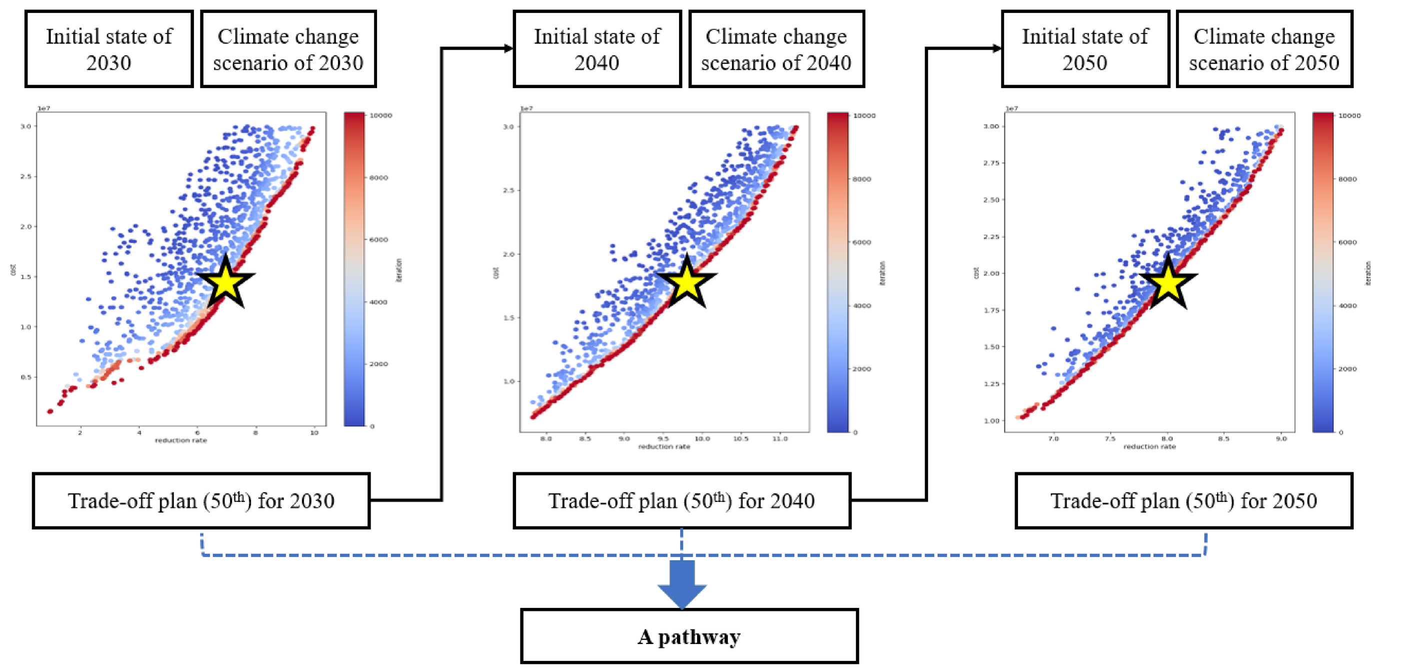


Methodology

Study site is Hwagok 8-dong in Seoul, Korea (0.53km2). It was selected due to its high rate of aging houses, high vulnerability in terms of exposure and sensitivity to climate change, and lack of green infrastructure. The canyon was segmented into units considering the continuity of the street and two different orientations.



This study considers four types of GI: green roofs, green walls, street trees, and green alley. Sidewalk canyons (starting with 'c') can accommodate all four technologies. Non-sidewalk canyons (starting with 'b') can accommodate three technologies excluding street trees.



The optimal solution, which maximizes the cooling effect and minimizes the cost, was identified using the multi-objective optimization algorithm NSGA-II. A pathway was created with the optimal solutions sequentially connected. At each period, a trade-off between cost and effect (middle rank) was selected for the optimal solution.

Results & Discussion

Fig. 1

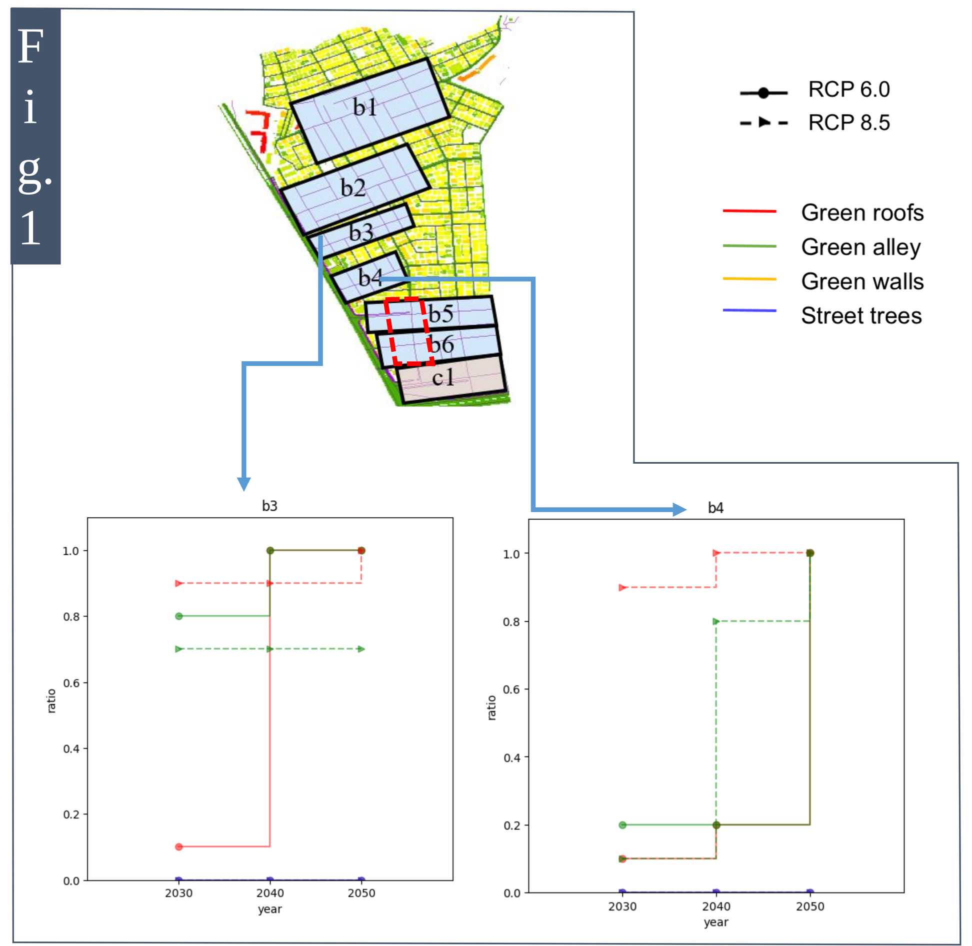


Fig. 2

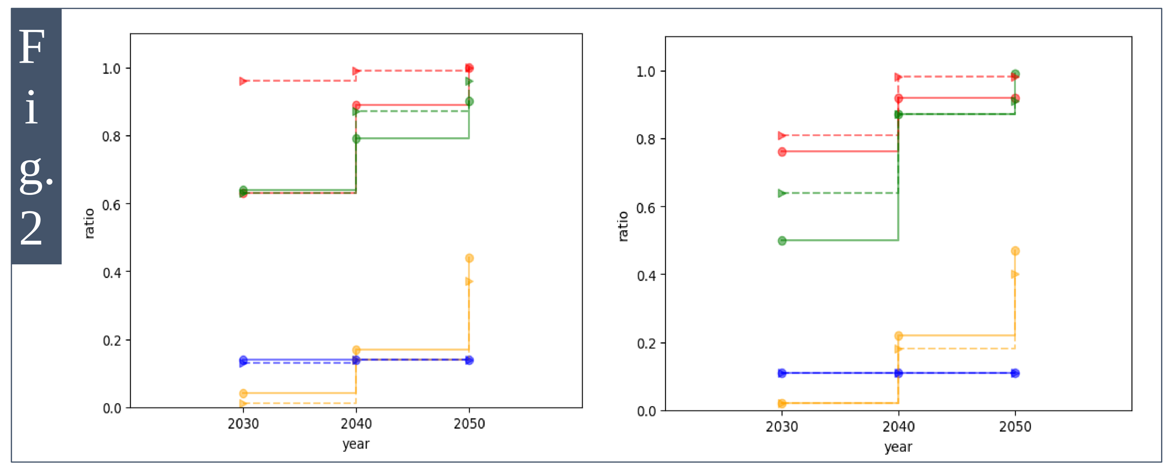
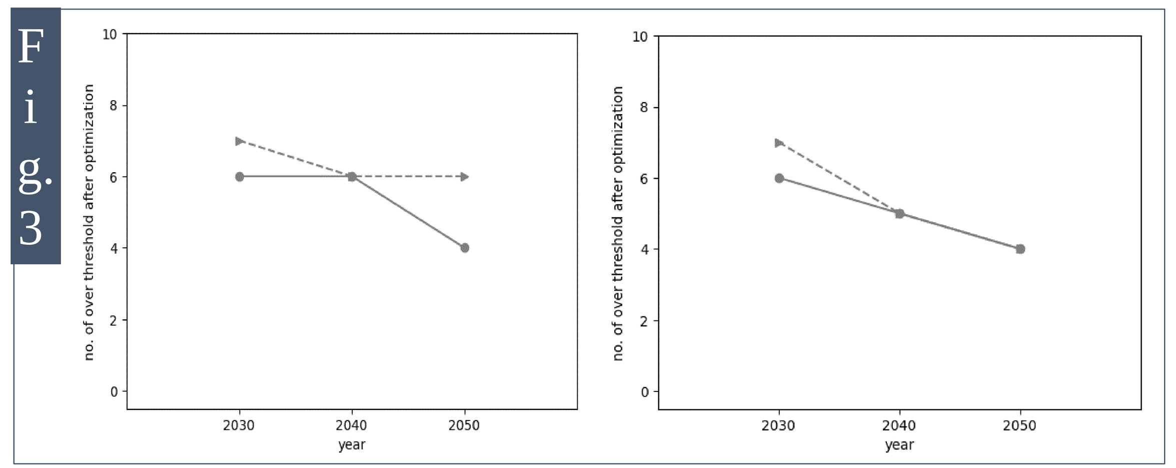


Fig. 3



There are differences in pathway characteristics for each canyon. For example, in an E-W orientation, there is a tendency for an initial high input of GIs in b3, where the H/W ratio is higher. In both RCP 6.0 and 8.5 scenarios, inputs are made by at least 2040. In b4, the green roof deployment in RCP 8.5 is similar to that of b3, but the installation of other GIs occurs later. In RCP 6.0, most GIs are installed by 2050. Therefore, areas with a high H/W ratio require earlier technology deployment, while areas with a lower ratio can afford a slightly delayed deployment (Fig. 1).

The overall ratio of technologies represented in the optimal pathway for the target area was roof > alley > wall (excluding street trees, as there is only one unit where they can be installed). Street trees showed the least variation, with the initial quantity remaining consistent over time. Green alley and green wall exhibited greater fluctuations over time. In both N-S and E-W orientations, green alley had a high growth rate in 2040, while green wall showed a significant increase in 2050. In the RCP 8.5 scenario, installations typically occur in larger quantities initially. As the scenario moves towards RCP 6.0, the initial installation quantity decreases, with an increase in 2040. By gradually installing in less urgent areas, particularly as adaptation improves, costs can be reduced (Fig. 2).

The threshold was set based on the average maximum summer temperature from 1991 to 2020, with the goal of reducing temperatures to this average value. In the optimal pathways, areas exceeding the threshold are effectively reduced (Fig. 3). Canyons with smaller areas, insufficient installation space, or high H/W ratios tend to remain above the threshold. Additionally, the N-S orientation showed greater variation depending on the scenario. For areas that are not reduced below the threshold, it may be necessary to consider adaptation technologies beyond GI. This information can assist decision-makers. Areas that consistently appear across multiple orientations and scenarios can be considered truly critical (Red box area with dotted line in Fig. 1).

Conclusion

Optimal pathways were developed within the canyon units based on the threshold. There were differences in optimal pathways depending on the spatial characteristics such as the H/W ratio or orientation. Additionally, variations were observed depending on the climate change scenarios, highlighting the importance of integrating mitigation efforts with adaptation strategies.

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