Study on the Layout of Green Space and its Rainwater Surface Runoff Performance within the Residential Street-Block of Nanjing, China

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Keywords: green space, layout, residential street-block, rainwater surface runoff.

Abstract: Green space plays an important role in the microclimate and rainwater cycle of the built environment. However, traditionally, urban morphological research rarely discusses the green space and the relationship between green space element and other morphological elements, such as building fabric and plot pattern. Previous studies of rainwater surface runoff control have also focused on the green space itself, and the research model is too far from the real urban form.

In the traditional city, the layout of the green space in the block is basically internal. When the traditional plot pattern of the block is broken in the modern city, the building fabric is totally changed. It also led to a more diverse layout of green space. This paper focuses on the urban green space layout characteristics of the contemporary residential street-block of Nanjing, China. The abstract models are constructed according to the layout of green space of the real residential street-block. Two block series are in calculation to analyze the impact of different types of green layout on the runoff.

1. Introduction

More and more, people realize that the green space plays an important role in the microclimate of the built environment and the health of the citizens. In urban rainwater circulation, green space has an irreplaceable role in ecological and economical aspects.

However, on the one hand, for a long time, urban morphological research rarely discusses the green space as an independent element of urban form, not to mention the relationship between green space element and other morphological elements, such as building fabric and plot pattern. For example, the morphological analysis of M.R.G. Conzen (1960) is mainly based on the three fundamental physical elements: streets, plots, buildings and their related open spaces. In Kropf's opinion (2014), the elements and levels of urban form are much more complicate, but the green element is still excluded. Osmond (2010) built a hierarchy of open space, the green space was subdivided as an element of open space, but did not analyze the relationship with other elements. On the other hand, previous studies on the control of surface runoff in rainwater have also focused on the green space itself, including area expansion or improvement of temporary water storage capacity. Although recent studies have found that the interaction

DOI 10.36158/978889295356724
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between the layout of green space and other elements of urban form has a significant impact on the absorption of rainwater, the research model is either too macroscopic or far from the real urban form (Kim &Park, 2016; Zellner, 2016).

Therefore, the study of the relationship between green space elements and other urban morphological elements is not only conducive to the development of urban form research, which can also provide morphological support for the research of urban rainwater surface runoff control.

In the traditional city, the layout of the green space in the block is basically internal. When the traditional plot pattern of the block is broken in the modern city, the building fabric is totally changed. It also led to a more diverse layout of green space. This paper focuses on the urban green space layout characteristics of the contemporary residential street-block of Nanjing, China. Firstly, due to the division of the street, a street block is relatively independent in both form and surface runoff, forming a clear basic spatial unit of relationship study. At the same time, a street block is the most important area for the source control of urban rainwater, and the proportion of residential blocks is the highest in all types of urban blocks, and the layout of green spaces is highly constrained by the building fabric within the residential blocks. Therefore, residential block is also the most important type of block for urban rainwater surface runoff control.

2. Methodology

In contemporary Chinese city, residential areas have long been influenced by the theory of residential quarter planning. A residential quarter is a residential plot, and a residential quarter is composed of at least one "residential building group" according to the size of the plot. In the residential quarters built in 1980-1993, the standard only made a limit of 1-2 m^2 public green area per person within the quarter. After 1993, the green coverage in a residential quarter should not less than 30% in new developed area or not less than 25% in rebuilt area, and need to be arranged in three levels: the center garden of residential quarter, green space of the group and green space around the building. The center garden of residential quarter and the green space of the group shall not be less than 4000m2 and 400m2, and, respectively, the width of the short side of the green space shall not be less than 8m. However, in reality, the setting of road density by urban road planning makes the size of the block become the main limiting factor for the size of the residential plot. In most of the residential blocks (which means more than 50% area is residential plots), the actual size of most residential quarter is between the scale of "quarter" and "groups" or only a "group" size set by the norms. "Quarter" and "group" gradually evolved into "neighborhood block". Therefore, except for meeting the requirements of the green coverage, the classification of the green space arrangement in the site plan of the residential quarter is increasingly blurred. At the same time, under the constraints of the building and planning related norms such as economics and sunshine standards, most of the residential building fabrics are constructed of paralleled stripe buildings, which constitute a further constraint on the layout of the green space.

Since the shape and size of the block is mostly determined by the street system, we can get a standard square block with 264*264m (Figure 1) according to Chinese "Code for transport planning on urban road" (width of road: Main road 50m, Sub-main road 40m, Branch road 20m; Density of road: Main road 1.2km/km , Sub-main road 1.4km/km^2, Branch road 4km/km^2). Considering the actual size of buildings, roads and green area, the cells are set to a square of 6m x 6m for the further runoff calculation. Filtering according to the ± 10% interval of this area, 9 residential blocks in Nanjing old city area were screened out. (Figure 2)

We can see that the green space is distributed much homogenously around the residential buildings. So the abstract models are constructed according to the layout of green space. The surface materials include building (20% coverage), permeable green area (40% coverage) and impervious ground. Two block series are in calculation by the software called "Hydro-block v1.0" (Liu, 2019), to analyze the impact of different types of green layout on the runoff (the amount of runoff per cell and the max depth of water within the block).

3. Analysis and Results

3.1. *Series I: Dispersed green area*

The block with homogeneously dispersed strip buildings cannot place concentrated green area. The calculations examined four position of the green area in two directions of slope of block: in back (upside) of the building, in front (down side) of the building, in both sides of the building and interlace arrangement (Figure 3, Series I-a, b, c, d).

In the case of up-down slope, the reduction of surface runoff is in back > both sides > staggered arrangement > in front. At the same time, the interlace arrangement of buildings and green spaces in the water flow direction also helps to reduce the surface runoff (Figure 3, Series I-e). In the case of left-to-right slopes, there is little difference in the eight layouts as well as the up-down slope. Compared with the block SI-b4, it can be seen that the building fabric change has little significant influence on the surface runoff in the layout of dispersed green area.

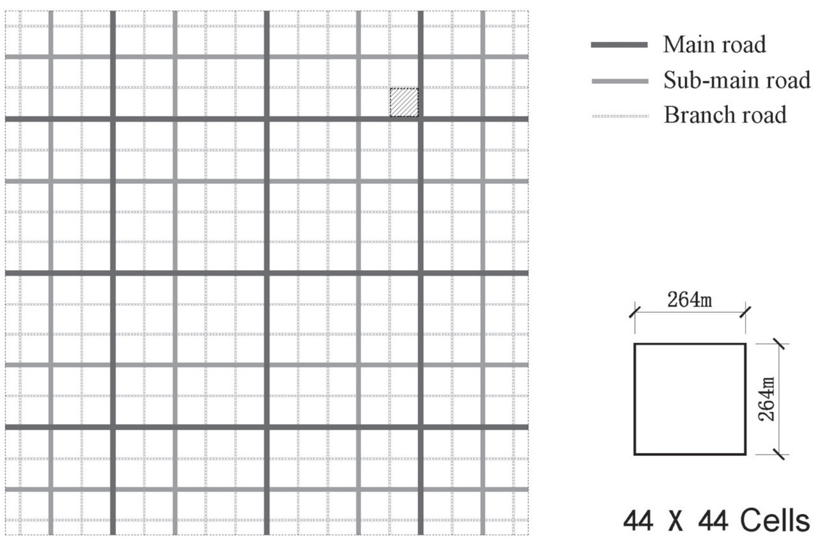

Figure 1. *Homogenized orthogonal road system.*

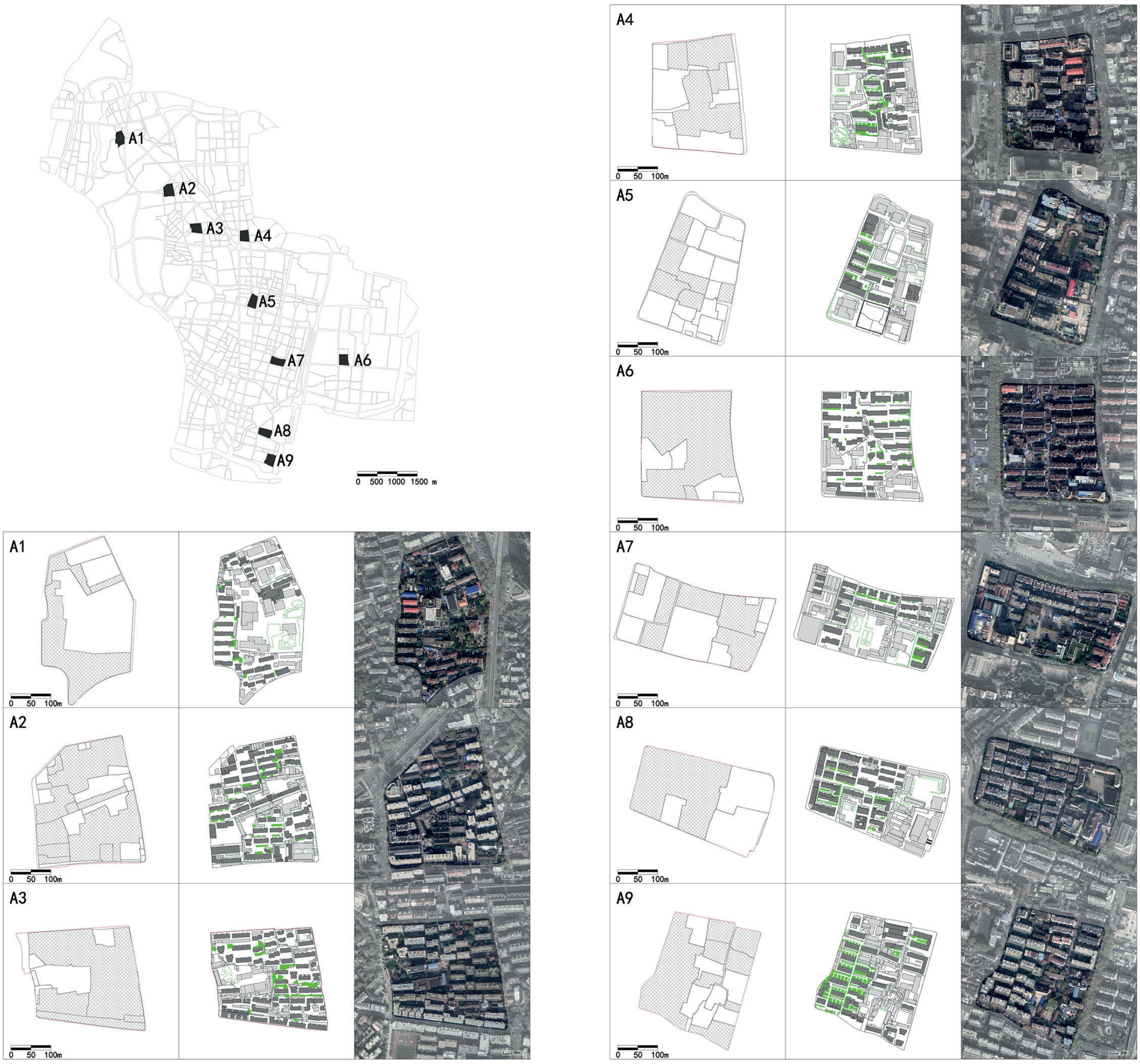

Figure 2. *Typical residential blocks in Nanjing old city.*

3.2. *Series II: Mixed green area layout*

Previous study shows that the green area around the block can markedly reduce the runoff, so we also examines if mix the concentrated and dispersed layout of green area can combine their advantages.

In the blocks of homogeneously dispersed stripe buildings fabric (Figure 3, Series II-a, b, c, d), the mixed layout significantly reduces the surface runoff compared with the simply dispersed layout. For example, the runoff per cell of S II-b1 is only 30% of S I-b1. However, the maximum water depth of the mixed green space layout is significantly larger than the purely dispersed green space. (Figure 3, Series II-f)

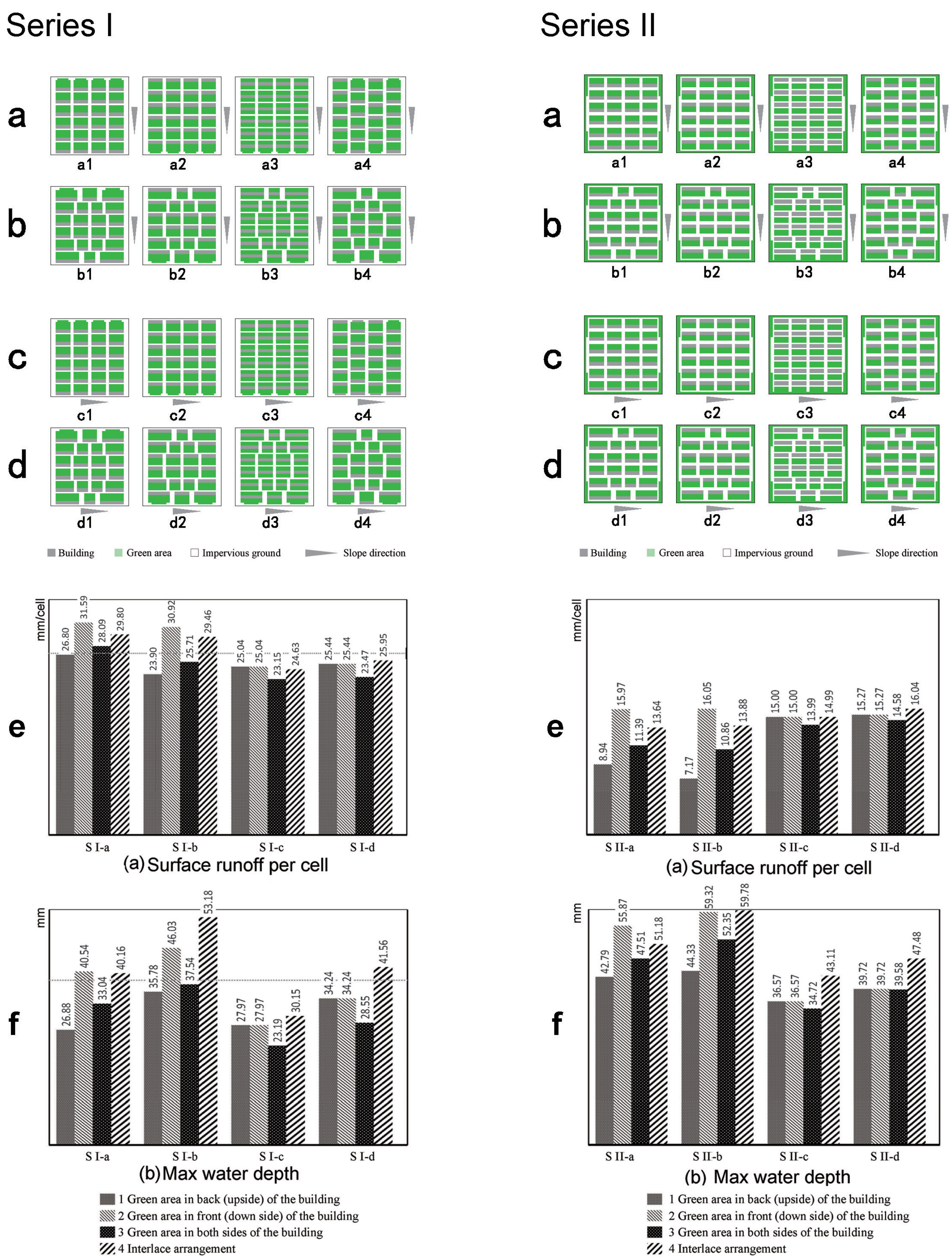

Figure 3. *Residential block models and the surface runoff calculation.*

3.3. *Impact of rainfall intensity and soil type*

In this model, two different types of soil samples were selected for the calculation. The initial infiltration rate of soil type A decreases relatively moderately, and the stable infiltration rate is relatively high. The initial infiltration rate of soil type B drops sharply and the stable infiltration rate is low.

Under the same soil type, the lower intensity of the rainfall, the more obvious the differences are showed in the runoff reduction of the different layout of the blocks. In the same intensity rainfall events, the better permeable soil of type A reduces the surface runoff much stronger than type B, and the difference of the surface runoff of different layouts is also much more obvious in soil of type A than type B. For example, In the case of soil of type A, the surface runoff per cell of block S II-b2 in the 2, 10, 50, and 100-year recurrence interval is 4.29, 2.24, 1.64, and 1.50 times of block S II-b1 block. However, in the case of soil of type B, the difference between the two blocks is within 5% (Figure 4).

4. Conclusion

Under the same building fabric and site topography, the positional relationship between green space and buildings will affect the surface runoff of rainwater and the depth of water in the site to varying degrees. The green space layout of existing residential blocks is mostly on the north and south sides of the building. This is not an optimal layout for the reduction of surface runoff. The surrounding green space around the block can play the role of surface runoff reduction more efficiently.

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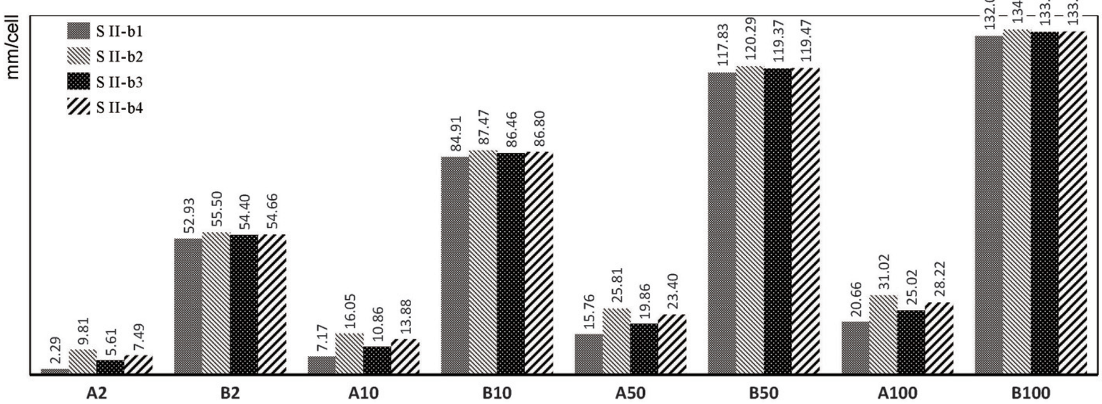

Figure 4. *Runoff per cell under different rainfall intensities and soil types.*

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