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Topographical Assessment for Phytostructure Distribution

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Abstract: This review formulates greenspace distribution in relation to topography. The fate of rain precipitation on land would be controlled by greenspace. In the event of rainfall, water evaporation and water use for plants tissue building were neglected and hence, the precipitation would be released to infiltration and runoff. It was found that stormwater runoff of nearly 50% precipitation could be reduced by the presence of greenspace and therefore, infiltration was equal to runoff. This came up to the relationship between greenspace area (Av) and slope of land (S) for a given city as Av = (fr/fi)*$S^{1/2}$. Greenspace distribution would be larger on the steep of land than on the mild slope of land.

Key words: Greenspace area, infiltration, runoff, slope of land

INTRODUCTION

Greenspace area could be determined with reference to population number instead of city area. Owing to the various population numbers among cities, the important point was no single quantitative greenspace area over the city area could be generalized for all cities (Samudro and Mangkoedihardjo, 2006). Since the greenspace area has been determined, the subsequent arrangement was how it should be distributed within the city area. The greenspace distribution was preferably on wetlands, river lines, plateau and north south direction that all follow natural guidance such as solar intensity, sun movement and photosynthetic reaction. This supported the study of Briggs and Whitwell (2002) in their work with reducing stormwater using wetlands and water way in combination with plants.

Plants growth performance is directly influenced by solar radiation. Light intensity is natural guidance on how phytostructure should be distributed. The sun intensity is higher on the plateau than on the low ground level and hence, distribution of greenspace area on the plateau of a city must be kept to ensure the availability of photosynthetic energy. This is supporting the traditional thinking and conventional practice that greening on the plateau is to maximize infiltration into deep soil at the upstream level. Subsequently, it is maximize groundwater availability and minimize surface runoff which eventually reducing flood in low land area. All of these natural guidance might be practically translated into the application of green roof by which runoff was reduced (Briggs and Whitwell, 2002; Johnston *et al*., 2004; MacMillan, 2004; Moran *et al*., 2004; Rankins *et al*., 2001).

Since greenspace has to be provided on the plateau, it is important to explore greenspace distribution with regard to topographical feature of a city. How much area of greenspace should be distributed on steep slope land and mild slope land, representing phytostructure with an attempt to reduce runoff, was the main objective of this present review. To some extent, greenspace distribution according to natural guidance would also be presented to have complete feature of greenspace distribution. The results would be valuable as a tool for spatial plan of a city in particular and integrated watershed management in general.

MATERIALS AND METHODS

This review was based on the role of greenspace in balancing rain precipitation. An amount of rain water (Qp) would undergo infiltration (Qi) into deep soil and runoff (Qr) along the soil surface. Water evaporation to atmosphere and water use for plants tissue building were neglected in the event of precipitation. Therefore the water balance could be simplified in the following equation:

$$Qp = Qi + Qr \quad (1)$$

Infiltration flow (Qi) was depended on soil profile characteristics and hence, the formula of Darcy could be applied as follows:

$$Qi = K*I*Av \quad (2)$$

Soil profile to conduct water was accounted for soil permeability (K) which was site-specific value. I was defined as the headloss of water through soil depth. Av was vertically surface area of soil which in the presence of plants was nothing less than greenspace area.

Runoff flow (Qr) was depended on soil surface characteristics and hence, the formula of Manning for open channel hydraulics could be applied as follows:

$$Qr = (1/n)*Ah*R^{2/3}*S^{1/2} \quad (3)$$

Soil surface characteristic was represented as roughness constant (n) of soil surface. Ah was horizontally face area of runoff. R was hydraulic radius of the horizontally face area of runoff. Slope of land (S) was defined as the differences of ground level along the length which was nothing less than the topographical feature.

The three equations were rearranged and resulted in the following equation:

$$Qp = K*I*Av+(1/n)*Ah*R^{2/3}*S^{1/2} \quad (4)$$

The last equation was the working model for greenspace distribution that was accounted for topographical feature of a city.

RESULTS

The result was obtained by numerous studies with regard to the application of plants in mitigating the effects of excess stormwater. The existing wetlands in coastal area could reduce the amount of stormwater entering streams and rivers. It was found that water way of about 2 m in combination with cattails (*Typha latifolia*) was effective in reducing runoff (Briggs and Whitwell, 2002). The presence of a perennial grass strip reduced about 55% volume of total runoff (Rankins *et al*., 2001). In addition, several specific grasses such as big bluestem, eastern gamagrass, switchgrass and tall fescue could reduce runoff of at least 59%.

Similar results were found from a green roof experiment that total runoff could be reduced by 55%. Surprisingly, peak flow was reduced by 85% for smaller storm events but was less for larger events (MacMillan, 2004). Moran *et al*. (2004) studied plant growth and runoff from two extensive greenroofs and found that both roofs retained about 60% of the total recorded rainfall and reduced the average peak flow by 85%. Effects of runoff were studied on a membrane roof, pre-development conditions and the green roof with 3.6 m of growing medium. It was found that the green roof could potentially reduce runoff by 70% and peak flow by 30-80% (Johnston *et al*., 2004).

According to the above mentioned data, the runoff flow in the presence of greenspace was Qr ≤ 50% Qp, consequently the infiltration flow was Qi ≥ 50% Qp. For general and practical use, the limit level of 50% Qp was applied for both runoff and infiltration. As a result, equation 4 would be transformed into the following equation:

$$K*I*Av = (1/n)*Ah*R^{2/3}*S^{1/2} \quad (5)$$

or

$$Av = [(Ah*R^{2/3}/n)/(K*I)]*S^{1/2} \quad (6)$$

With regard to Av, it was nothing less than greenspace area for a given city. Av as such was defined as the product of width (W) and length (L) of greenspace area. Thus Av was a fixed value for a given city. Similarly, slope of land (S) was topographical feature and therefore it was fixed value for a given city.

By definition of Eq. 3, Ah was the product of width (W) and depth of runoff (H), R was the ratio of Ah/wetted perimeter, i.e., ((H*W/(2H + W)). In addition to roughness constant (n), all were representing the size of runoff which was generally irregular depending on land surface characteristics. Those parameters were treated as a runoff factor (fr) in the form of:

$$fr = Ah*R^{2/3}/n \quad (7)$$

Similarly, the parameters of K and I were vary from place to place, representing soil profile characteristics in carrying out infiltration. These could be treated as an infiltration factor (fi) in the form of:

$$fi = (1/K*I) \quad (8)$$

Rearrangement of Eq. 7 and equation 8 into equation 6 would result in a simplified equation as follows:

$$Av = (fr/fi)*S^{1/2} \quad (9)$$

DISCUSSION

It was important to note that greenspace area Av has to be determined firstly then greenspace distribution follows the land slope. With regard to greenspace area, the readers could use simulation models such as multimedia fugacity (Hertwich, 2001; Mackay *et al*., 1996); CenW (Kirschbaum, 1999, 2000), CENTURY (Kirschbaum and Paul, 2002). For countries having water use characteristics that were comparable to Indonesia, Samudro and Mangkoedihardjo (2006) have suggested using equation 10 as follows:

$$GA = (29P^{0.7} - 3.2P) \quad (10)$$

The greenspace area GA (in sq-km) could be calculated based on million of population number (P).

Equation 9 was clearly shown that greenspace area would be larger in a land having steep slope than in mild slope within the city. This was a topographical method to explain that greenspace area should be largely provided on the steep ground level. This was also represented by the effectiveness of green roof in controlling runoff where greenspace was applied on the plateau.

In fact, cities have various topographical features and hence, zoning could be applied for land slope and the greenspace area. The principle of equation 9 was still valid and need further treatment as in the following arrangements. By definition, Av was greenspace area within a city and therefore,

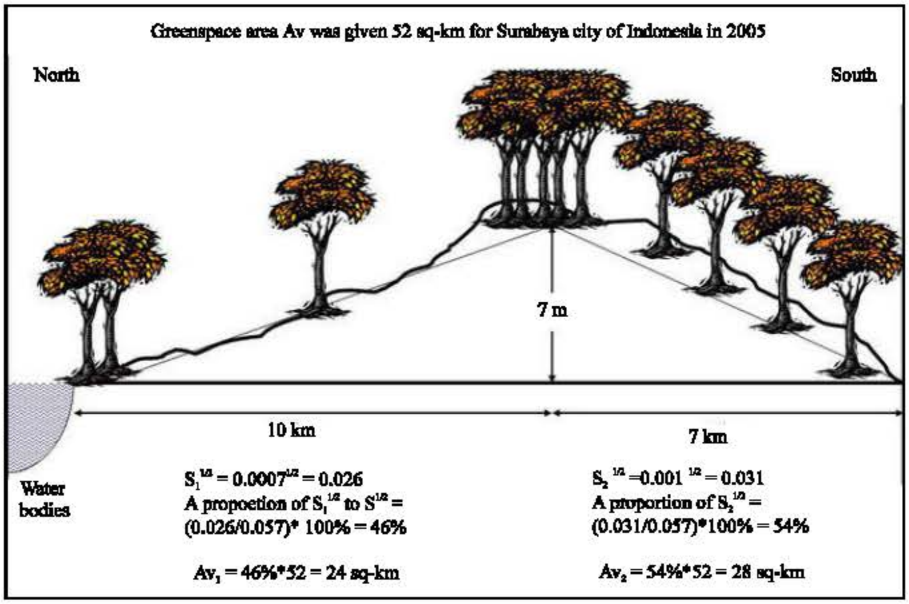

Fig. 1: Illustrative greenspace distribution

$S^{1/2}$ was the slope of land within a city, representing the entirely topographical feature of a city. Accordingly, topographical zones (e.g., $S_1^{1/2}$, $S_2^{1/2}$... $Sn^{1/2}$) were nothing less than proportional to the entire topographical city. The results of the topographical zones have to be multiplied by the given greenspace area to account the greenspace of the zone.

The following example for Surabaya city of Indonesia (Fig. 1) was provided to show how greenspace distribution should be arranged in a simple form, emphasizing slope of land and a complete feature of greenspace distribution based on natural guidance. In order to suppress runoff, the controlling factor of (fr/fi) was assumed to be 1 and applicable to all topographical zones within a given city. The cross section of the city was north south direction in order to the greenspace receives the same incidence of solar radiation. The plateau has the largest area of greenspace in response to the highest intensity of solar radiation. The steep zone has larger greenspace area than the mild zone as a result of the equation 9. However, greenspace area in the mild zone has to be distributed largely near the water sources to account photosynthetic reaction.

CONCLUSIONS

This review concluded that it was able to formulate greenspace distribution based on topographical feature of a city. The steep slope of land would be preferred in distributing larger greenspace than in mild slope of land provided that the greenspace area for a city has been determined. This achievement still has a qualitative result due to the difficulties in predicting the ratio of runoff and infiltration factors. However, it would be agreed that the ratio has a maximum value of 1 which means an amount of runoff would be completely infiltrated within the city by means of greenspace. Further research offers a window into the reaches of the quantitative measure of the runoff and infiltration factors.

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