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Impact of Urban Development on Singapore's Only Primary Rainforest

Geography

KEYWORDS : Forest boundary environment, Forest micro-climate, Edge-interior relationships, Forest fragmentation

Kalyani Chatterjea Associate Professor, National Institute of Education, Nanyang Technological University, 1 Nanyang Walk, Singapore 637616.

ABSTRACT

Bukit Timah Nature Reserve (163 km^2)in Singapore is surrounded by dense urban residential development. While the forest interior still retains a pristine forest micro-climate, the peripheral areas are characterized by concrete-covered surfaces, high-rise buildings, and highways with high radiation potentials and other associated environmental attributes. This research investigates changes in four specific environmental factors, such as atmospheric temperature, relative humidity, soil temperature, and wind velocities in the interior forests, as well as the forest boundaries. The research determines the changes at the forest peripheries and also analyses the extent of influence into the forest interior. Steep environmental gradients and several hot spots with intense alterations of environment have been demarcated, although forest interiors still retain the original microclimatic conditions of a typical rainforest. These assessments are useful in forest conservation and forest boundary management.

INRODUCTION

Bukit Timah Nature Reserve (BTNR), a 163 ha protected primary rainforest, is only 12 km away from the city centre and is surrounded by high rise residential developments. Although the forest was earlier seated amidst scattered forests, orchards, and low-density rural residencesin the pre-independence period, rapid urban developments have resulted in fragmentation of this forest and currently it is surrounded by two major highways, Bukit Timah Expressway (BKE) and Pan-Island Expressway (PIE), many high-rise residential developments and a water pipeline. Although the forest boundaries have been expanded from the previous 75 ha to 163 ha and buffer areas have been established to provide some protection to the forest interiors, regular expansions of urban developments in the surrounding areas are a major concern as these have significant impacts on the forest interior environments and as such on the survival of the only remaining primary rainforest in the heart of Singapore. The study looks at the environmental changes brought about by the surrounding urban developments and how the forest interior micro-climate has come close to a very exposed boundary environment, putting stress on the survival of the forest interior characteristics. This research aims to assess the degree of change in specific environmental parameters and also analyses the data to demarcate zones of impact around the forest. The results are expected to provide resources that may be used to manage the boundary integrity and help in long-term conservation of the forest reserve.

THREATS OF FOREST BOUNDARY CHANGES

Tobias (2013) mentioned that changes in any of the factors such as air, water, or soil will have significant impact and will alter the forest environment. Gayton (2007) found out that the amount of impermeable surfaces such as in paved streets, car parks, and buildings create the 'Edge effect', and Ghose (2004) commented that such drastic alterations in the landuse bring about changes in the habitat, with temperature increases, reduced humidity, and changed soil moisture conditions. The collective result of all these can affect the growth environment of the forest, which is characteristically a warm, humid, sultry, and low-light environment.As such there is a need to assign buffer zones to protect the forest interiors from the drastic changes in peripheral areas. The case of BTNR is of particular importance as this is the only remnant primary rainforest in urban Singapore and, according to Smithsonian Institute (2005) BTNR consists of 15,000 trees of 312 species, underscoring the diversity and good health of the forest.

METHODOLOGY

Currently, the 163ha BTNR is surrounded on all four sides by urban landscapes comprising high-density, high-rise buildings, concrete-covered car parks, tarmac-covered roads, and open areas along water pipelines. Such non-forested landscapes can have impacts on several environmental conditions. This study has recorded spatial changes in air temperature (AT), relative humidity (RH), soil temperature (ST), and wind velocities (WV) in the interior forest as well as at the peripheral areas. These changes are spatially analyzed by mapping the recorded environmental attributes and delineating zones with differential impacts on the forest environment, as well as to ascertain gradients of environmental changes. A total of 700 field data points have been used to record the environmental conditions from March 2012 till end of 2013 in four phases and the generated data is used to draw conclusions on the current impacts of the peripheral landuse changes on the forest.

DATA ANALYSIS

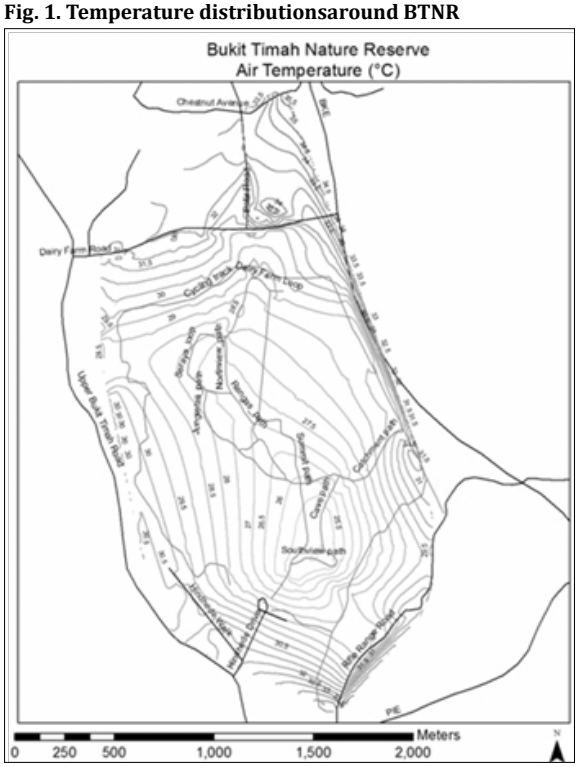
Table 1 shows data obtained from the various landcovers. Based on these measurements, isolines have been drawn for AT, RH, ST, and WV.

Table 1. Environmental Data Obtained from Various Landcovers

Land use type	ATemp (°C)	RH (%)	STemp (°C)	WV (m/s)
Interior Forest (n=259)	24.5-29.5	77.1-94.1	22.0-30.0	0.0-1.80
Forest Buffer (n=132)	27.6-34.7	58.5-97.3	26-36	0.7-0.9
Highway I (n=70)	28.8-33.0	64.2-92.7	27.5-34.0	5.3
Highway II (n=70)	30.3-34.2	68.2-88.5	30.5-35.0	5.7
Major Roads (n=109)	29.0-34.0	64.2-92.7	27.5-35.0	5.7
Condominium (Completed) (n=20)	30.0-37.0	60.6-85.3	N.A.	2.3
Condominium (Under construction) (n=20)	32.1-37.0	60.6-73.2	29.5-37.0	2.3
Car Park (n=20)	31.3-37.8	57.3-72.5	30.5-38.0	0.4-1.9

Temperature distributions in and around the forest show a very close relationship with the landcover: typically increasing sharply from inner forest locations to outside, along all major roads and highways. Inner forest temperatures vary from 24–29.5°C, while the outer areas recorded 37.8 °C, a drastic rise of about 8-13°C , in some locations within 200-500 meters. These sharp increases were located along boundaries with highways and concrete-covered surfaces of car parks. The average increase from forest interiors to the outer edge was 7.3 °C. All data points on concrete-covered surfaces, roads recorded temperatures ranging from >30 to a highest of 39°C while the forest interiors never went above 29°C. Buffer areas with scattered forests also recorded high temperatures of 34.7°C. These are vegetated areas close to densely built-up zones.

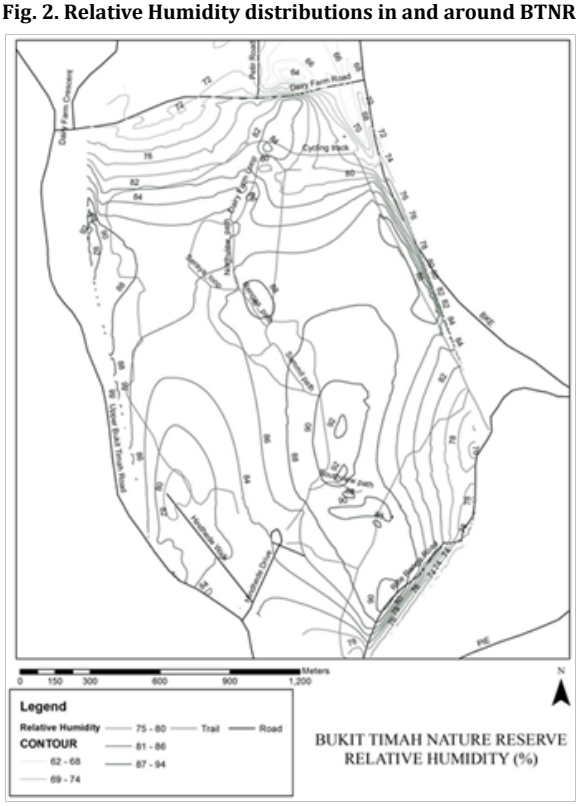
Fig. 1. Temperature distributionsaround BTNR



Relative humidity readings followed the same pattern, only in reverse, with interior locations recording higher values of 77–94%, while the outer peripheries recording drier conditions, with RH values dipping to 52.2%.

Again, the locations of such drastic changes coincided with the major highways and the concrete-covered areas of car parks and condominiums.

Fig. 2. Relative Humidity distributions in and around BTNR



With such dry conditions in the outer peripheries, there were also simultaneous high soil temperature records

Although characteristically wind is of very low intensities in humid tropics within as well as outside forested areas, data revealed sudden gusts of wind (5.7m/sec) at the open peripheries on some occasions, while velocities never went above 0m/sec in 92% of the monitoring stations the forest interiors. All sites recording some wind flow variations are located in the open car parks at the forest fringe, along highways, and in the open construction sites around the peripheral areas of BTNR. It is, therefore, concluded that while the forest interiors are protected from the threats of sudden gusts of wind, the trees that have been exposed owing to the clearance of land at the forest boundaries will be vulnerable to the sudden thunderstorms and extreme rainstorm events and may lead to treefalls. There wererecords of many uprooted trees at the BTNR forest boundaries during the storms of December, 2009 (Chatterjea 2010). During the samestorm events, however, there were no treefalls inside the forest. These records clearly show that wind effects are exacerbated by creation of open areas at the forest verges.

DISCUSSION AND CONCLUSION

The parameters measured reflect how anthropogenic landscapes affect a remnant forest by altering the microclimate of the peripheral areas that were originally a part of the forest interior. While edge forests are thought to buffer the influences of such interferences, edges have been considered to extend from 50-100m, depending on the forest structure and the meteorological variable (Didham et al, 1999). As BTNR is very small such external influences will leave hardly any location out of influence. The current data shows that temperature gradients at the peripheral areas are 100 times steeper than the forest interiors and the steepest gradients are invariably located adjacent to major highways, construction sites, and car parks. These new altered landscapes are superimposed on locations that were under forest cover just a decade ago and the sudden change has exposed the previous forest interiors to drastic changes in the microclimate. The rate of temperature change from forest interiors, through forest buffer areas, to the exterior locations is 0.065–0.03°C per meter distance. There is clear indication that temperature gradients are steeper along wider roads. This is in line with observations that road width is a significant factor in determining the degree of edge effect (Nyandwi, 2008). The gradients of temperature change vary with the type of landcover, with gentler gradients along verges with narrower roads and the gradients become gradual across the inside of the forest. This also supports Pohlman et al's (2007) observations indicating that edge effect magnitudes and ranges vary according to different landscape matrices. Stark open linear breaks caused by highways impact peripheral microclimate more intensely than narrow roads with over-hanging vegetation covers. RH measured for this study reveal very similar pattern, reversing the values, with higher values in the forest interiors but drying out at the verges. Here, too, the relative degree of such changes varies according to the edge characteristics. Boundaries along minor roads and scattered forested buffers recorded a rate of RH change of only 7.5% p/m distance, while the rate jumped to 22.5–33% change p/m distance along major roads, car parks, and construction sites. The outer boundaries recorded a much drier condition, being exposed to the tropical sun and with surfaces having high radiative potentials. Soil temperatures reflected the same pattern, recording significant rise of more than 8°C at the forest edges over the interior soil temperatures. When all the changes are superimposed, we get a condition of high AT, low RH, high ST, and sudden windy conditions at the forest edges, particularly at the highly impacted zones of concrete covered and wide tarmac road surfaces. As these are the locations with also the steepest gradients of environmental change from edge to interior, it seems clear that the forest will be heavily impacted with such landscapes coming too close to the forest interior. In humid tropics, with the characteristic constant temperatures, such adverse effects of an altered landscape have a continuous influence on the forest, unlike in places with seasonal variations.

Such exposure can affect the forest microclimate and the bio-

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logical dynamics within this remnant piece of tropical forest in the heart of Singapore, in spite of the statutory protection by the conservation laws. Unless an urgent look is taken at the severe impact of the surrounding development projects on the forest itself, the very attraction of the tranquility of BTNR will be lost to the residents and the last remnant of the biologically rich tropical forest will become just a patch of greenery.

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