ICUC, Toulouse 2015 9th International Conference on Urban Climate

Impact of urban form on sunlight availability for

urban farming in Asian cities at different latitudes

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MASTER PLAN 2014 FOR LIM CHU KANG PLANNING AREA

LEGEND		51				152			
	RESIDENTIAL	W	BUSINESS 1 - WHITE	E	EDUCATIONAL INSTITUTION		WATERBODY		CEMETERY
	RESIDENTIAL WITH COMMERCIAL AT 1ST STOREY		BUSINESS 2	W	PLACE OF WORSHIP		ROAD	÷ -2	AGRICULTURE
	COMMERCIAL & RESIDENTIAL	W	BUSINESS 2 - WHITE		CIVIC & COMMUNITY INSTITUTION		TRANSPORT FACILITIES		PORT / AIRPORT
	COMMERCIAL		BUSINESS PARK		OPEN SPACE		RAILWAY		RESERVE SITE
	HOTEL	W	BUSINESS PARK - WHITE		PARK		MASS RAPID TRANSIT		SPECIAL LISE
	WHITE		RESIDENTIAL / INSTITUTION		BEACH AREA		LIGHT RAPID TRANSIT		PLANNING AREA BOUNDARY
	BUSINESS 1	H	HEALTH & MEDICAL CARE		SPORTS & RECREATION	U	UTILITY	F	PLOT RATIO BOUNDARY

http://www.ura.gov.sg/maps/





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http://openbuildings.com/

Tablada, A., Zhao X.. 2014: Sunlight availability for food and energy harvesting in tropical generic residential districts. 30th Passive Low Energy Architecture Conference (PLEA), Ahmedabad.



Aims of the study

 To quantify the sunlight availability in 27 cases with a series of densities and urban morphologies located at three different latitudes in Asia: Singapore, Hanoi and Beijing.



Aims of the study

- To quantify the sunlight availability in 27 cases with a series of densities and urban morphologies located at three different latitudes in Asia: Singapore, Hanoi and Beijing.
- To translate sunlight availability into coefficients of self-sufficiency in terms of food (vegetables and fruits) and assess the effect of latitude.





Point block

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Cases and building indicators

	Typology	Building height (H _b) (m)	Site coverage (C _s)	Plot Ratio (PR)
1	Point Block	48	10%	1.3
2	Point Block	66	16%	3.1
3	Point Block	63	27%	4.9
4	Slab Block	24	13%	1.3
5	Slab Block	45	18%	3.1
6	Slab Block	39	33%	5
7	Contemporary Block	21	16%	1.3
8	Contemporary Block	36	21%	3
9	Contemporary Block	36	35%	5

Settings and calculation methods

Autodesk Ecotect + Daysim-Radiance

Daylight Autonomy (DA) Average illuminance levels

Points on the ground and facades Whole year

DA (in this paper): percentage along the whole year in which each point receive >10 000 lux from 8:00 till 18:00 (optimal for certain vegetables and fruits for about 8 hours)

When the DA is below 80% (less than 8 hours with 10 000 lux), a reduction coefficient is applied for the calculation of the annual yield.



Considerations for farming and PV integration

Farming area on the ground

derived from the actual land use at Punggol New Town (northeast of Singapore)

- 15% for roads
- 35% for open space and recreation.
- 50% remaining area is distributed between buildings and farming areas (varies according to C_s)

The farming area on the façade

0.5m of planters along 30% of the perimeter of the façade as part of a balcony or external common corridor.

PV panels

- 70% of the facade perimeter with BIPV panels (as shading devices)
- 80% of the roof area with PV panels.



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Selection of crops and food self-sufficiency

Selection criteria (fruits and vegetables)

- 1. suitability for local context
- 2. preference among local residents
- 3. productivity

Two scenarios are considered:

1. <u>Conventional:</u>

refers to urban ground farming methods. Both traditional ground soil and the use of soil planters.

2. <u>Hybrid:</u>

combination of 'conventional' + 'vertical' methods (50% ground surface each)

Vertical refers to A-shaped soil-based structures (SkyGreen.com) (only vegetables) 4 times + productive than the conventional ones.

Farming area: 14.6 m2 /person for self-sufficiency



http://www.mnd.gov.sg/

Results / Sunlight availability



DA (%) Illuminance >10 klx

Results / Sunlight availability / effect of orientation

DA (%) Illuminance >10 klx for PR = 3.1



Results / Farming potential and food self-sufficiency (hybrid method)



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Results / Farming potential and food self-sufficiency



Results / Farming potential and food self-sufficiency

	Hanoi vs. Singapore			Beijing vs. Hanoi			
	PR=1.3	PR=3.1	PR=5	PR=1.3	PR=3.1	PR=5	
Point Block	-3.6%	-6.9%	-5.7%	1.2%	-1.1%	-0.6%	
Slab Block	-1.5%	-5.1%	-4.9%	-0.2%	-0.5%	-1.3%	
Contemporary	-5.5%	-8.3%	-5.4%	-0.4%	-1.6%	-1.5%	
Block							
	From 8.00	to 18.00	Hanoi	(W/m2)	Beijing (W/m2)	_	
	Global rad	liation	3	66	341		
	Direct radiation		2	.38	302		

Food self-sufficiency reduction (%) according to latitude

In locations with similar latitudes but with clearer sky conditions than in Hanoi (e.g. Havana, 23.2°N) larger differences are observed with respect to Beijing, especially from January till March.

Summary and Conclusions

- Sunlight availability and therefore the potential of food selfsufficiency is strongly affected by the factor of density, then by typology and lastly by latitude.
- The impact of density on sunlight availability is evident in all latitudes. However, it is lower for equatorial than for higher latitudes
- The facade orientation is less important on lower latitudes than on higher ones
- Sky conditions through the year may have equal or larger influence on sunlight availability than latitude (<20° difference)

Recommendations

- The potential food production on latitudes near the Equator can be maximized by the use of more intensive farming methods and the installation of denser planter systems on building facades without affecting daylight conditions inside apartments
- The DA reduction on higher latitudes could be offset if the amount and distribution of planters better corresponds with the uneven sunlight incidence between and on each facade

Continuation of the study

- Elaborating correlations between PR and food self-sufficiency for Hanoi and Beijing (same as for Singapore)
- Elaborating a map of sunlight availability on building facades and ground according to typology and density
- Exploring integration of farming and PV areas according to differentiated sunlight availability –vertically and horizontally
- Comparing studied cases with other on similar latitudes but with similar sky conditions among them
- Assessing more complex urban morphologies closer to real cases

Thank you for your attention

Continuation...

Slab Block (16 cases)



Contemporary Block (16 cases)

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Self-sufficiency	Block	Slab	Contemporary
Food vs PR	1.9	1.8	1.7
Energy vs Hb	39m (13 fls)	30m (10 fls)	33m (11 fls)

Method

- 1. calculation of <u>incident sunlight</u> and <u>daylight autonomy</u> (DA) is calculated on the ground around buildings and on building facades for three typologies and three densities in three latitudes
- 2. calculation of food <u>self-sufficiency ratio</u> considering two farming methods and a limited area for planters on facades

Model simplification

Shading devices (30 cm overhang along all facades on every floor) were not modelled

Shading devices reduces sunlight:

-4% on ground

-12% on facades

Ground An equivalent reflectance coefficient (-20%) on the facade

Façade Coefficient of 0.9 is applied directly on the final illuminance levels



Population

- 70% of GFA is residential,
- 20% institutions and
- 10% commercial

Average area per capita in the HDB = $25m^2$

Considering a floor plan efficiency (rental flat area out of GFA of residential building) equal to 85%.



http://www.straitstimes.com/

PV panels and energy self-sufficiency

- Polycrystalline Silicon (pc-Si): Rooftop
- Thin-film Amorphous Silicon Copper Indium Selenide (a-Si CIS) : Shading devices on facade

Typical efficiencies and temperature factors were considered: pc-Si = 13% a-Si CIS = 8%

Energy use per capita typical HDB apartment: 1287 kWh (April 2013 - March 2014)

Solar collectors for water heating are not considered at this stage.



Rooftop PV on an HDB Block, Tampines, Singapore. Taken by HDB Building Research Institute Staff in 2011.



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