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MATHEMATISCH-NATURWISSENSCHAFTLICHE FAKULTÄT

Building type based estimation of relevant parameters for urban infrastructure planning using VHR satellite imagery and UAV data

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Background & Relevance

Urbanization

- Global phenomenon of migration from rural to urban environments
- Global turning point in 2007
- Regional differences, highest urbanization rates in SE-Asia and Africa

Challenges for urban infrastructure planning

- Urban infrastructure planning is key for slum reduction
- Goal: increase sustainability through integrated planning approaches
- UN General Secretary Gutierres: **„Towards evidence planning“**

New Urban Agenda, UN-Habitat 2016, https://habitat3.org/the-new-urban-agenda

Hypothesis:

Residential building type can provide relevant knowledge for urban infrastructure planning

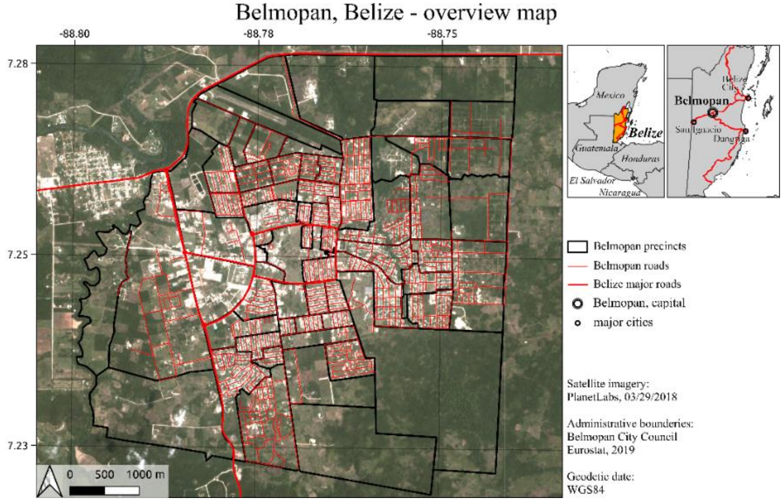
- **Socio-economic information** as proxy for residential water & energy consumption and solid waste & waste water production
- **Electricity consumption**

Warth et al. 2020

Study city: Belmopan

Planned capital city of Belize

- Relocation of the city due to repeated hurricane destructions
- Inauguration: 1970
- First elected city administration: 2000
- Inhabitants: 25,583 (est. 2021)
- Population growth 2014 - 2018: 6.4% p.a.



Warth et al. 2020, Belmopan City Council

Data for the studies

VHR satellite imagery

- Two WorldView-1 stereo pairs (2018/03)
- PlanetLabs (2019/03)

UAV imagery

- 6 study areas in Belmopan
- 15 UAV flight campaigns
- 2,800 single images

Household surveys

- 2019/01-03: 405 interviews on socio-economy
- 2019/11-12: 190 interviews on electricity consumption

Methods

Building detection

- Manual footprint detection
- Prioritization of time efficiency over scientific excellency

Warth et al. 2020

Random forest building type classification

- RF classification of building footprints
- Classification attributes: geometric attr., building height, quality of life indicators
- Residential building types: 4 single family building type classes, 4 multi-family building type classes

Photgrammetry and structure-from-Motion UAV data processin

- Orthomosaic generation
- DSM/nDSM generation (building height, roof complexity, PV analysis)

Statistical analysis of household data

Pattern detection in relation to building type for:

- Socio-economic indicators
- Residential electricity consumption

Results – building type classification:

WV-1 data classification

- Full coverage of Belmopan: 6,627 buildings
- Initial RF classification: OA 56.7%
- Threshold based classification refinement: OA 86.3%

Building Type	Share of total number
BT 11 – Single Family Basic	11.5%
BT 12—Single Family Standard	46.2%
BT 13—Single Family Advanced	18.3%
BT 14—Single Family Complex	8.6%
BT 21—Multi-Family Basic	0.5%
BT 22—Multi-Family Standard	2.0%
BT 23—Multi-Family Apartment	1.4%
BT 24—Multi-Family Modern Apartment	<0.1%

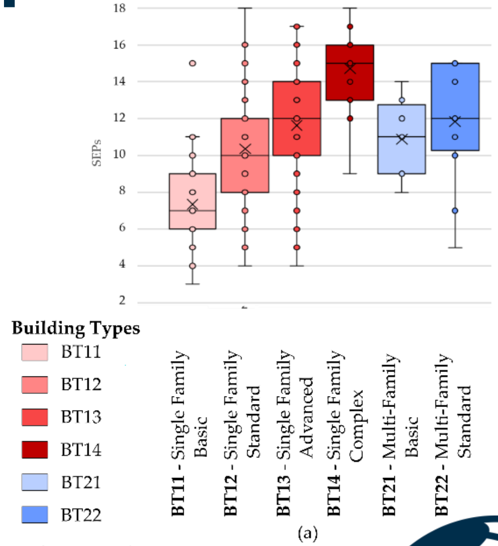
UAV data classification

- Partial coverage of Belmopan: 1,619 buildings (24.4% of building stock)
- Increased accuracy from added roof complexity information
- RF classification accuracy:
  OA 73 %

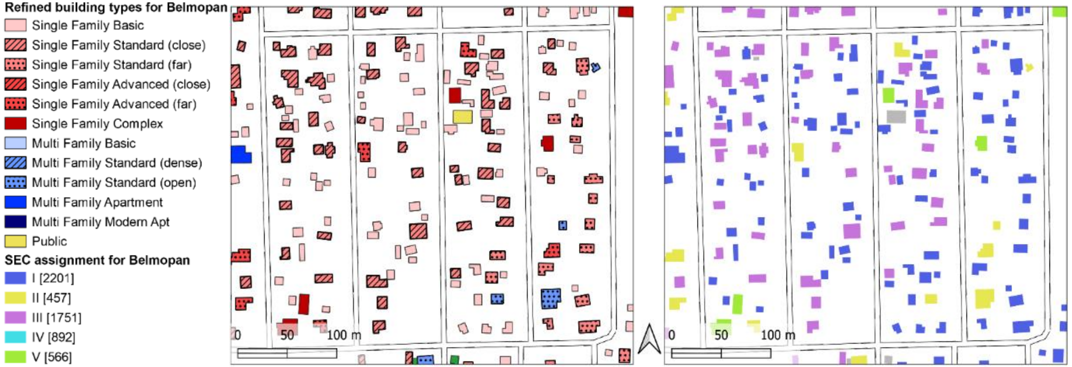
Results – prediction of socio-economic information based on building type:

Determination of socio-economic measure for households as 15-point scale:

- Household assets
- Monthly household expenses
- Highest educational degree of the main earner



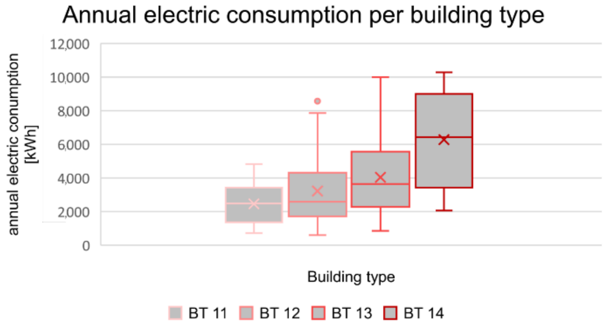
Result: **Distinctive socio-economic characteristics for building types**

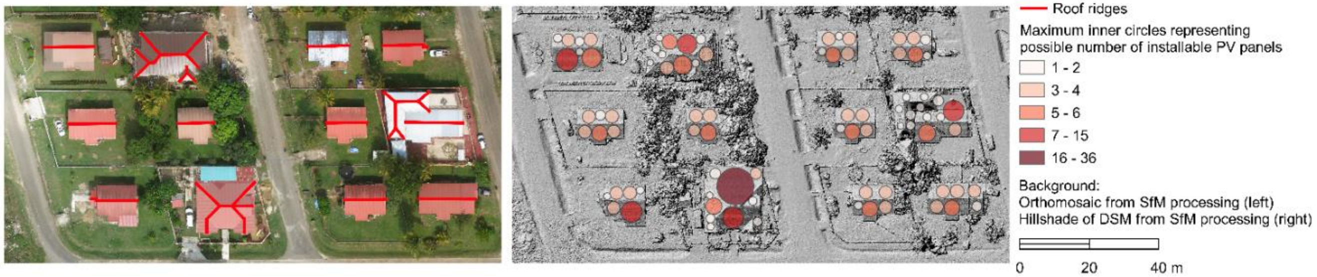


Warth et al. 2020

Results – estimation of electricity consumption and PV energy balancing (1/2):

- Statistics: **Distinctive electricity consumption patterns**
- PV energy balancing:
    - Determination of roof-based PV suitability (DSM)
    - Solar radiation model: NSRDB
    - Realistic scenario: 2 PV panels per building
    - Ideal scenario: best roof fully equipped with PV





NSRDB: National solar radiation data base

Warth et al. 2021

Results – estimation of electricity consumption and PV energy balancing (2/2):

Main findings:

- Belmopan can cover substantial parts of energy demand through PV
- Approach enables data provision for socially fair energy strategies

Energy price: 0.21 US$/kWh
GNI p.c.: 4,700 US$

	Scenario 1: maximum number of PV panels on best FOR		Scenario 2: maximum two PV panels on best FOR	
	PV balance [kWh/year]	PV energy coverage [%]	PV balance [kWh/year]	PV energy coverage [%]
Total	1,847 (+/- 4,049)	148% (+/- 108)	-2,607 (+/- 903)	29.5 % (+/- 6.5)
BT 11	-337 (+/- 1,930)	86% (+/- 78)	-1,573 (+/- 227)	36.0% (+/- 9.9)
BT 12	1,318 (+/- 3,420)	141% (+/- 106)	-2,191 (+/- 118)	32.0% (+/- 3.7)
BT 13	3,489 (+/- 4,443)	186% (+/- 110)	-2,971 (+/- 74)	26.5% (+/- 1.8)
BT 14	1,670 (+/- 5,528)	127% (+/- 88)	-5,203 (+/- 63)	17.1% (+/- 1.0)
BT 21	3,189 (+/- 2,625)	202% (+/- 84)	-2,120 (+/- 104)	32.1% (+/- 3.3)
BT 22	925 (+/- 2,779)	122% (+/- 65)	-3,230 (+/- 87)	24.1% (+/- 2.0)

Warth et al. 2021

Conclusions

Methodology

- Socio-economic information and residential electricity consumption in relation to building type
- Transferability of the approach needs **local knowledge** on urban structure and household information
- Accuracy of building type classification highly profits from spatial resolution

PV balancing

- Belmopan can cover substantial parts of energy consumption through PV
- Approach allows to define strategies to financially relieve vulnerable population

Thank you for your attention!

References

Warth, G.; Braun, A.; Assmann, O.; Fleckenstein, K.; Hochschild, V. *Prediction of Socio-Economic Indicators for Urban Planning Using VHR Satellite Imagery and Spatial Analysis.* Remote Sensing 2020, 12, 1730. https://doi.org/10.3390/rs12111730

Warth, G.; Braun, A.; Assmann, O.; Fleckenstein, K.; Hochschild, V. *Photovoltaic energy balancing in Belmopan based on building types, UAV aerial imagery and household data.* Geography and Sustainability 2021, under review

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