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Quantification of Artificial Surfaces Impact on Urban Heat Island of Novi Sad (Vojvodina, Serbia)

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Abstract

Within urban zones land cover, being the expression of human activities, could be greatly modificated by changes in urban surfaces. Land cover modifications can be measured with mathematical metrics that quantify different aspects of landscape pattern. This research examines land cover patches by a set of landscape metrics for area and size. (Number of patches - NP, CA – Class area, Mean patch size - MPS, % - class ratio). The classification of land cover patches was based on Corine Land Cover 2006 (CLC2006) seamless vector data. The main goal of the research is to investigate the impact of artificial surfaces on Urban Heat Island (UHI) in the City of Novi Sad. The methodology is based on crossing of landscape and geographical approach to UHI research. UHI metrics of Novi Sad reveal strong human impact indicating direct proportional relation between presence of artificial surface areas and increased air temperatures.

Key words: Corine Land Cover, Urban Heat Island, GIS, Novi Sad, Serbia

Introduction

It is crucial in land cover and climate change research to systematically describe the environment in order to detect its changes, human-related causes and responses. Earth's land surface and its changes are central in most of the biophysical processes of global environmental change. Therefore, land change is qualified as a forcing function within the global environmental change (Grugia et al., 2010, Jansen and Di Gregorio, 2002; Turner, 2002; Turner, 2006).

Land cover has been defined by the attributes of the Earth's land surface and immediate subsurface, including biota, soil, topography, surface and groundwater, and human (mainly built-up) structure (Lambin et al., 2006).

This paper analyse land cover patches and urban temperature intensity of the City of Novi Sad (Vojvodina, Serbia). The main purpose of the analyses is to quantify land cover patches within zones of annual mean urban heat island (UHI) temperature intensity of Novi Sad. Quantified land cover patches are bringing most useful information about state of UHI that is impacted by human influences.

Materials and methods

According to Oke (1984) and Svensson et al. (2002) three types of models can be applied for climate related research in urban environments: numerical, physical and empirically based models.

For input model, authors were used model of annual mean UHI intensity created by Unger et al. (2011a; 2011b), that is based on empirical modeling study of Balázs et al. (2009). Statistical calculations were done

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using ArcGIS 9.3 software. Quantification of landscape elements (land cover patches) in this papers were based on following landscape metrics:

- **NP (Number of patches)** – equals the number of land cover patches in each patch type – class.
- **CA (Class area)** – equals the sum of the areas belonging to a given class. Units of equals: quadrate meters (m^2).
- **MPS (Mean patch size)** – equals the sums of the area of all land cover patches divided by the number of patches of the same type. Units of equals: quadrate meters (m2).
- **% (Percentage)** – represent ratio of each land cover class.

The classification of land cover patches was based on Corine Land Cover 2006 (CLC2006), that provides consistent information on land cover and land cover changes across Europe.

CLC classification consists of 44 land cover categories. The five general levels are: 1) artificial surfaces, 2) agricultural areas, 3) forests and semi-natural areas, 4) wetlands, and 5) water bodies (Heymann et al., 1994).

Land cover patches – class types that are represented in investigated area are following:

112 Artificial surfaces. Urban fabric. Discontinuous urban fabric
121 Artificial surfaces. Industrial, commercial and transport units. Industrial or commercial units
122 Artificial surfaces. Industrial, commercial and transport units. Road and rail networks and associated land
123 Artificial surfaces. Industrial, commercial and transport units. Port areas
141 Artificial surfaces. Artificial, non-agricultural vegetated areas. Green urban areas
142 Artificial surfaces. Artificial, non-agricultural vegetated areas. Sport and leisure facilities
211 Agricultural areas. Arable land. Non-irrigated arable land
231 Agricultural areas. Pastures
242 Agricultural areas. Heterogeneous agricultural areas. Complex cultivation patterns
243 Agricultural areas. Heterogeneous agricultural areas. Land principally occupied by agriculture, with significant areas of natural vegetation
311 Forest and semi natural areas. Forests. Broad-leaved forest
321 Forest and semi natural areas. Scrub and/or herbaceous vegetation associations. Natural grassland
324 Forest and semi natural areas. Scrub and/or herbaceous vegetation associations. Transitional woodland-shrub
331 Forest and semi natural areas. Open spaces with little or no vegetation. Beaches, dunes, sands
411 Wetlands. Inland wetlands. Inland marshes
511 Water bodies. Inland waters. Water courses
512 Water bodies. Inland waters. Water bodies

Study area

Novi Sad is located in the northern part of Serbia (Vojvodina Province) (45°15' N, 19 °50' E). The investigated area is plain (mostly from 80 to 86m a.s.l.) on Holocene sediments with a gentle relief, so generally, the climate is free from orographic effects (Unger et al. 2011a; 2011b).

According to Koppen-Geiger climate classification, the region around Novi Sad is categorised as Cf climate (temperate warm climate with a rather uniform annual distribution of precipitation) (Kottek et al., 2006). In Novi Sad, the annual mean air temperature is 11.1°C with an annual range of 22.1°C. The mean annual precipitation amount is 615 mm (based on data from 1949 to 2008). Novi Sad is the second largest city in Serbia and has a population of 285.756 inhabitants (data from 2009) in a built-up area of approximately 60 km^2 (Savić et al. 2013).

Results and discussion

Based on previous research of Unger et al. (2011a, 2011b) and Popov and Savic (2010) there are nine different zones of annual mean UHI temperature intensity in area of Novi Sad (0°C, +0.5°C, +1°C, +1.5°C, +2°C, +2.5°C, +3°C, +3.5°C and +4°C). Evaluation of zones is based on quantification of land cover patches in each zone, and this research is focused on the comparison of artificial surface impacts on each. The main result is land cover patches analyse with highlight on artificial surfaces impact on increasing temperatures in Novi Sad (Figure 1).

The zone of 0°C of UHI intensity occupies 37.11ha, and it is 0.64% of the total urban area (Table 1). This is external zone and the smallest one, with climate conditions the most likely as rural area in Novi Sad surroundings.

Number of patches (NP) in 0°C zone is 7. That is 3.78% from all patches in research area. That means this zone is moderate fragmented compared with other zones. Total area of artificial surfaces (112, 121, 141) encompass 36.12% of 0°C zone.

The area of 0.5°C zone occupies 661.40ha, that is 11.35% of the total urban area (Table 2).

NP in 0.5°C zone is 43. That is 23.24% from all patches in research area. That means this zone is extensively fragmented compared with other zones. Total area of artificial surfaces (112, 121, 141, 142, 122) encompass 26.76%. Even this is smaller than in the 0°C zone, the impact of artificial surface is more evidence because there are five artificial surfaces patches.

Figure 1. Annual mean UHI temperature intensity and CLC of Novi Sad

Table 1. *0°C zone of UHI temperature intensity*

Class	NP	CA	MPS	%
242	1	126024.85	126024.85	33.96
141	1	103175.8	103175.8	27.80
411	1	66977.68	66977.68	18.05
112	1	27055.28	27055.28	7.29
311	1	24704.33	24704.33	6.66
511	1	19380.59	19380.59	5.22
121	1	3805.73	3805.73	1.03

Note: NP – number of patches; CA – class area; MPS – mean patch size

The area of 1°C zone occupies 975.40ha, that is 16.74% of the total urban area (Table 3).

NP in 1°C zone is 44. That is 23.78% from all patches in research area. That means this zone is extensively fragmented compared with other zones. Total area of artificial surfaces (112, 121, 141, 142, 122, 123) encompass 54.36%. Comparing with previous zone, percentage of area under the artificial surfaces is higher for 27.6% and temperature is higher for 0.5 °C.

The area of 1.5°C zone occupies 886.83ha, that is 15.22% of the total area (Table 4).

Table 2. *0.5°C zone of UHI temperature intensity*

Class	NP	CA	MPS	%
211	6	1708140.8	284690.14	25.83
511	1	1022749.9	1022749.9	15.45
242	7	957568.77	136795.54	14.48
112	4	855701.29	213925.32	12.94
121	5	524174.95	104834.99	7.93
311	3	326947.66	108982.55	4.94
141	2	280863.46	140431.73	4.25
231	4	275651.18	68912.79	4.17
411	3	234983.99	78328	3.55
324	2	164723.08	82361.54	2.49
243	2	83360.43	41680.21	1.26
142	1	77541.13	77541.13	1.17
331	1	70257.25	70257.25	1.06
122	1	31345.77	31345.77	0.47
512	1	69.98	69.98	0.01

NP in 1.5°C zone is 36. That is 19.46% from all patches in research area. That means this zone is extensively fragmented compared with other zones. Total area of artificial surfaces (112, 121, 141, 122, 123) encompass

Table 3. *1°C zone of UHI temperature intensity*

Class	NP	CA	MPS	%
112	4	3254138.6	813534.64	33.36
242	8	1281730.7	160216.34	13.14
121	6	1200064.5	200010.75	12.30
211	6	932607.46	155434.58	9.56
511	1	846785.85	846785.85	8.68
141	3	679486.74	226495.58	6.95
243	3	462332.95	154110.98	4.73
311	1	309672.83	309672.83	3.17
324	3	299679.5	99893.17	3.07
231	2	134407.61	67203.8	1.37
331	1	115805.73	115805.73	1.18
142	1	92225.77	92225.77	0.94
122	1	65718.91	65718.91	0.67
512	1	56744.23	56744.23	0.58
411	1	12258.66	12258.66	0.12
123	1	10003.53	10003.53	0.10
321	1	355.64	355.64	0.01

77.47% of 1.5°C zone. Comparing with previous zone, percentage of area under the artificial surfaces is higher for 23.11%.

The area of 2°C zone occupies 852.28ha, that is 14.63% of the total urban area (Table 5).

NP in 2°C UHI zone is 27. That is 14.59% from all patches in research area. That means this zone is moderate fragmented compared with other zones. Total area of artificial surfaces (112, 121, 122, 123, 141) encompass 90.95% of the zone. Comparing with previous zone, percentage of area under the artificial surfaces is higher for 13.48%.

The area of 2.5°C zone occupies 914.34ha (Table 6), that is 15.69% of the total area.

Table 4. *1.5°C zone of UHI temperature intensity*

Class	NP	CA	MPS	%
112	4	5136849.8	1284212.5	57.92
121	5	908205.43	181641.09	10.24
242	7	458564.38	65509.2	5.17
243	3	431331.52	143777.17	4.86
511	1	425861.95	425861.95	4.80
141	2	356923.56	178461.78	4.02
122	3	352700.77	117566.92	3.98
324	2	274137.01	137068.51	3.09
211	4	232541.76	58135.44	2.62
311	1	134573.62	134573.62	1.52
123	1	115902.5	115902.5	1.31
512	1	29638.4	29638.4	0.33
331	1	9504.73	9504.73	0.11
231	1	1660.8	1660.8	0.02

Table 5. *2°C zone of UHI temperature intensity*

Class	NP	CA	MPS	%
112	3	5724945.7	1908315.2	67.17
121	5	1452142.7	290428.54	17.04
122	3	345689.88	115229.96	4.06
511	1	329673.8	329673.8	3.87
242	4	240835.79	60208.95	2.83
123	1	167078.69	167078.69	1.96
243	3	97675.33	32558.44	1.15
141	1	61789.41	61789.41	0.72
324	2	39381.42	19690.71	0.46
211	2	32768.74	16384.37	0.38
512	1	23284.04	23284.04	0.27
311	1	7536.59	7536.59	0.09

NP in 2.5°C zone is 12. That is 6.49% from all patches in research area. That means this zone is less fragmented compared with other zones. Total area of artificial surfaces (112, 121, 122, 123) encompass 96.06% of the zone. Comparing with previous zone, percentage of area under the artificial surfaces is higher for 5.11%.

Table 6. *2.5°C zone of UHI temperature intensity*

Class	NP	CA	MPS	%
112	2	6944938.1	3472469.1	75.96
121	4	1265686.3	316421.59	13.84
122	2	396237.23	198118.62	4.33
511	1	250420.89	250420.89	2.74
123	1	176351.99	176351.99	1.93
242	2	109816.23	54908.11	1.20

The area of 3°C zone occupies 705.82ha, that is 12.11% of the total urban area (Table 7).

NP in 3°C zone is 10. That is 5.41% from all patches in research area. That means this zone is less fragmented compared with other zones. Total area of artificial surfaces (112, 121, 122, 123) encompass 99.98%. Comparing with previous zone, percentage of area under the artificial surfaces is higher for 3.92% and temperature is higher for 0.5 °C.

The area of 3.5°C zone occupies 586.71ha, that is 10.07% of the total area (Table 8).

NP in 3.5°C zone is 5. That is 2.70% from all patches in research area. That means this zone is less fragmented compared with other zones. Total area of ar-

Table 7. *3°C zone of UHI temperature intensity*

Class	NP	CA	MPS	%
112	2	4667418.9	2333709.5	66.13
121	4	1877349	469337.26	26.60
122	2	484992.93	242496.46	6.87
123	1	27254.58	27254.58	0.39
511	1	1184.55	1184.55	0.02

Table 8. *3.5°C zone of UHI temperature intensity*

Class	NP	CA	MPS	%
112	1	5539619.8	5539619.8	94.42
121	3	249244.87	83081.62	4.25
122	1	78329.8	78329.8	1.34

tificial surfaces (112, 121, 122) encompass 100% of the zone. Comparing with previous zone, percentage of area under the artificial surfaces is higher for 0.02%.

The area of 4°C zone occupies 206.19ha, that is 3.54% of the total urban area (Table 9).

Table 9. *4°C zone of UHI temperature intensity*

Class	NP	CA	MPS	%
112	1	2061949.7	2061949.7	100

NP in 4°C zone is 1. That is 0.54% from all patches in research area. That means this zone is less fragmented compared with other zones, i.e. this zone is not fragmented at all. Total area of artificial surfaces (112) encompasses 100%. Comparing with previous zone, percentage of area under the artificial surfaces is the same and temperature is higher for 0.5 °C.

Conclusion

According to the results of the urban heat island pattern in Novi Sad the main conclusions of this study are as follows:

This research examined land cover patches by a set of landscape metrics for area and size and annual mean UHI temperature intensity zones. Evaluation of artificial surface ratio values by temperature zones varies from 26.76% to 100% in densely built-up downtown, and temperatures vary from 0°C to +4°C. The impact of artificial surfaces on increasing temperatures is evident, because in almost all zones (except 0.5°C zone), increasing of percentage of area under the artificial surfaces indicates the increasing temperatures in the same area. Results show that total area of temperature zone is opposite proportional with increasing of temperatures, which indicates that artificial surface impact is more effective in smaller zones.

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