LOGISTICS SPRAWL IN PRAGUE'S SUBURB FROM SATELLITE IMAGES

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Abstract
The construction of logistics centres and the selection of their localities affects not only the activities of urban goods movement, but also the urban environment. The phenomenon called as logistics sprawl, i.e. the relocation of logistics facilities away from inner urban areas to suburban areas has received an increasing level of attention from scientific community and public as well. The paper results are focused on the square increase of logistics centres in Prague's suburb with the use of satellite images. These images were compared with the cadastre of the Czech Republic. Build up squares of logistics centres enlarged about 400.10^4 (m^2) in suburb from the year 2013 to 2018 at the expense of agricultural land. This fact can exacerbate the quality of life in the Prague´s suburban areas.

Key words: *logistics centres; remote sensing; land use; environmental impact.*

INTRODUCTION

There are many efforts to define and classify logistics centres academically. Using freight village term synonymously, logistics centre is defined as: traffic logistical interconnection points within a logistics network that primarily function is an interface between local and long-distance goods transport (*Winkler & Seebacher*, *2011*). In an ideal case, the logistics centres should be located near urban agglomerations and have a quick access to regional and long-distance. The second condition to fulfil requirement for logistics centre is its access to at least two transport modes (*Europlatforms*, *2019*), in particular to road and rail (intermodal terminal). Logistics centres or logistics facilities can be distinguished into different types that require land depending on the category and objective of the facility, which can be a warehouse, distribution centres (DC), truck terminal or intermodal facility (*McKinnon, 2009*). As logistics facilities represent a pivotal component of the overall logistics network, urban planners need to carefully assess the merits and limitations of land use allocation related to these facilities. They affect the overall land-scape, resource use as well as the future economic and social geography of suburban areas (*Cidell, 2011*). *Lindsey et al.*, (*2014*) indicated that for public stakeholders, the location of logistics facilities affect regional truck traffic patterns and influence the well-being of individuals in local communities by contributing to several issues such as noise, air quality, safety and congestion. *Visser & Francke* (2018) found that the total number of square meters occupied by logistics centres has multiplied by two and half over the past twenty years in the Netherlands. It is evident that particular attention should be given to this progress of land use (land take) especially when the land is primarily devoted to the agricultural purposes or even it is wild nature. *Aljohani &Thomson* (*2016*) presented a summary of the empirical findings illustrating the additional distance trucks travel due to logistics sprawl in several European and North American cities. Furthermore, the paper (*Aljohani &Thomson*, *2016*) provides an overview of the measures and policies implemented in various metropolitan areas to reintegrate small-scale logistics facilities within inner urban areas to act as consolidation centres. They focused on the taxonomy of impacts of logistics sprawl and listed these main impact groups i.e. impacts on urban freight geography, contribution of logistics sprawl to increased distance travelled by trucks, contribution of logistics sprawl to negative environmental impacts and impacts on commuting of logistics employment (*Aljohani & Thomson, 2016*). As the main environmental negative impacts are taken into account the increase of

greenhouse gas emissions and pollutions as well as increasing fuel consumption and unsustainable nature of urban logistics as a result of the additional congestion (*Dablanc and Ross* (*2012*) and *Wygonik et al.* (*2014*) *in Aljohani & Thomson, 2016*). *Aljohani & Thomson* (2016) concluded that impact of logistics sprawl is significantly understudied as much of the prior research has been descriptive in nature while failing to quantity the actual negative environmental impacts.
Remote sensed data, generally from satellites or unmanned aerial systems, can provide accurate and timely geospatial information of urban and peri-urban areas. These data can have various spectral, spatial or temporal resolution (*Taubenböck et al., 2012*). Currently, the most used satellite systems became Landsat with medium spatial resolution (30 m) and Sentinel 2 from European Space Agency Copernicus Programme with 10 m spatial resolution for visible and near-infrared part of electromagnetic spectra. In contrary to relatively new Copernicus programme Landsat images have a regularly sampled historical archive of 40 years (*Ghosh et al., 2014*). Land cover classification seems to be as one of the most studied topics in remote sensing, especially for agricultural, forest or land changes purposes (*Zhu & Woodcock, 2014*). Currently, many advanced tools as classification workflows allow this process make relatively easy. Nevertheless, it is not easy to make it accurate. Higher classification accuracy is usually achieved using different land cover product (*Friedl et al., 2010*).
The main aim of this paper is to describe the increase of quantity of Prague's logistics sprawl during the last 5 years, with the support of supervised classification of satellite images (downloaded for selected areas in the year 2013 and 2018). This result of the main aim will be compared with the supporting information from the cadastre of the Czech Republic to determine and prove the accuracy of input satellite images (from Landsat 8 and Sentinel 2).

MATERIALS AND METHODS

The eight logistics areas were selected to be the aim of conducted survey. Five of them are located in the district Prague-East and three in the district Prague-West. All these surveyed areas are located alongside of highways and one of them near the road of the first class (see Table 1); where large amounts of logistics centres have been constructed up to now and continue to be constructed.
Landsat 8 Operational Land Imager (OLI) images from 15.5.2013 and 13.5.2018 were down-loaded from Geological Survey of U.S. (USGS) (https://earthexplorer.usgs.gov/) in Level 1 – Top of Atmosphere reflectance format. The images were converted to Level 2 Bottom of Atmosphere reflectance format with the help of atmospheric correction module ENVI 5.5 SW. Sentinel 2B Multispectral Instrument (MSI) from 14.5.2018 was downloaded from Copernicus Open Access Hub (https://scihub.copernicus.eu/) in L2A format which equals the Bottom of Atmosphere reflectance. Preprocessing of Sentinel 2 image consisted of individual band resampling to the same spatial resolution. In the case of this image it was 10 m. The surveyed areas were cut and classified into five categories supported of supervised classification tool (ENVI 5.5 software made by Excelis, Inc., McLean, USA). Basic four categories as "arable land", "forest land", "built-up area", and "water area" were selected for better landscape type differentiation. The fifths category was "logistics centres". Result of supervised classification workflow were raster data formats of surveyed areas. Rasters were edited with the help of "Edit Classification Image" post-classification tool and then converted to vector data formats and processed by the geo-processing tool in ArcGIS 10.4.1 software (ESRI, Redlands, CA, USA). The areas were obtained in square metres. Next processing was based on statistical comparison of L8 images from 2013 and 2018 and then L8 from 2013 and S2 from 2018 (S2 images have been available since 2016). The results derived from satellite images were then verified by actual information from the cadastre of the Czech Republic (https://nahlizenidokn.cuzk.cz/, 28.3.2019). It was calculated only for the areas III. and VII., where the highest increase of logistics centres square was monitored.

RESULTS AND DISCUSSION

Overview of surveyed areas, its location and areas derived from satellite images and the cadastre of the Czech Republic is presented in Table 1. The increase of logistics centres square in surveyed areas from 2013 to 2018 are then available in Table 2. Surveyed areas based on Landsat 8 images supervised classification in 2013 was visualized in Fig. 1. Visualization of surveyed areas based on Sentinel 2 images supervised classification in 2018 in Fig. 2.

Tab. 1 Overview of surveyed areas, its location and areas derived from satellite images Landsat 8 (L8) and Sentinel 2 (S2) in 2013 and 2018 and the cadastre of the Czech Republic (CR) in 2019.

Designation of areas	Designation of highways	2013 L8 [$m^2.10^4$]	2018 L8 [$m^2.10^4$]	2018 S2 [$m^2.10^4$]	Cadastre of the CR [$m^2.10^4$] 2019
I. Zdiby, Klecany	D8	44.7	56.1	80.9	-
II. Zápy, Brandýs nad Labem	D10	62.7	102.5	116.2	-
III. Šestajovice, Mochov	D11	114.8	217.7	233.2	221.8
IV. Průhonice, Čestlice	D1	202.0	323.9	307.1	-
V. Mirošovice, Pyšely	I/3	4.1	18.1	21.3	-
VI. Středokluky	D7	42.7	113.3	82.6	-
VII. Hostivice, Jeneč	D6	57.0	109	108.1	100.1
VIII. Rudná	D5	74	85.9	82.9	-
Total square – Praha-East		428.3	718.4	758.7	-
Total square – Praha-West		173.6	308.2	273.5	-
Total		602.0	1026.6	1032.2	-

Tab. 2 Increase of logistics centres in surveyed areas derived from Landsat 8 images (L8 /L8 – 2013 vs. 2018) and L8 and Sentinel 2 images (L8 / S2 – 2013 vs. 2018) and its relative expression.

Designation of areas	Increase of LC [$m^2.10^4$] Landsat 8	Increase of LC [$m^2.10^4$] Sentinel 2	Increase in % Landsat 8	Increase in % Sentinel 2
I. Zdiby, Klecany	11.3	36.1	4	11
II. Zápy, Brandýs nad Labem	39.9	53.5	14	16
III. Šestajovice, Mochov	102.9	118.3	35	36
IV. Průhonice, Čestlice	121.9	105.1	42	32
V. Mirošovice, Pyšely	14.0	17.2	5	5
VI. Středokluky	70.7	39.9	52	40
VII. Hostivice, Jeneč	52.0	51.1	39	51
VIII. Rudná	12.0	8.9	9	9
Total square – Praha-East	290.0	330.4	100	100
Total square – Praha-West	134.6	99.9	100	100
Total	424.6	430.3	-	-

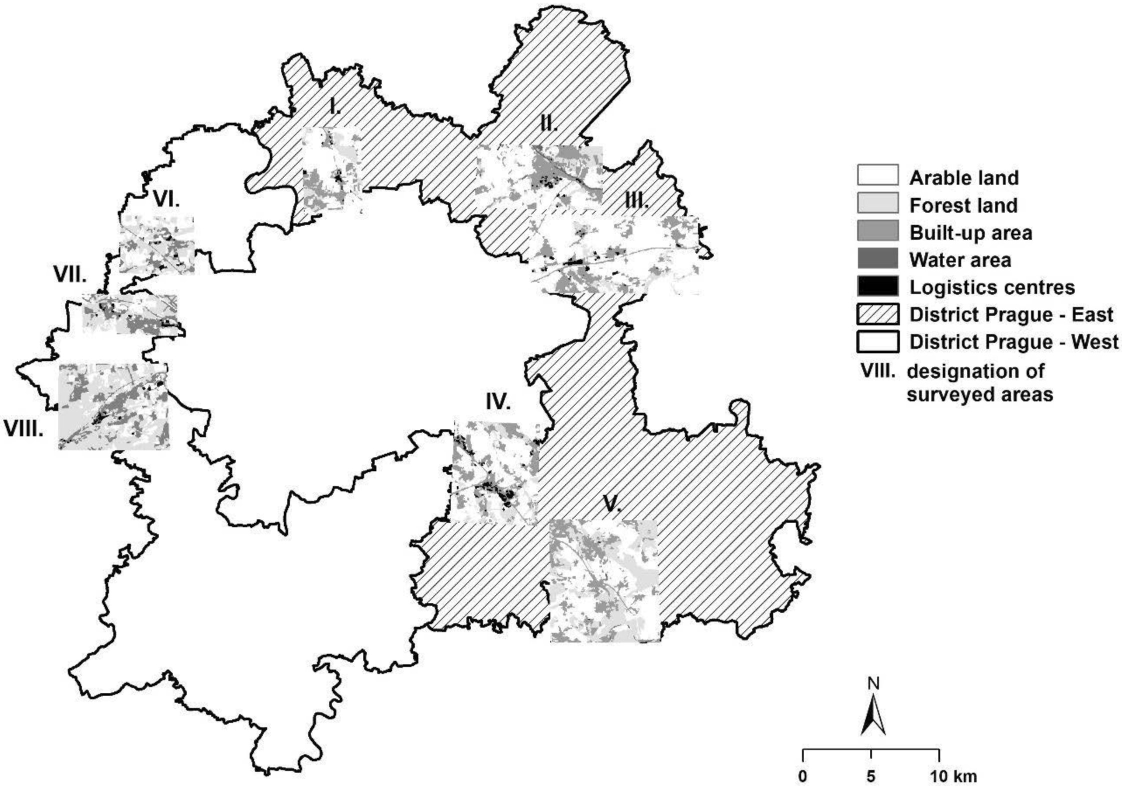

Fig. 1 Surveyed areas based on Landsat 8 images supervised classification in the year 2013.

The highest increase of logistics centres square was detected in the areas: VI. (Středokluky) and VII. (Hostivice, Jeneč) in Prague – West district, and then in areas III. (Šestajovice, Mochov) and IV. (Průhonice, Čestlice) in Prague – East district. On the contrary the lowest increase was found in areas: V. (Mirošovice, Pyšely in Prague – West district) and VIII. (Rudná in Prague – West district) (see Table 1, 2 and Fig. 1, 2).

The results showed that the built-up square of logistics centres differs on the base of satellite images used for this comparison. The satellite images (S2 and L8) used in this study had medium spatial resolution of 10 and 30 m per pixel. This spatial resolution seems to be sufficient and in many case standard for land cover classification and change detection and can provide consistent and repeatable measurements at an appropriate spatial scale (*Verbesselt et al., 2010; Wulder et al., 2008*). Nevertheless, the obtained results found out that the spatial resolution of L8 images were too coarse for the detection of smaller buildings. The calculation carried out in the cadastre of the Czech Republic for areas III. and VII. showed that the better spatial resolution of Sentinel 2 image can exacerbate the image classification for the right object detection. The advantage of using these satellite systems seems to be revisit period (8 days with multiple Landsat sensors in orbit, and 3 days for Sentinel 2) and wide spatial coverage (185 km for Landsat and 290 km for Sentinel 2 field of view). The availability of many images increase the chance of cloud-free data (*Gómez et al. 2016*). That is why it was possible to find two images from different source for almost the same date (13.5. 2013 and 15.5.2018) for this study. Supervised classification with subjectively setting of the classes enables to enhance possibilities how to identify land cover types one by one (*Chen et al. 2014*). This should minimize effects of spectral confusion among land cover classes as in our study. However, the areas surveyed in this study were selected with the aim to identify the logistics centres only on the base of spectral characteristics of detected land cover. Sometimes it can be very difficult to differ the land cover as iron roof and bare soil or concrete surface. In this case should help collection of training samples due the supervised classification workflow. Accuracy of those classification increase by using of many accurate inputs for example from cadastre information, land use / land cover application. This statement is in accordance with *Gómez et al.,* (2016) who recommend supervised classification, machine learning or ensemble algorithms for more accurate and efficient classification.

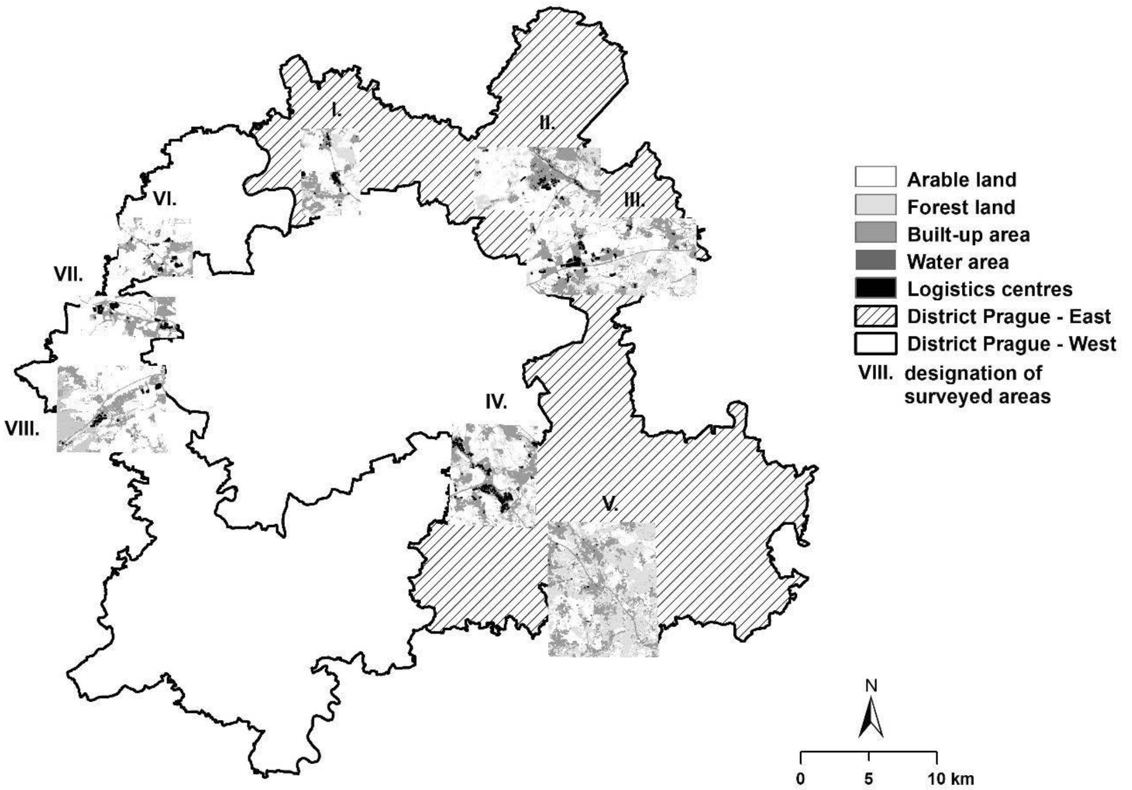

Fig. 2 Surveyed areas based on Sentinel 2 image supervised classification in 2018.

The Fig. 2 showed that the logistics sprawl in the Prague´s suburban areas is at the expense of agricultural land. This fact can exacerbate the quality of life how it is described in the study of *Patino & Duque* (*2013*). Remote sensing can be one of very powerful and efficient tool for the evaluating of life quality together with information from situ. The challenge for the further work, focused on this topic, can derive other various indices describing social and economic dimensions and the environmental aspects of the suburban areas.

CONCLUSIONS

This paper found out and proved that the satellite remote sensing is powerful and efficient tool to detect and evaluate changes within suburban and urban areas. The carried out research illustrates that freely accessible satellite images from Landsat 8 and Sentinel 2 (with medium spatial resolution), can provide sufficiently precise information about logistics sprawl and they can be used for its quantitative evaluation. The eight logistics areas alongside of highways were surveyed in the districts Prague-East and Prague-West. The satellite images from the year 2013 and 2018 were analysed with the aim to get an evidence of the logistics centres sprawl. These procedures were carried out with the support of supervised classification of satellite images and they were compared with information from the cadastre of the Czech Republic. The highest increase of build-up square of logistics centres was determined in the areas “Středokluky” and “Hostivice, Jeneč” in district Prague-West and then in areas “Šestajovice, Mochov” and “Průhonice, Čestlice” in district Prague-East. The build-up square of logistics centres enlarged about 300.10^4 (m^2) in district Prague – East and 100 $.10^4$ (m^2) in district Prague-West from the year 2013 to 2018. This total “land take” place at the expense of high quality agricultural land. This fact points out to a low agricultural land preservation that should be paid more attention.

REFERENCES

1. Aljohani, K. & Thompson, R.G. (2016). Impacts of logistics sprawl on the urban environment and logistics: Taxonomy and review of literature. *Journal of Transport Geography, 57*, 255–263.
2. Chen, J., Chen, J., Liao, A., Cao, X., Chen, L., Chen, X., He, Ch., Han, G., Peng, Sh., Lu, M., Zhang, W., Tong, X., & Mills, J. (2015). Global land cover mapping at 30 m resolution: a POK-based operational approach. *ISPRS J. Photogramm. Remote Sens., 103*, 7-27.
3. Cidell, J. (2011). Distribution centres among the rooftops: the global logistics network meets the suburban spatial imaginary. *Int. J. Urban Reg. Res. 35 (4),* 832–851.
4. ČUZK Nahlížení do katastru nemovitostí (cadaster of the Czech Republic). Retrieved from https://nahlizenidokn.cuzk.cz/
5. Friedl, M.A., Menashe, D. S., Tan, B., Schneider, A., Ramankutty, N., Sibley, A., et al. (2010). MODIS collection 5 global land cover: Algorithm refinements and characterization of new datasets. *Remote Sensing of Environment, 114*, 168–182.
6. EUROPLATFORMS. The European Logistics Platforms Association. Retrieved from http://www.europlatforms.eu/?page_id=150
7. Ghosh, A., Sharma, R., & Joshi, P.K. (2014). Random forest classification of urban landscape using Landsat archive and ancillary data: Combining seasonal maps with decision level fusion. *Applied Geography, 48*, 31-41.
8. Gómez, C., White, J.C., & Wulder, M.A., (2016). Optical remotely sensed series data for land cover classification: A review. *ISPRS J. Photogramm. Remote Sens., 116*, 55-72.
9. Lindsey, C., Mahmassani, H.S., Mullarkey, M., Nash, T., & Rothberg, S. (2014). Industrial space demand and freight transportation activity: exploring the connection. *J. Transp. Geogr. 37,* 93–10.
10. McKinnon, A. (2009). The present and future land requirements of logistical activities. *Land Use Policy, 26,* 293–301.
11. Patino, J.E. & Duque, J.C. (2013). A review of regional science applications of satellite remote sensing in urban settings. *Computers, Environment and Urban Systems, 37*, 1-17.
12. Taubenböck, H., Esch, T., Felbier, A., Wiesner, M., Roth, A., & Dech, S. (2012). Monitoring urbanization in mega cities from space. *Remote sensing of Environment, 117,* 162-176.
13. Verbesselt, J., Hyndman, R., Zeileis, A., & Culvenor, D. (2010). Phenological change detection while accounting for abrupt and gradual trends in satellite image time series. *Remote Sens. Environ., 114*, 2970–2980.
14. Visser J., & Francke J. (2018). Logistics sprawl: the spatial structure of logistics centres and hinterland container terminals. Retrieved from *https://www.researchgate.net/publication/324543132*
15. Winkler H., & Seebacher G. (2011). Management of freight villages: findings from an exploratory study in Germany. *Int J Logist Rest Appl.,14*(4), 271-283.
16. Wulder, M.A., White, J.C., Goward, S.M., Masek, J.G., Irons, J.R., Herold, M., Cohen, W.B., Loveland, T.R., & Woodcock, C.E. (2008). Landsat continuity: issues and opportunities for land cover monitoring. *Remote Sensing of Environment, 112*, 955–969.
17. Zhu, Z., & Woodcock, C.E. (2014). Continuous change detection and classification of land cover using all available Landsat data. *Remote Sensing of Environment, 144*, 152-171.

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