An Assessment of Urban Area Extraction Using ALOS-2 Data

Saygin Abdikan
Dept. of Geomatics Engineering
Zonguldak Bulent Ecevit University
Zonguldak, Turkey
sabdikan@beun.edu.tr

Caglar Bayik
Dept. of Geomatics Engineering
Zonguldak Bulent Ecevit University
Zonguldak, Turkey
caglarbayik@beun.edu.tr

Mustafa Ustuner
Dept. of Geomatic Engineering
Yildiz Technical University
Istanbul, Turkey
mustuner@yildiz.edu.tr

Fusun Balik Sanli
Dept. of Geomatic Engineering
Yildiz Technical University
Istanbul, Turkey
fbalik@yildiz.edu.tr

***Abstract*— Urbanization has a dynamic structure especially in megacities and therefore rapid detection of the urban is vital for sustainable management of the city. In this work, we apply a multi-source feature data approach to investigate the urban area of Istanbul, Turkey which is a megacity with an approximate 15 million inhabitant, and under strong both anthropogenic and natural pressures. In order to analyse and compare the spatial pattern of the urban footprint, different techniques are applied. Speckle divergence, backscatter and repeat pass interferometric coherence values are considered for the analysis. To this aim, L-band HH and HV polarized ALOS-2 Synthetic Aperture Radar (SAR) data were acquired from Japan Space Exploration Agency's (JAXA). Pixel based Random Forest Classification method was used for the urban mapping. During the classification, different scenarios have been applied using speckle divergence, backscatter and coherence information. Overall, user and producer accuracies were calculated from the error matrix. While comparing HH and HV polarimetry, in each scenario HH provided much higher accuracies than HV results. Speckle divergence and backscatter values yielded similar accuracies which is around 88% for urban class. However, coherence gave approximately 69% while it is classified individually. The contribution of coherence was extracted while coherence was stacked with speckle divergence, and the result was improved to 91%. The urban areas was extracted with a maximum accuracy of maximum 93% while all information was combined. The preliminary results allow us to obtain a comprehensive image of urban structure, and indicate that the results may reference address for further analysis of multi-temporal SAR data over large and complicated mega cities.**

Keywords*— *ALOS-2, urban, coherence, polarimetry, classification

I. Introduction

In the last decades, urbans are changing rapidly and most of the mega-cities which host more than ten million people are changing more dynamically. It is difficult to control the expansion of the urban areas due to their unbalanced urbanization. Nowadays, there are less people live in rural areas and 55% of the world's population live in urban areas. This amount was 30% in 1950 and expected to be 68% in 2050 [1]. Urbanization also has impact on other structures such as built-up areas, infrastructure of transport, and construction of industry which play an important role on environment [2]. It may trigger risky areas where earthquakes, fire, flooding or landslides have high impact.

As a proven technology remote sensing support to better analyze urban monitoring. Accurate and multi-temporal analysis of urbanization pattern can be provided by satellite remote sensing. This information can be used to extract spatial distribution and rate of urbanization growth [2].

Synthetic Aperture Radar (SAR) uses microwave wavelengths and has the capacity of sun independent imaging which makes it advantages over optical sensors. SAR satellites have been under investigation for urban extraction in different studies. Mainly three categorize as follows radar backscatter, texture and fusion of SAR and other data source are considered for the extraction of urban areas [3]. [4] applied speckle divergence and then grey-level co-occurrence on Sentinel-1 data. K-means classification was used to extract urban boundaries which was compared with Sentinel-2 data. It is concluded that among the texture parameters mean and homogeneity considered most effective textures. [5] used Sentinel-1 data to detect built-up area applying coherence, speckle divergence and difference between the local mean and local median (MM). The results indicated that VV polarization yielded higher accuracies than for the VH polarization. Combination of polarization and, ascending and descending orbits provided higher accuracies. All methods provided higher accuracies while MM gave slight higher accuracies. [3] calculated different texture measures and applied principal component analysis to reduce features. The result is combined with inhomogeneity parameter to extract urban regions in TerraSAR-X data. Coherence image is also used for the identification of urban areas. It shows the similarity level between two SAR images [6]. Coherence image of Advanced Land Observing Satellite-2 (ALOS-2) Phased Array type L-band Synthetic Aperture Radar-2 (PALSAR-2) was used for the change detection analysis after earthquake [6]. However, accuracy was calculated 35%. As noted here, different information as input and different extraction approaches have been introduced. In this study we used ALOS-2 data acquired over Istanbul, Turkey for the investigation due to its rapid industrialization and rapid increase in population. It suffered from both natural and man-induced activities such as earthquake [7,8], geological structure and human activities [9]. [10] extracted most current distribution of landslide using Sentinel-1 and ALOS-2 time series data. The urban area is under risk and accurate urban areas needs to be monitored continuously for the management and planning activities.

This study discusses the evaluation of ALOS-2 imagery for urban extraction comparing different urban mapping approaches which are applied on dual polarimetric SAR imagery.

II. Methodology

A. Data and Pre-processing

In the study, two date L-band HH and HV polarized ALOS-2 Synthetic Aperture Radar (SAR) data were acquired during in September 30 and in October 14 of 2018. ALOS-2 images were acquired in ascending orbit direction, Strip Map mode Level-1 Single Look Complex product which contains phase and amplitude information (Table I). In the pre-processing images, both phase and amplitude information were incorporated. Pre-processing steps including radiometric calibration, multi-looking, topographic correction data and co-registration were performed with open source tools of Sentinel Application Platform (SNAP) software. A multi-look of two at the range and four at azimuth was applied to obtain speckle-filtered and smoothed image for further analysis. The final product has a 15 meter spatial resolution. As a final step of the pre-processing chain, pixel digital numbers were converted to sigma nought in decibel (dB).

TABLE I. Specifications of ALOS-2 data

Specifications	Descriptions
Satellite/Sensor	ALOS-2/PALSAR-2
Wavelength	L-band (24 cm)
Acquisition mode	Strip Map
Data product	FBDR 1.1 SLC
Orbit	Ascending
Off Nadir angle	32.5
Pixel space	4.29 (R) x 3.96 (A)
Polarization	HH + HV

B. Coherence

The quality of the interferometric phase varies according to the type and amount of noise from different sources. This quality can generally be determined by the value known as "coherence". Coherence is an important concept for SAR imaging systems. Coherence ("γ") is defined as the cross-correlation coefficient between two co-registered complex images z_1 and z_2 in Eq. (1) [11]:

$$\frac{\left|\sum_{i=1}^{L} z_{1i}\, z_{2i}^{*}\right|}{\sqrt{\sum_{i=1}^{L}|z_{1i}|^2 \ \sum_{i=1}^{L}|z_{2i}|^2}} \qquad (1)$$

With this formula, the mean of adjacent pixels in an area is obtained. "*" represents the complex conjugate and is average of total number of azimuth and range pixels. It ranges from 0 (no correlation) to 1.0 (a perfect correlation). Evaluation of all correlation sources requires the determination of geophysical properties of the surface and understanding of the sensor effects. It is expected have high correlation at urban areas.

C. Speckle Divergence

Speckle Divergence (SD) approach based on local statistics, it detects the dissimilarity between local image heterogeneity and the theoretical scene-specific heterogeneity of the speckle [12]. It provides a texture file and aims to preserve small scale structure in urban area while removing noise. In the image high values indicate urban area and low values open and water space.

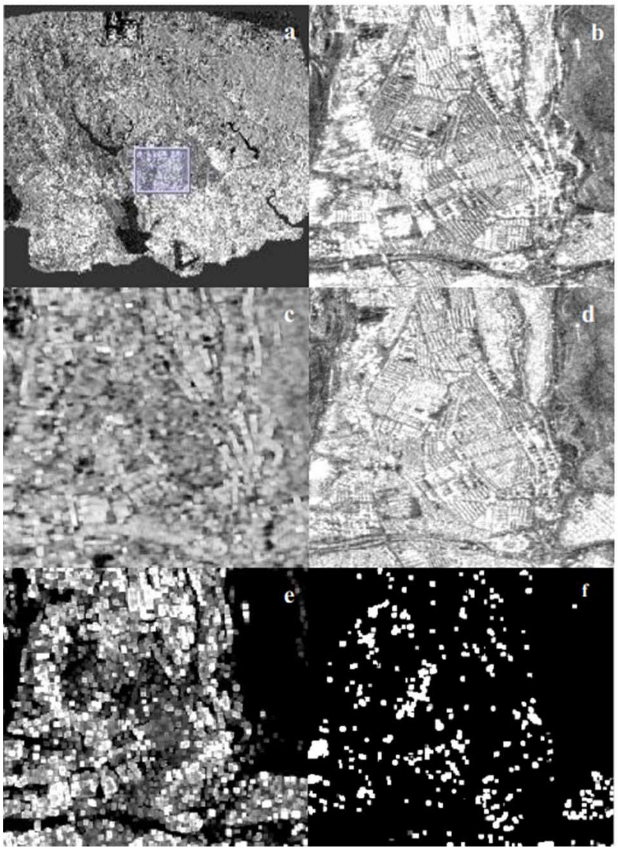

Fig. 1. a) Study area and the subset, b) HH polarized backscatter, c) HH-Coherence, d) HV polarized backscatter, e) SD of HH image, f) SD of HV image.

Fig. 1 shows some of the input images used in the classification. As noticed HH and HV channels provide different backscatter information due to the scattering of target to the polarized wavelength. Some buildings give stronger backscatter to HV polarization, however for the same region HH gives lower backscatter (Fig. 1b and 1d). The SD results of the SAR images also provide different results in different polarization (Fig 1e and 1f).

D. Classification

Considering single image processing, SAR sensors have disadvantage over optical sensors due to not providing spectral information [13]. In remote sensing, classification of land cover is most common way to extract information from the images. A wealth of different classification approaches have been developed and tested such as maximum likelihood, minimum distance, support vector machine and neural network [14]

In this study, pixel based Random Forest (RF) was chosen for the urban mapping due to obtaining high accuracy and low computational cost. RF which is an ensemble based classifier uses the subset of training samples to assign pixels into a class by applying the majority voting rule [15]

Speckle divergence, backscatter and coherence information were combined in different scenarios for the urban mapping. In the first step, SD, backscatter and coherence data were classified individually. Here SD and backscatter data are combination of two dated data. Later, contribution of coherence information to speckle divergence and backscatter were tested. Finally, all information was combined and the urban/non-urban map was analyzed. A set of region of interest were selected for both urban and non-urban areas. To evaluate the results accuracy assessment was conducted using a set of 300 randomly distributed points over the study area.

E. *Study Area*

Land use/cover structure of Istanbul changes very rapidly due to drastic increase of population and urbanization. It has a strategic location which has borders in both Asian and European continents (Fig. 2). As a mega-city Istanbul has more than ca. 15 million inhabitant which demands new infrastructures and settlements. Urbanization is mostly located at the south coastline while forest covers the northern part and agriculture is located on inlands.

Fig. 2. Study area (Green frame shows the cover of ALOS-2 data and red frame shows the study area)

III. Results and Discussion

In this experiment, classification accuracies are calculated for each of the 12 classified images including backscatter, SD and coherence calculated from two SAR images using both HH and HV polarimetric data (Table II and III).

In general, accuracies are higher in the results of HH images than HV polarized images. SD and backscatter values of HH images yielded same results but coherence value is lower than these results.

TABLE II. Accuracy values for HH images

HH				
	Overall Acc.	***User Acc.***	***Prod Acc.***	***Kappa***
SD (t1&t2)	88	88	88	0.76
Coh (t1&t2)	72	73.57	68.67	0.44
dB	88	88	88	0,76
SD+Coh	87.67	85.53	90.67	0.75
dB+Coh	87	87.25	86.67	0.74
dB+Coh+SD	87	83.23	92.67	0.74

However, in the results of HV SD classification is unsuccessful as also noticed in the figures 3. In HH images, coherence did not contribute to the accuracy except it increased the producer accuracy of SD + Coh combination. In the results of including all images improvement is higher than the rest and the producer accuracy reached up to 92.67% and 0.76 kappa statistics. In HV images coherence has contribution to SD but could not add improvement to backscatter values. The backscatter of HV image achieved 94% accuracy however, the kappa value is quite low which does not show a reliable result. Combination of all HV images also could not provide higher accuracy comparing to HH images.

TABLE III. Accuracy values for HV images

HV				
	Overall Acc.	***User Acc.***	***Prod Acc.***	***Kappa***
SD (t1&t2)	0	0	0	0
Coh (t1&t2)	50	50	46	0
dB	69.67	63.23	94	0.39
SD+Coh	53	52.54	62	0
dB+Coh	68.67	62.84	91.33	0.37
dB+Coh+SD	66	60.43	92.67	0.32

In Fig. 3a the complex building structure have different directions and sizes. In the image there is also vegetated area which is located at the right of the image. The results of HH polarized backscatter showed that main urban footprint is extracted, meanwhile some part of the array buildings can also be recognized (Fig. 3b). However, it is not clearly visible in HV polarized images comparing to HH image (Fig. 3d). As noticed in SD of HH image and, Coherence added SD of HH image indicates similar results (Fig. 3c and 3e). Coherence did not provided high results where vegetated area also gave high coherence due to short temporal baseline (Fig. 3f). Incorporation of coherence information to backscatter value also resulted in similar values (Fig. 3g). The highest producer accuracy was achieved with including all images and the resulted image provides better extraction of urban area (Fig. 3h).

The results of the experimental study indicated that coherence image provides valuable information to extract urban area, however, it may also include high correlated non-urban regions. In the results also hilly regions turn out bright pixel values which cause to be extracted as urban due to geometry of SAR

IV. CONCLUSION AND FUTURE PERSPECTIVES

The study area Istanbul which has the most important role for the economic activities of Turkey is also one of the most populated city in Europe. Many mega-cities suffer from unplanned urbanization which cause unsustainable management of the city. This complex cities need to be monitored and rapid mapping to mitigate risks in any emergency situation. In the context of such conditions, this work investigate to explore the extraction of urban areas. To this aim, we used ALOS-2 data which was acquired in two date. Three approaches were applied and compared for the urban extraction. The results yielded high accuracies using backscatter, coherence and speckle divergence information of SAR data.

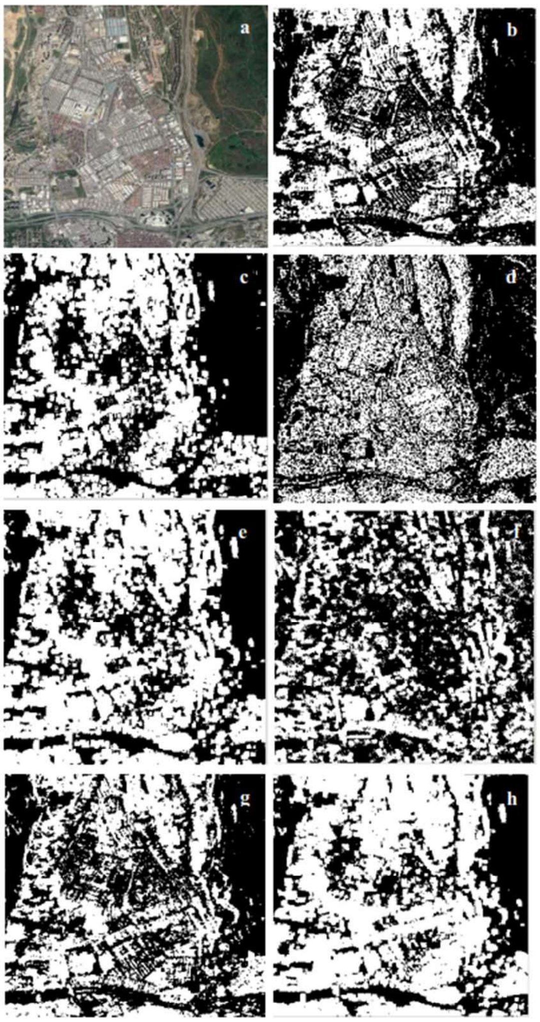

Fig. 3. a) Selected region on Google Earth, classified images of b) HH polarized backscatter, c) SD of HH image, d) HV polarized backscatter, e) Coherence and SD of HH image, f) Coherence of HH image, g) Coherence and backscatter of HH image, h) HH images of backscatter. White and black colour shows the urban and non-urban classes, respectively.

As a further study, we will analyze Gray-Level Co-Occurrence Matrix as texture information, and polarimetric parameters to improve the results by applying object-based classification. Sentinel-1 data will be also analyzed and multi-frequency analysis of L-band and C-band will be tested.

ACKNOWLEDGMENT

The ALOS-2 data were provided by JAXA in the framework of the research project no 3210

REFERENCES

[1] WUP 2018 Report, World Urbanization Prospects: The 2018 Revision, 2018

[2] Seifert, F. M. "Improving Urban Monitoring toward a European Urban Atlas.-Gamba, P. & Herold, M.(Eds.): Global Mapping of Human Settlements: Experiences, Data Sets, and Prospects." (2009): 231-249.

[3] Aghababaee, H., Niazmardi, S., and Amini, J.: 'URBAN AREA EXTRACTION IN SAR DATA', Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., 2013, XL-1/W3, pp. 1-5.

[4] C. D. Storie, "Urban Boundary Mapping Using Sentinel-1A SAR Data," in IGARSS 2018-2018 IEEE International Geoscience and Remote Sensing Symposium, 2018: IEEE, pp. 2960-2963.

[5] K. Koppel, K. Zalite, A. Sisas, K. Voormansik, J. Praks, and M. Noorma, "Sentinel-1 for urban area monitoring—Analysing local-area statistics and interferometric coherence methods for buildings' detection," in 2015 IEEE International Geoscience and Remote Sensing Symposium (IGARSS), 2015: IEEE, pp. 1175-1178.

[6] M. Watanabe et al., "Detection of damaged urban areas using interferometric SAR coherence change with PALSAR-2," Earth, Planets and Space, vol. 68, no. 1, p. 131, 2016.

[7] T. Walter et al., "Geohazard supersite: InSAR monitoring at Istanbul city," EOS Trans, vol. 91, pp. 313-324, 2010..

[8] A. C. Zülfikar, N. Ö. Z. Fercan, S. Tunç, and M. Erdik, "Real-time earthquake shake, damage, and loss mapping for Istanbul metropolitan area," Earth, Planets and Space, vol. 69, no. 1, p. 9, 2017.

[9] F. Calò, S. Abdikan, T. Görüm, A. Pepe, H. Kiliç, and F. Balik Şanli, "The space-borne SBAS-DInSAR technique as a supporting tool for sustainable urban policies: The case of Istanbul Megacity, Turkey," Remote Sensing, vol. 7, no. 12, pp. 16519-16536, 2015.

[10] C. Bayik, "Investigation of the Landslides with Multi-Temporal and Multi-Frequency SAR-GNSS Data: Beylikdüzü-Esenyurt Example " Ph.D. Thesis, Zonguldak Bülent Ecevit Üniversitesi, Turkey, 2018.

[11] C. Prati and F. Rocca, "Improving slant-range resolution with multiple SAR surveys," IEEE Transactions on Aerospace and Electronic Systems, vol. 29, no. 1, pp. 135-143, 1993.

[12] T. Esch, M. Thiel, A. Schenk, A. Roth, A. Muller, and S. Dech, "Delineation of urban footprints from TerraSAR-X data by analyzing speckle characteristics and intensity information," IEEE Transactions on Geoscience and Remote Sensing, vol. 48, no. 2, pp. 905-916, 2010..

[13] U. Soergel, " Radar Remote Sensing of Urban Areas", Springer Netherlands, 2010.

[14] V. N. Mishra, R. Prasad, P. Kumar, D. K. Gupta, and P. K. Srivastava, "Dual-polarimetric C-band SAR data for land use/land cover classification by incorporating textural information," Environmental Earth Sciences, vol. 76, no. 1, p. 26, 2017.

[15] Z. Zhu, C. E. Woodcock, J. Rogan, and J. Kellndorfer, "Assessment of spectral, polarimetric, temporal, and spatial dimensions for urban and peri-urban land cover classification using Landsat and SAR data," Remote Sensing of Environment, vol. 117, pp. 72-82, 2012.