MAPPING KABUL'S PRIVATE URBAN GREEN SPACES USING GEOGRAPHIC INFORMATION SYSTEM-SUPERVISED CLASSIFICATION

EMAL AHMAD HUSSAINZAD*, MOHD JOHARI MOHD YUSOF AND SREETHERAN MARUTHAVEERAN

Department of Landscape Architecture, Faculty of Design and Architecture, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia
**Corresponding author e-mail: emal_ahmad2011@yahoo.com*

Received: 16th July 2019, **Accepted:** 23th December 2019

ABSTRACT

Private green spaces are considered an important part of urban greenery. However, the extent of private green spaces in an informal city like Kabul is unknown. To this end, this study has mapped out the private green spaces in the informal settlements of Kabul city. A Geographic Information System (GIS)-supervised image classification technique was used to identify these private green spaces in three of the 22 police districts (PDs) in the city. Briefly, the classification consisted of defining training samples, extraction of signature and classification of the imagery. As a result, 330.3 hectares were identified as private green spaces, which made up 12.3 % of the total area of informal settlements in these three districts. With 217.1 hectares, PD7 had the largest area of private green spaces among the three police districts, contributing to 65.7 % of the overall area of private green spaces, followed by PD8 (21.3 %) and PD16 (13 %). In future, the map generated in this study could be used to monitor, manage and conserve the existing urban greenery in the face of private green spaces. The results could also be utilised by the Kabul Municipality and other relevant departments to implement an upgrading programme in the informal settlements of Kabul city, which would lead to fulfilling the environmental needs of the residents.

Keywords: Informal settlements; pixel-based analysis; private gardens; urban domestic gardens; vegetation mapping.

INTRODUCTION

The world's population is approximately 7.6 billion presently and is predicted to reach almost 10 billion by the middle of this century (UN, 2017). Urbanisation has been one of the main factors of this vast population growth, with the number of people living in urban areas exceeding the number living in rural areas nowadays (UN, 2018). In Afghanistan, where rapid urbanisation is being witnessed, the majority of people live in informal settlements with limited access to urban facilities (Nazire & Kita, 2016).

Generally, informal settlements are defined as dwellings with no security of tenure, facing lack of basic services and infrastructures, and not built according to planning of the city (Gram-Hansen *et al*., 2019). UN-Habitat (2003) defined informal settlements as houses that are not recognized and addressed by governments as integral or equal part of cities. Informal settlements, in a neighbouring country of Afghanistan-Iran, are referred to dwellings that

have lower access to public facilities and are faced with poor household economy and high population density in the area (Irandoost *et al*., 2014). Informal settlements in Afghanistan are houses that are against the master plan and/or built on lands bought from illegal market (Gebremedhin, 2005).

The construction of informal settlements in developing countries is a distinct impact of urbanisation (Paar & Rekittke, 2011). If measures are not taken, there will be around 2 billion people living in these kinds of dwellings by 2030 (UN-Habitat, 2003). Thus, cities like Kabul, with its remarkable urban development and rapid relocation, have been experiencing large numbers of informal dwellings (Nazire *et al.*, 2016). As a result of vast urbanisation, and the resulting rise in informal settlements, infrastructure such as transport, water management and public green spaces are put under pressure and may even disappear (Pafi *et al.*, 2016). Kabul, being the capital and largest city of Afghanistan, has attracted millions of people from rural areas and the provinces who have flocked into the city and constructed informal settlements. Despite the fact that these informal settlements provide housing for more than 80 per cent of the urban population of Kabul city, they lack public facilities such as schools, clinics and public green spaces (The World Bank, 2005; Fazli, 2016). Further details about settlements in Kabul city are presented in Table 1.

Informal settlements have lower socioeconomic status and less access to urban green spaces (Lin *et al.*, 2014). Although Kabul Municipality and other relevant departments have launched projects targeting informal settlements, such as upgrading of roads and other physical development, the government has failed to provide these settlements with green space initiatives (Fig. 1).

Table 1: Statistics about formal and informal settlements of Kabul city
(Source: The World Bank, 2005)

Total	**Residential Land Use**	**Area (ha)**	**Population**	**Area (%)**	**Population (%)**	**Average Density**
	Formal	3,266	531,000	31%	18%	163
	Informal	7,156	2,442,000	69%	82%	341
	Total Residential areas	10,422	2,973,000	100%	100%	285
Of which						
Formal	Apartments	180	91,000	1.7%	3.1%	505
	Townhouses	17	5,000	0.2%	0.2%	293
	Detached houses	3,069	435,000	29.5%	14.6%	142
Informal	Detached houses	333	88.000	3.2%	3.0%	264
	Courtyard houses	5,796	1,980,000	55.6%	66.6%	342
	Houses on slopes	1,026	375,000	9.8%	12.6%	365

Fig. 1: Informal settlements and the one-dimensional or physical upgrading interventions. (Source: Nazire *et al*., 2016)

The lack of interest from the government, an absence of useful information and competition for space in informal settlements are the reasons why environmental projects have not been conducted so far (Nazire *et al.*, 2016). Interestingly, the majority of the users of the few public green spaces available in the formal areas of Kabul city are men; women are faced with security, social and cultural restrictions in accessing them (Telesetsky, 1998; Alvi, 2011; d'Cruz *et al.*, 2014; Diyarbakirlioglu & Yigit, 2017).

With the increase in urban population, thousands of people die every year because of air pollution and high summer temperatures around the world. To mitigate these effects, urban green spaces are considered to be the most effective and sustainable sources for cleaning and cooling the air (Zupancic *et al.*, 2015). Kabul, one of the most polluted cities in the world (AirVisual, 2018) and where conditions are deemed to be very unhealthy, does not have the full benefit of these mitigating effects. There are few public green spaces within the city and none in its informal areas, with only private urban green spaces available for the use of the majority of city residents.

As far as the definition of the term "private green space" is concerned, it should be context-specific. In Switzerland, private green space is referred to small privately owned greenery within urban area that is adjacent to or surrounding dwellings (Lindemann-Matthies & Marty, 2013). Similar definition of private green space can be found in UK context (Gaston *et al*., 2005). In Netherlands, private green space is referred to an outdoor extension of a dwelling (Coolen & Meesters, 2012). In Australia, it is considered an urban green space that can be used by family members mostly for recreational activities (Halkett, 1978). Private green space in informal settlements of Kabul city is referred to the urban green space that is

extension of a building and is surrounded by walls of the house. It is mostly used by the family members living in the informal settlement. Relatives and friends to the family use the private green space during their visits and occasions organized in the informal settlement.

Cameron *et al.* (2012) pointed out in a study in the United Kingdom that, contingent on the age and geographical position of cities, private green spaces can comprise up to 36 % of total urban spaces. Farahani *et al.* (2018) explained, in a qualitative study conducted in Australia, that private green spaces can provide many benefits and play a major role in residents' lives. For example, private green spaces can bring pleasure, satisfaction and happiness to residents. However, the activities and facilities in private green spaces are of a different quality when compared with public green spaces. Farahani *et al.* (2018) also concluded that there are people who turn to private green spaces to compensate for the lack of public green spaces. Thus, their use of private green spaces is dependent on the availability and accessibility of public green spaces. A study by Gaston *et al.* (2005) in Sheffield in United Kingdom revealed the contribution of private green spaces to the provision of habitats for wildlife as well as their capacity to hold remarkable numbers of trees, ponds, nest boxes and compost heaps. Similarly, private green spaces are considered an integral part of dwellings because they provide casual leisure to the dwellers (Coolen & Meesters, 2012).

Although private green spaces are considered an important part of urban green spaces, the majority of cities do not have enough private green spaces in their inventories (Mishra & Bell, 2016; Baker & Smith, 2019). Hardly any research has concentrated on private green spaces in the urban milieu (Loram *et al.*, 2008; Mathieu *et al.*, 2007; Cameron *et al.*, 2012; Farahani *et al.*, 2018). Researchers have mostly focused on the human responses to public green spaces rather than private green spaces (Farahani *et al.*, 2018). The reason behind these shortcomings in regard to research is the failure of governments to manage and control private green spaces. Limitations in providing resources and inaccessibility of sites are also pointed out as challenges to conducting research on the distribution and other qualities of private green spaces (Loram *et al.*, 2007; Kendal *et al.*, 2012). Nevertheless, with the advent of high-resolution imagery and GIS technology, it is now easy to monitor and map urban green spaces, an undertaking that was costly and time-consuming not so long ago (Mohd Yusof, 2012).

Kabul has experienced the same lack of research on private green spaces and the Kabul Municipality and relevant ministries and departments have only focused on public green spaces. According to JICA (2011), approximately 750 hectares of park areas are available across Kabul city. GoIRA (2016) claimed to have mapped 123 hectares of public green areas in the city. Nonetheless, public green spaces make up only a very small proportion of the city's formal areas. It is hard to set up additional public green spaces in the city due to the high value of land, budgetary constraints, and more importantly, because of the informal and compact shape of the city. Poor management has also been considered a key factor in the deterioration and decrease of public green spaces (Darkhani *et al.*, 2019). The inequality in the distribution of public green spaces in cities is a valid reason to prioritise urban green space studies and projects (Farahani *et al.*, 2018). To date, no such studies have been conducted to map the extent of private green spaces in Kabul city. Hence, this research was aimed at mapping private green spaces in the informal settlements of the city. The study used GIS-supervised classification and high-resolution aerial imagery to identify the distribution of private green spaces.

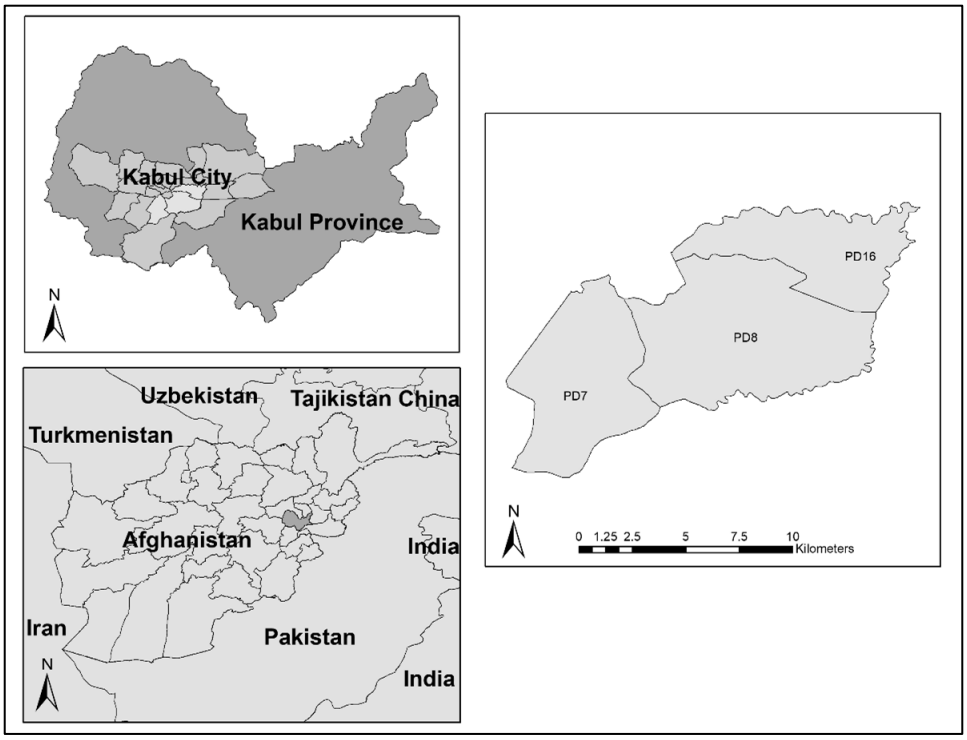
METHOD

Study area

Kabul is located in the eastern region of Afghanistan. The city experiences four seasons each year. The temperature in winter falls below 0°C and increases to around 40°C in summer (Camalan, 2007). There are 22 police districts (PDs) in the city and three police districts were selected as study area for this research (Fig. 2).

The police districts were chosen based on their characteristics, which were representative of the entire city. In all of these PDs, majority of the residents live in informal settlements. The characteristics also included the lack of public green spaces in informal area of these three PDs. Lack of women's parks in the informal area of these PDs could be a more specific characteristic resembling the entire city. The selection was also based on their reasonable security levels, allowing a smooth data collection process for future research on the relevant topics. The total area of the three PDs was 106 km^2 with PD7 covering 32.5 km^2, PD8 comprising 48.4 km^2 and PD16, 25.1 km^2. The majority of the urbanized area was occupied by informal settlements. Nearly half a million women lived in these three districts with the total population being around one million (CSO, 2017). This confirmed prior reports that revealed the almost equal ratio between men and women in Kabul city and in Afghanistan as a whole.

Fig. 2: Location of the study



Supervised classification of private green spaces

Table 2 shows the three-band high-resolution aerial imagery (0.5 m) used in this study. The orthophoto was captured in 2016 and was received from Afghanistan's Ministry of

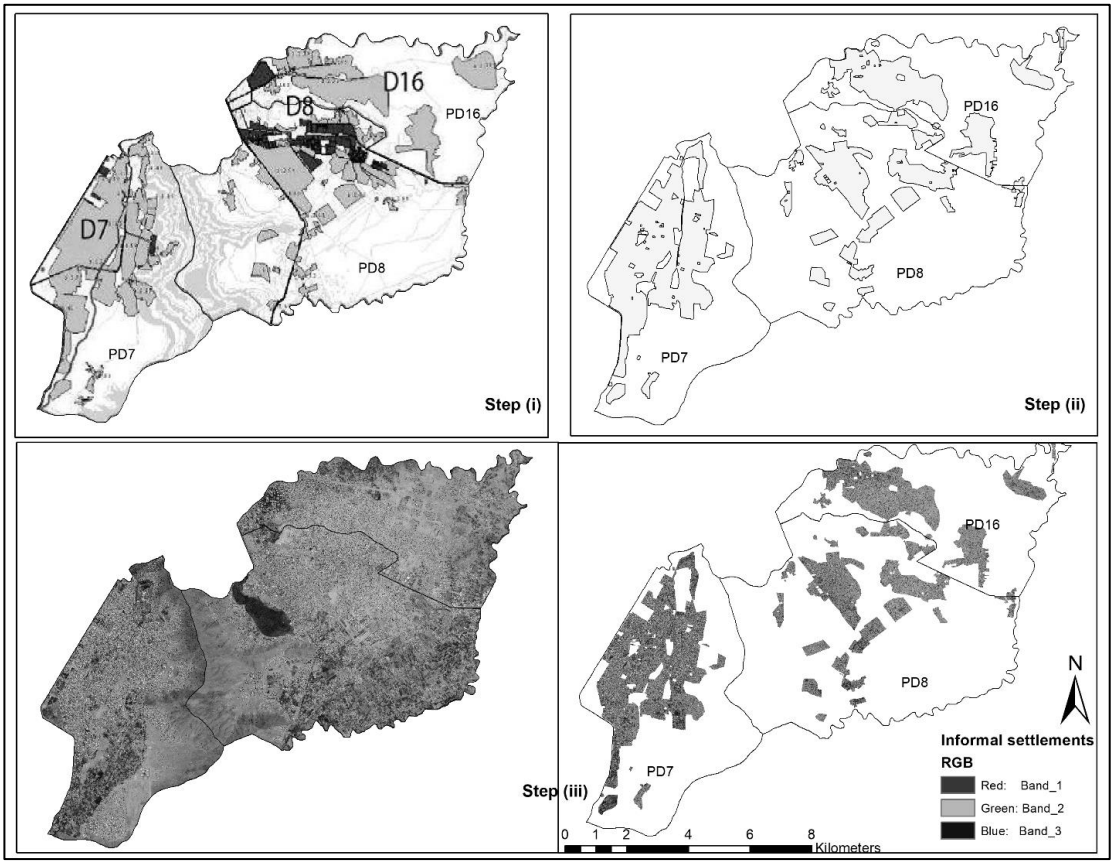
Agriculture, Irrigation and Livestock (MAIL). The entire process of mapping private green spaces was completed using ArcGIS 10.5 software. The total area of the three PDs was 10,600 hectares with 2, 687.3 hectares identified as informal settlements.

Table 2: Statistics of individual layers/bands of high-resolution aerial imagery

Layer/Band	Min	Max	Mean	STD
1/RED	1.0000	241.0000	116.5792	29.0065
2/GREEN	1.0000	253.0000	119.3274	29.5891
3/BLUE	1.0000	255.0000	116.6754	28.5434

The delimitation of the area of informal settlements was completed in three steps: (i) georeferencing the JPEG for urbanized area differentiating formal and informal settlements of the three PDs in 2007 by Ministry of Urban Development (Nazire *et al.*, 2016); (ii) converting the informal areas of the georeferenced file to vector polygons and updating them for informal settlements according to the imagery of 2016; and (iii) cropping the imagery based on the vector (Fig. 3).

Fig. 3: The delimitation of the area of informal settlements for the study



With the available type of imagery, GIS-supervised classification was used to map private green spaces in the informal settlements of these three districts. Preprocessing, post-processing and accuracy assessment were the three main stages in the classification process. The three steps in the post-processing stage were: (i) defining training samples; (ii) extraction of signature; and (iii) classification of the imagery. The maximum likelihood approach was used for supervised classification. Fig. 4 presents a reproducible flowchart of the classification. In line with the objective of this study, the imagery was categorised into two classes: (i) 'Private green spaces'; and (ii) 'Others'. A total of 76 training samples were created for private green spaces and their homogenous distribution was verified (Fig. 5).

Fig. 4: Flowchart of the supervised classification and mapping of private green spaces (PGS) in the informal settlements of Kabul city

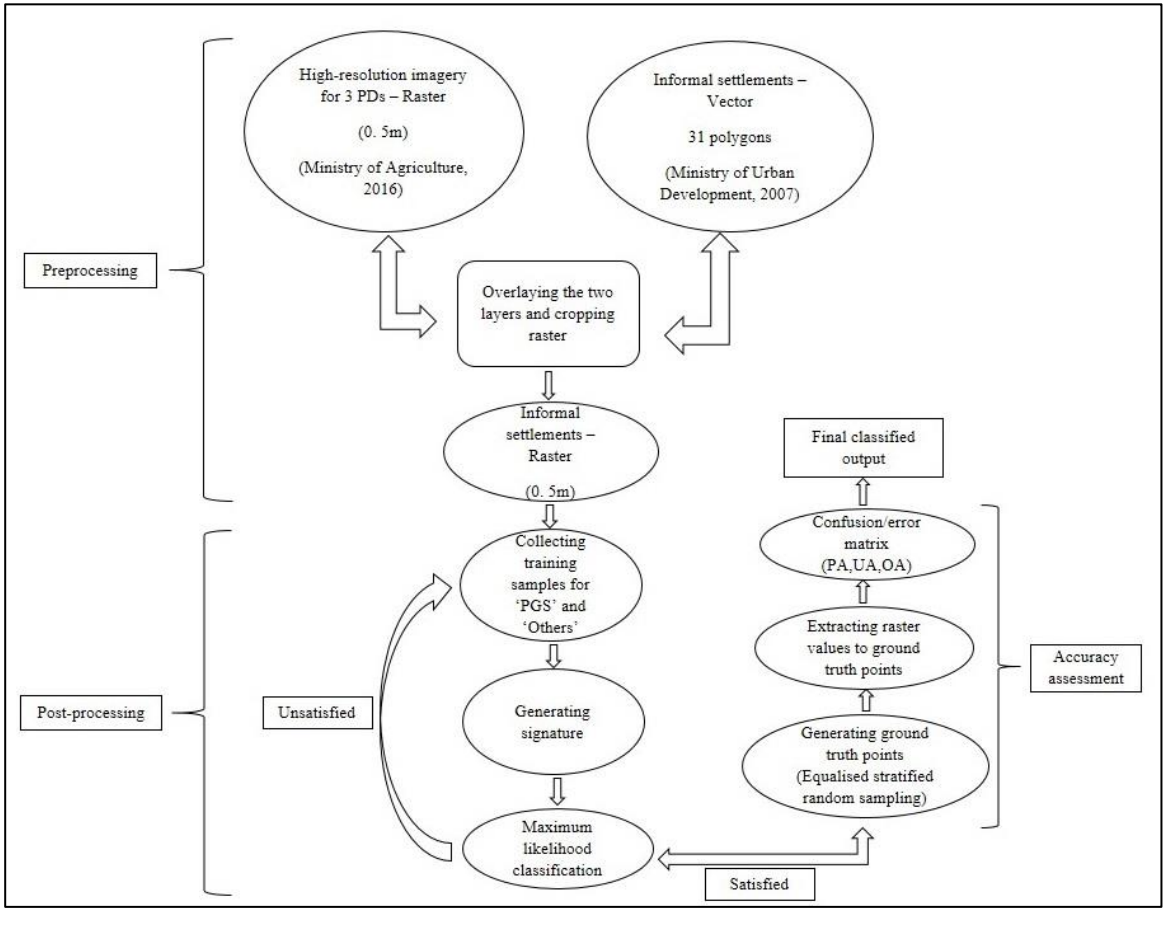
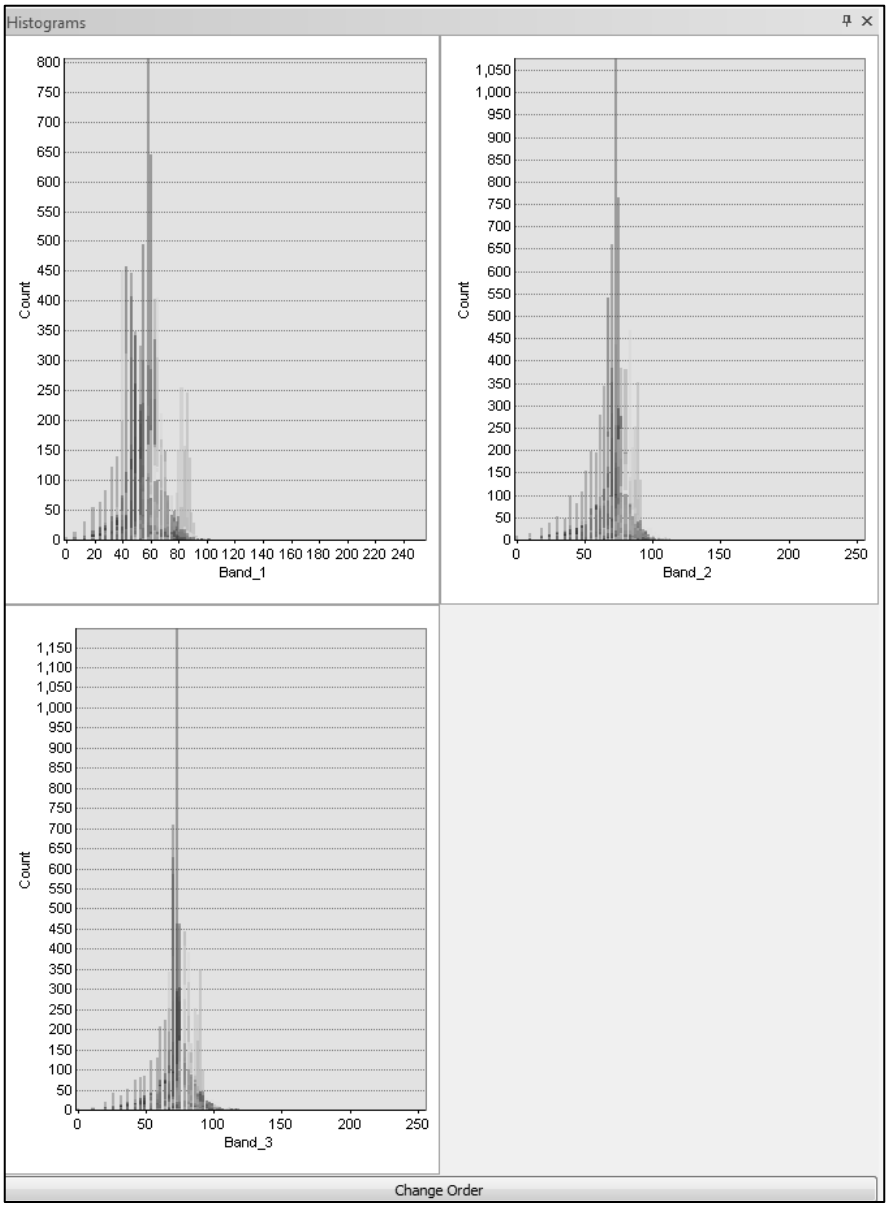


Fig. 5: Homogenous distribution of training samples for PGS



Accuracy assessment

A three-step process was used to conduct an accuracy assessment: (i) generating ground truth points; (ii) extracting raster values to ground truth points; and (iii) calculation in a confusion/error matrix. On examining the area and distribution of the private green spaces, an equalised stratified random sampling approach was utilised to create 100 reference points for the assessment, 50 for each class. The user accuracy (UA), producer accuracy (PA) and overall accuracy (OA) were then estimated (Estoque *et al*., 2015), where:

a) UA was the total number of correct pixels in a class divided by the sum of pixels in the row;
b) PA was the total number of correct pixels in a class divided by the sum of pixels in the column;
c) OA was the total number of correct pixels summed along the major diagonal divided by the total number of pixels in the error matrix.

(UA, PA and OA were expressed as percentages).

RESULTS AND DISCUSSION

Two classes, 'Private green spaces (PGS)' and 'Others' were created as a result of the supervised classification of the imagery for informal settlements in the three districts. Out of the 2,687.3 hectares of informal settlements in the three districts, 330.3 hectares were identified as private green spaces (Fig. 6). The 'Others' class, which included all spaces except private green spaces, covered 2,357 hectares of the total area. Private green spaces made up 12.3 % of the total area of informal settlements and the remaining 87.7 % consisted of the rooftops and other unvegetated items that were considered under the 'Others' class.

With 217.1 hectares, PD7 had the largest acreage of private green spaces among the three districts, which constituted 65.7 % of the overall area of private green spaces.

To facilitate discussion of the current results, it is important to mention that 46.8 % of the total area of PD7, or 3,250 hectares, was reported to be urbanised (JICA, 2011). The results of the current study confirmed JICA's report showing that PD7 had more than 40,000 informal dwellings, which was the most among the three PDs and which made up 95 % of the urbanised area (JICA, 2011). The majority of the informal settlements were courtyard houses that allowed space for establishing private green spaces (The World Bank, 2005). With a lower number of informal settlements compared with PD7, PD8 and PD16 had 21.3 % and 13 % of the identified private green spaces, respectively (Table 3). Such a positive relation between number of settlements and area of private green spaces was also noticed by Davies *et al*. (2009) in UK context.

Fig. 6: Distribution of private green spaces in the informal settlements of Kabul city

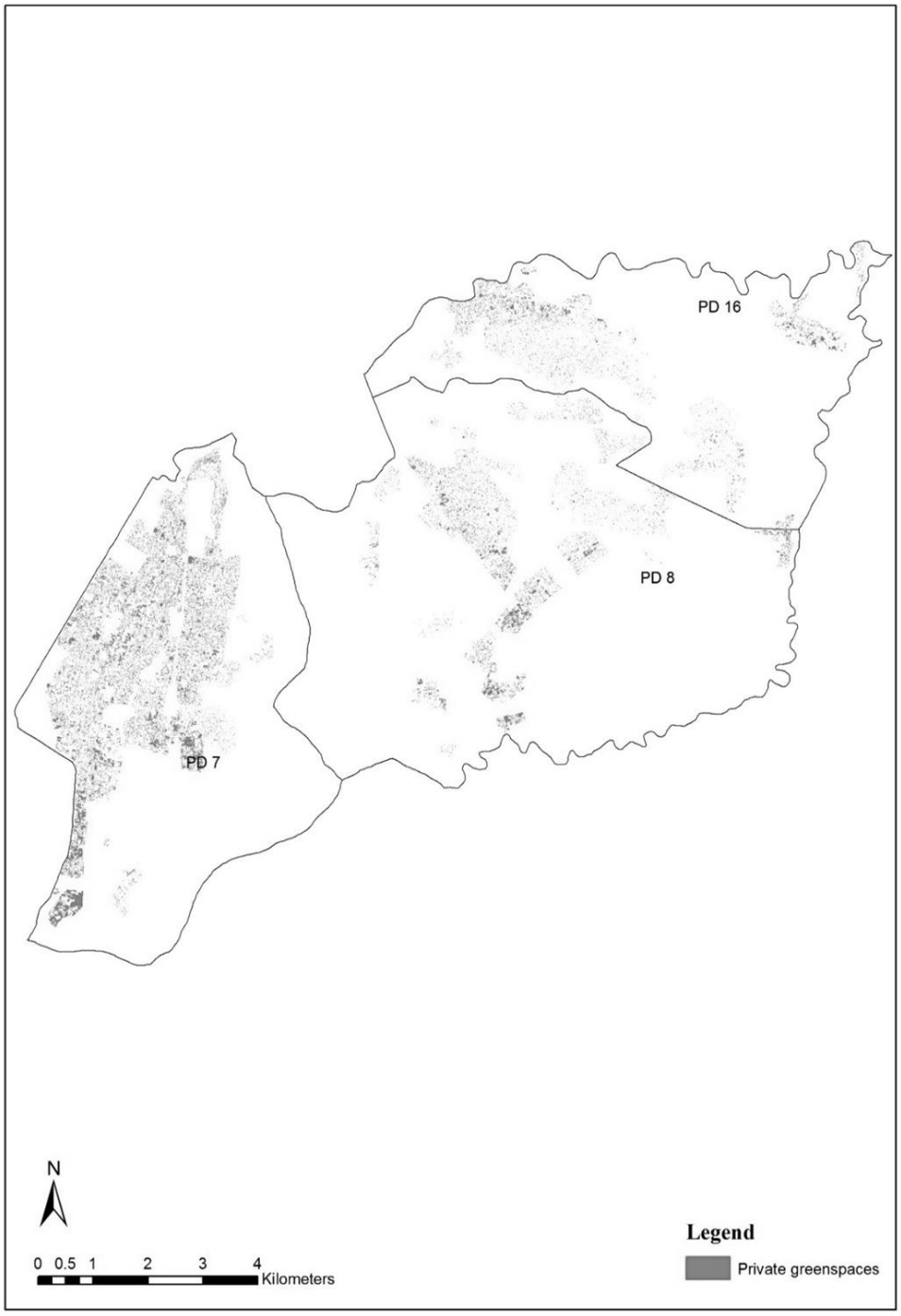


Table 3: Details on the police districts

PD	Population	Total area (ha)	Area of informal settlements for the study (ha)	Others in study area (ha)	PGS in study area (ha)	PGS in study area (%)
PD7	403,561	3,250	1,239.1	1,022	217.1	65.7
PD8	335,481	4,840	784.3	714	70.3	21.3
PD16	165,336	2,510	663.9	621	42.9	13
Total	904,378	10,600	2,687.3 (100%)	2,357 (87.7%)	330.3 (12.3%)	100

With private green spaces making 12.3 % of the total area of the informal settlements, the results of the study revealed some similarity to the relevant global literature. Previous studies found that private green spaces contribute remarkably to the total urban area. Gaston *et al*. (2005) and Cameron *et al.* (2012) mentioned that private green spaces comprised more than 20 % of the city area in Sheffield, United Kingdom. Other cities in UK were reported with similar percentages (Loram *et al.*, 2007). The total private green space area in a study in Dunedin of New Zealand was reported even higher reaching up to around 35 % of the urban area (Mathieu *et al.*, 2007). All of the above studies, including the current one, showed a remarkable size of private green spaces covering urban lands. The difference in reported percentages is understood from the difference in location of the studies (Cameron *et al.*, 2012).

Comparing the area of the two types of urban green spaces in Kabul city, the results showed that the area of private green spaces in informal settlements can be several times more than that of the public green spaces (JICA, 2011; GoIRA, 2016). These results show both similarities and differences to global literature. Aligned current findings, a few studies in other countries pointed out that private green spaces make up majority of the urban greenery. Jaganmohan *et al*. (2012) stated that private green spaces of Missouri, USA, occupy three times more area than its parks. Similar results were presented by Office for National Statistics (ONS) about Great Britain. ONS (2018) confirmed the existence of 529,300 hectares of private green spaces. However, the functional public green spaces in Great Britain that included public parks and even playing grounds covered only 124,800 hectares. On the other hand, there were places where public green spaces made higher percentage of the urban greenery. An example of such a place could be Paris where public green spaces represented 63.6 % of the total urban green spaces (Mimet *et al*., 2019). Another example was Brisbane city of Australia where its public green space area was reported higher than that of private green space (Rupprecht & Byrne, 2014).

Informal settlements lack space for the establishment of public green spaces in their area (Nazire *et al.*, 2016). Thus, their residents are left with only private green space access within their surroundings, a type of green space that was mapped by the current study. In addition, women are, more often than not, confined to their households and can only use private green spaces due to security, social and cultural restrictions (Sahab & Kaneda, 2016). These private green spaces provide similar benefits to public green spaces such as social cohesion, mental health and well-being, physical health, maintaining biodiversity, and cooling air (and improvement of its quality), as well as socioeconomic benefits (Farahani *et al.*, 2018). Therefore, the findings are considered of great value not only for confirming the potential of

private green spaces mentioned by previous studies (Gaston *et al.*, 2005; Smith *et al.*, 2005; Colding *et al.*, 2006; Balooni *et al.*, 2014; Dewaelheyns *et al.*, 2018) but also for keeping the hope alive for an environmental upgrading intervention in the deprived community of informal settlements. The private green spaces map generated in this study could be used by the Kabul Municipality and other relevant national and international departments to implement a programme to establish and upgrade urban green spaces that would fulfil the environmental needs of the residents of informal settlements, especially women. More specifically, the generated map could be utilized to identify settlements with different types and levels of green space intervention needed. Moreover, the inventory map generated in this study could be used to monitor the status of private green spaces for better management and sustainable planning of Kabul city (Darkhani *et al.*, 2019). The results could be used to conduct further studies on quantity and quality of private green spaces, as well as on residents' preferences towards them.

Since there were only two classes in the GIS-supervised classification, the accuracy of the results was more than satisfactory. By combining and decreasing the number of categories in the classification process, UA, PA and OA assessment results could be improved (Mathieu *et al.*, 2007). In the current study, only one error was spotted in each class that decreased the UA and PA of each class to 98%. Nevertheless, the overall accuracy of 98% showed that the supervised classification used in this study to map private green spaces was very effective (Fig. 7). However, it should be noted that the increase in classes for private green spaces in future studies (trees, shrubs and grass) could decrease the level of accuracy in the matrix table. Contrary to the currently used pixel based approach, Object based image analysis (OBIA) approach of image classification was unsuccessful in this study. Using segment mean shift function algorithm as a first step for the approach (Junainah *et al*., 2019), different parameters were tested to carry out image segmentation (Table 4). None of which resulted in satisfactory segmentation of the imagery and identification of private green spaces (Fig. 8). Thus, OBIA method failed to move forward in the current study. The reasons for this failure were mentioned by Natya and Rehna (2016). They pointed out the existence of different types of classification techniques that could be chosen based on the performance, type of imagery and application area. Although OBIA failed in satisfactory segmentation of the available imagery for private green spaces, in future studies, it can be utilized with imageries of better quality as well as of higher spatial and spectral resolution to improve the classification process (Natya and Rehna, 2016).

Fig. 7: Accuracy assessment

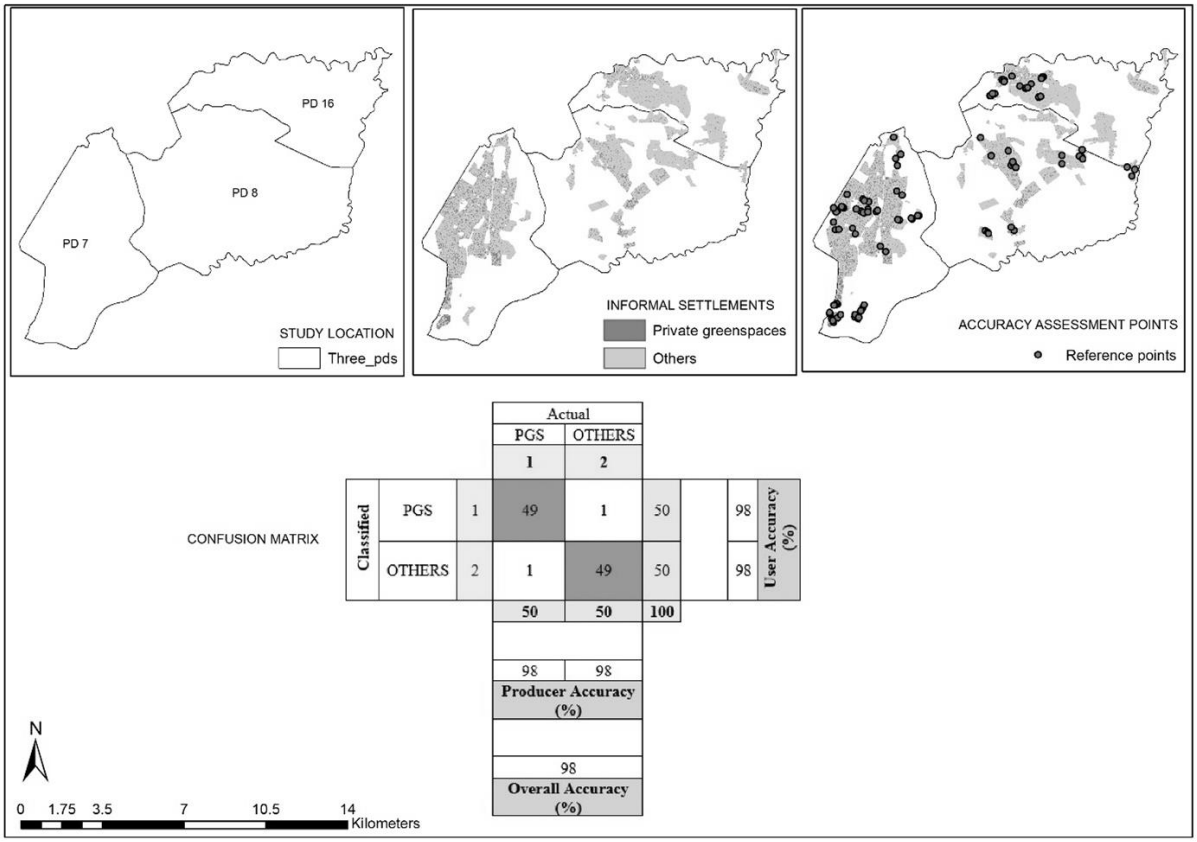
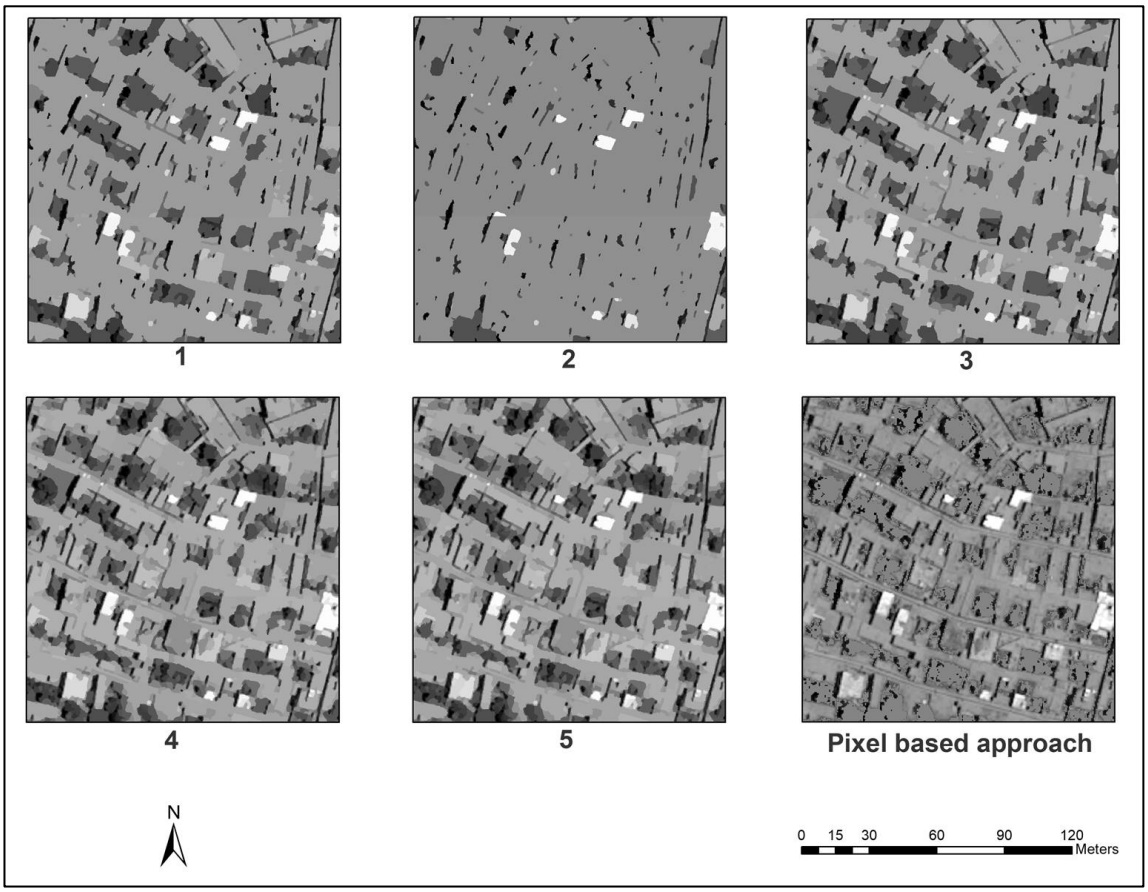


Table 4: Tested parameters for segmentation

Number of test	Spectral detail (Max. value 20)	Spatial detail (Max. value 20)	Min. segment size in pixels (Max. value 20)
1	15	15	20
2	12	16	18
3	16	15	20
4	18	15	20
5	18	15	18

Fig. 8: Image segmentation with different parameter testing for OBIA (see 1 – 5) and pixel based approach results. Pixel based approach showed significant and satisfactory results for the current imagery.



CONCLUSION

Up to the knowledge of the authors, this was the first time private green spaces were mapped in informal settlements of Kabul city. Based on the authors' knowledge, this was also the first study that mapped private green spaces in an informal context of any city in the world, specifically the war-torn ones. GIS-supervised classification and its maximum likelihood approach was preferred to classify the aerial imagery into two classes, 'Private green spaces' and 'Others'. As long as the private green spaces are concerned, the study found a significant amount of urban greenery in the deprived community of informal settlements making more than 10 % of the area. This study also noticed that the increase in number of informal settlements was accompanied with the increase in the area of private green spaces. The study was useful to recommend local authorities on application of GIS technology in mapping the urban greenery specifically in informal settlements. The generated map made it possible to identify settlements with private green spaces and helped

the authors to propose a potential private green space upgrading and establishing intervention. To be mentioned that the proposed environmental interventions using this map could upgrade the quality and quantity of private greenery in informal settlements. As a result, the deprived community, specifically women, will have access to at least one type of urban greenery. The identification of the remarkable part of urban greenery in informal settlements would also increase the confidence of the residence and help them remove the disparities existed between formal and informal areas of the city.

ACKNOWLEDGEMENTS

I would like to thank Mr Hedayatullah Subhan, an officer of the Afghanistan Ministry of Agriculture, Irrigation and Livestock, for providing the imagery used in this study. I would also like to thank Mr Haqmal Munib, a Norwegian Refugee Council (NRC) employee in Afghanistan, for providing the shapefiles required for Kabul city. I am grateful to Universiti Putra Malaysia (UPM) for providing an IPS grant (No: 9642100) as financial support for this research. My special gratitude goes to the Higher Education Development Program (HEDP), Afghanistan, for providing the scholarship to pursue my studies at UPM.

REFERENCES

AirVisual. (2018). *Air quality and pollution city ranking*. Retrieved on 15 December 2018 from https://www.airvisual.com/world-air-quality-ranking

Alvi, H. (2011). *Women in Afghanistan: A Human Rights Tragedy a Decade After September 11. Human Rights and Human Welfare*. Retrieved on 25 October 2018 from https://www.du.edu/korbel/hrhw/workingpapers/2011/66-alvi-2011.pdf

Baker, F., & Smith, C. (2019). A GIS and object based image analysis approach to mapping the greenspace composition of domestic gardens in Leicester, UK. *Landscape and Urban Planning*, 183, 133–146. https://doi.org/10.1016/j.landurbplan.2018.12.002

Balooni, K., Gangopadhyay, K., & Kumar, B. M. (2014). Governance for private green spaces in a growing Indian city. *Landscape and Urban Planning*, 123, 21–29. https://doi.org/10.1016/j.landurbplan.2013.12.004

Camalan, I. (2007). *The Weather in Kabul*. Retrieved on 01 January 2019 from https://www.researchgate.net/publication/263194635_The_weather_in_Kabul

Cameron, R. W. F., Blanuša, T., Taylor, J. E., Salisbury, A., Halstead, A. J., Henricot, B., & Thompson, K. (2012). The domestic garden - Its contribution to urban green infrastructure. *Urban Forestry and Urban Greening*, 11(2), 129–137. https://doi.org/10.1016/j.ufug.2012.01.002

Colding, J., Lundberg, J., & Folke, C. (2006). Incorporating Green-area User Groups in Urban Ecosystem Management. *Ambio*, 35(5), 237–244. http://dx.doi.org/10.1579/05-A-098R.1

Coolen, H., & Meesters, J. (2012). Private and public green spaces: meaningful but different settings. *Journal of Housing and the Built Environment*, 27(1), 49–67. doi:10.1007/s10901-011-9246-5

CSO. (2017). *Estimated Population of Kabul City by District and Sex 2017-18*. Retrieved on 25 March 2018 from http://cso.gov.af/en/page/demography-and-socile-statistics/demograph-statistics/3897111

Darkhani, F., Tahir, O. M., & Ibrahim, R. (2019). Sustainable urban landscape management: An insight into urban green space management practices in three different countries. *Journal of Landscape Ecology*, 12(1), 37-48. doi:10.2478/jlecol-2019-0003

Davies, Z. G., Fuller, R. A., Loram, A., Irvine, K. N., Sims, V., & Gaston, K. J. (2009). A national scale inventory of resource provision for biodiversity within domestic gardens. *Biological Conservation*, 142(4), 761–771. https://doi.org/10.1016/j.biocon. 2008.12.016

d'Cruz, C., Patel, S., Mazvimavi, G. Z. (2014). *Affordable public spaces in Informal settlements*. Retrieved on 15 November 2018 from https://knowyourcity.info/wp-content/uploads/2015/04/FINAL_Edited_Updated_Sep29_Celine_SDI_Public_spaces_and_urban_poor_communities.pdf

Dewaelheyns, V., Jakobsson, A., & Saltzman, K. (2018). Strategic gardens and gardening: Inviting a widened perspective on the values of private green space. *Urban Forestry and Urban Greening*, 30, 207-209. https://doi.org/10.1016/j.ufug.2017.12.009

Diyarbakirlioglu, K., & Yigit, S. (2017). The Women of Afghanistan : Past and Present Challenges. *Journal of Social Science Studies*, 4(2), 208–216. https://doi.org/10.5296/jsss.v4i2.11349

Estoque, R. C., Murayama, Y., & Akiyama, C. M. (2015). Pixel-based and object-based classifications using high- and medium-spatial-resolution imageries in the urban and suburban landscapes. *Geocarto International*, 30(10), 1113–1129. https://doi.org/10.1080/10106049.2015.1027291

Farahani, L. M., Malleri, C., & Phelan, K. (2018). Private Gardens as Urban Greenspaces: Can They Compensate for Poor Greenspace Access in Lower Socioeconomic Neighbourhoods? *Landscape Online*, 18(April), 1–18. https://doi.org/10.3097/LO.201859

Fazli, M. (2016). Factors Behind the Growth of Informal Settlements in Kabul.In the *6th Annual Conference on Architecture and Urbanism* (pp. 81–86). https://doi.org/10.13164/acau.fa2016.9

Gaston, K. J., Warren, P. H., Thompson, K., & Smith, R. M. (2005). *Urban domestic gardens (IV): the extent of the resource and its associated features*. Biodiversity and Conservation. doi:10.1007/s10531-004-0513-6

Gebremedhin, Y. (2005). *Preliminary assessment of informal settlements in Kabul city*. Retrieved on 15 June 2019 from https://www.semanticscholar.org/paper/Preliminary-Assessment-of-Informal-Settlements-in-Gebremedhin/f4e80cd2f8832ce50bc6442e2885695936a3b283

GoIRA. (2016). *Atlas of Afghan City Regions 2016*. Ministry of urban development and housing.

Gram-Hansen, B., Helber, P., Varatharajan, I., Azam, F., Coca-Castro, A., Kopackova, V., & Bilinski, P. (2019). *Mapping informal settlements in developing countries using machine learning and low resolution multi-spectral data*. AAAI/ACM Conference on AI, Ethics, and Society. Retrieved on 15 June 2019 from https://www.researchgate.net/publication/330185678_Mapping_Informal_Settlements_in_Developing_Countries_using_Machine_Learning_and_Low_Resolution_Multi-spectral_Data

Halkett, I. P. B., 1978. The recreational use of private gardens. *Journal of Leisure Research*, 10, 13-20. DOI: 10.1080/00222216.1978.11969330

Irandoost, K., Tavallaei, R., & Azami, M. (2014). *Defining indicators of informal settlements in Iran*. Retrieved on 19 November 2019 from https://www.researchgate.net/publication/

273057823_Defining_indicators_of_informal_settlements_in_Iran

Jaganmohan, M., Vailshery, L.S., Gopal, D., & Nagendra, H. (2012). Plant diversity and distribution in urban domestic gardens and apartments in Banglore, India. *Urban Ecosyst*, 15, 1-15. doi:10.1007/s11252-012-0244-5

JICA. (2011). *Draft Kabul City Master Plan*. Retrieved on 25 January 2018 from http://open_jicareport.jica.go.jp/618/618/618_301_12058566.html

JICA. (2011). *Kabul City Current Status Report for Urban Development*. Retrieved on 25 January 2018 from http://open_jicareport.jica.go.jp/pdf/12068151.pdf

Junainah, A.K., Mohd Yusof, M.J., & Shafri, H.Z.M. (2019). Monitoring Urban Green Space (UGS) Changes by Using High Resolution Aerial Imagery: A Case Study of Kuala Lumpur, Malaysia. *Pertanika J. Sci. & Technol*, 27(4), 1971-1990. https://www.researchgate.net/publication/336709799_SCIENCE_TECHNOLOGY_Monitoring_Urban_Green_Space_UGS_Changes_by_Using_High_Resolution_Aerial_Imagery_A_Case_Study_of_Kuala_Lumpur_Malaysia

Kendal, D., Williams, N. S. G., & Williams, K. J. H. (2012). Drivers of diversity and tree cover in gardens, parks and streetscapes in an Australian city. *Urban Forestry and Urban Greening*, 11(3), 257–265. https://doi.org/10.1016/j.ufug.2012.03.005

Lindemann-Matthies, P., & Marty, T. (2013). Does eco-logical gardening increase species richness and aesthetic quality of a garden? *Biological Conservation*, 159, 37–44. doi:10.1016/j.biocon.2012.12.01178.

Lin, B. B., Fuller, R. A., Bush, R., Gaston, K. J., & Shanahan, D. F. (2014). Opportunity or orientation? Who uses urban parks and why. *PLoS ONE*, 9(1), 1–7. https://doi.org/10.1371/journal.pone.0087422

Loram, A., Tratalos, J., Warren, P. H., & Gaston, K. J. (2007). Urban domestic gardens (X): The extent & structure of the resource in five major cities. *Landscape Ecology*, 22(4), 601–615. https://doi.org/10.1007/s10980-006-9051-9

Loram, A., Warren, P. H., & Gaston, K. J. (2008). Urban Domestic Gardens (XIV): The Characteristics of Gardens in Five Cities. *Environmental Management*, 42(3), 361–376. doi:10.1007/s00267-008-9097-3

Mathieu, R., Freeman, C., & Aryal, J. (2007). Mapping private gardens in urban areas using object-oriented techniques and very high-resolution satellite imagery. *Landscape and Urban Planning*, 81(3), 179–192. https://doi.org/10.1016/j.landurbplan.2006.11.009

Mimet, A., Kerbiriou, C., Simon, L., Julien, J., & Raymond, R. (2019). Contribution of private gardens to habitat availability, connectivity and conservation of the common pipistrelle in Paris. *Landscape and Urban Planning*, 193 (2020) 103671. DOI: 10.1016/j.landurbplan.2019.103671

Mishra, HS & Bell, S. (2016). An assessment of the relative contribution of private residential gardens to the city-wide green space benefits and services: The case of Tartu, Estonia. in P Bauer, M Collender, M Jakob, L Ketterer Bonnelaume, P Petschek, D Siegrist & C Tschumi (eds), *Bridging the Gap. ECLAS Conference 2016* (pp. 347-350), Rapperswil, Switzerland. Conference Proceedings. Series of the Institute for Landscape and Open Space, vol. 14,

Mohd Yusof, M.J. (2012). Identifying green spaces in Kuala Lumpur using higher resolution satellite imagery. *International Journal of Sustainable Tropical Design Research and Practice*, 5(2), 93–106.

Natya, S., & Rehna, J. (2016). Land cover classification schemes using remote sensing

images: A recent survey. *British Journal of Applied Science & Technology*, 13(4), 1-11. doi: 10.9734/BJAST/2016/22037

Nazire, H., & Kita, M. (2016). Specifying characteristics of informal settlements by comparing four areas from the aspects of houses, land tenure and social factors in Kabul, Afghanistan. *Journal of Architecture and Planning*, 81, 2197-2206. https://doi.org/ 10.3130/aija.81.2197

Nazire, H., Kita, M., Okyere, S. A., & Matsubara, S. (2016). Effects of Informal Settlement Upgrading in Kabul City, Afghanistan: A Case Study of Afshar Area. *Current Urban Studies*, 4, 476–494. https://doi.org/10.4236/cus.2016.44031

ONS. (2018). *UK natural capital: ecosystem accounts for urban areas*. Retrieved on 23 November 2019 from https://www.ons.gov.uk/economy/environmentalaccounts/ bulletins/uknaturalcapital/ecosystemaccountsforurbanareas

Paar, P., & Rekittke, J. (2011). Low-Cost Mapping and Publishing Methods for Landscape Architectural Analysis and Design in Slum-Upgrading Projects. *Future Internet*, 3(4), 228–247. https://doi.org/10.3390/fi3040228

Pafi, M., Siragusa, A., Ferri, S., Halkia, M. (2016). *Measuring the Accessibility of Urban Green Areas.* A comparison of the Green ESM with other datasets in four European cities; EUR 28068 EN; doi:10.2788/279663

Rupprecht, C. D., & Byrne, J. A. (2014). Informal urban green-space: comparison of quantity and characteristics in Brisbane, Australia and Sapporo, Japan. *PLoS one*, 9(6), e99784. DOI:10.1371/journal.pone.0099784

Sahab, S., & Kaneda, T. (2016). *A Study on the Lifestyles and Daily Activities of Informal Settlers in Inner Kabul City*. Retrieved on 20 July 2018 from https://repository.corp.at/163/1/CORP2016_65.pdf

Smith, R. M., Gaston, K. J., Warren, P. H., & Thompson, K. (2005). Urban domestic gardens (V): relationships between landcover composition, housing and landscape. *Landscape Ecology*, 20(2), 235–253. https://link.springer.com/article/10.1007/s10980-004-3160-0

Telesetskyt, A. (1998). In the Shadows and Behind the Veil: Women in Afghanistan under the Taliban Rule. *Berkeley Journal of Gender, Law & Justice*, 13(1), 293–305.

The World Bank. (2005). *Why and how should Kabul upgrade its informal settlements*?. Retrieved on 02 January 2019 from http://documents.worldbank.org/curated/en/ 684031467995795185/Why-and-how-should-Kabul-upgrade-its-informal-settlements

UN DESA. (2017). *World population projected to reach 9.8 billion in 2050, and 11.2 billion in 2100*. Retrieved on 02 January 2019 from https://www.un.org/development/desa/ en/news/population/world-population-prospects-2017.html

UN DESA. (2018). *68% of the world population projected to live in urban areas by 2050*. Retrieved on 03 January 2019 from https://www.un.org/development/desa/en/news/ population/2018-revision-of-world-urbanization-prospects.html

UN-Habitat (2003). *The Challenge of Slums*. Global Report on Human Settlements, Nairobi: Human Settlement Programme. Retrieved on 10 November 2019 from https://www.un.org/ruleoflaw/files/Challenge%20of%20Slums.pdf

Zupancic, T., Westmacott, C., & Bulthuis, M. (2015). *The impact of green space on heat and air pollution in urban communities : A meta-narrative systematic review*. Retrieved on 03 January 2019 from https://davidsuzuki.org/wp-content/uploads/2017/09/impact-green -space-heat-air-pollution-urban-communities.pdf