INSTITUT TEKNOLOGI NASIONAL YOGYAKARTA
Technopreneur In Future Energy

MUTIASARI KURNIA DEVI <mutiasari@sttnas.ac.id>

[IJG] Submission Acknowledgement

1 message

Mr.Eko Haryono <e.haryono@ugm.ac.id> Wed, Nov 7, 2018 at 3:52 AM
To: Mutiasari Kurnia Devi <mutiasari@sttnas.ac.id>

Dear Mutiasari Kurnia Devi:

Thank you for submitting the manuscript, "Measuring Urban Form Units: Alternative for Characterizing Urban Growth Pattern in Yogyakarta Urbanized Areas" to Indonesian Journal of Geography. With the online journal management system that we are using, you will be able to track its progress through the editorial process by logging in to the journal web site:

Manuscript URL: https://jurnal.ugm.ac.id/ijg/author/submission/40599
Username: mutiasari

If you have any questions, please contact me. Thank you for considering this journal as a venue for your work.

Mr.Eko Haryono
Indonesian Journal of Geography

Chief Editor
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MUTIASARI KURNIA DEVI <mutiasari@sttnas.ac.id>

[IJG] Editor Decision: Major Revision Required

1 message

Eko Haryono <e.haryono@ugm.ac.id> Mon, Jun 24, 2019 at 7:29 PM
To: Mutiasari Kurnia Devi <mutiasari@sttnas.ac.id>
Cc: Lulu Mari Fitria <lulumari@sttnas.ac.id>, Muhammad Sani Roychansyah <saniroy@gmail.com>, Yori Herwangi <y.herwangi@gmail.com>

Dear Mutiasari Kurnia Devi,

After considering reviewer's comments (see the attachment in your OJS account), We have reached the decision to Accept your manuscript with major revision regarding your submission to Indonesian Journal of Geography, "Measuring Urban Form Units: Alternative for Characterizing Urban Growth Pattern in Yogyakarta Urbanized Areas".

You should improve the quality of your manuscript by revising your manuscript according to the reviewer's comments. Please carefully respond to reviewer's comments when submitting the revision and please clearly indicate the changes that you made (or highlight them) to address the reviewer's comments. Or, you can directly reply to reviewer's comments in the comments box written by the reviewer. You should also use the template attached below. We will not process any revised paper without a specific response to each reviewer's comments

Once again, thank you for submitting your manuscript to the Indonesian Journal of Geography and I look forward to receiving your revision no later than 30 days from now. If you failed to meet the deadline, we may have to consider your paper rejected.

NB: Please use the follow the guideline in the attached template for your revision.

Best wishes,
Dr. Eko Haryono
Editor in Chief
Indonesian Journal of Geography,
Faculty of Geography, Universitas Gadjah Mada, Yogyakarta

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INSTITUT TEKNOLOGI NASIONAL YOGYAKARTA
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MUTIASARI KURNIA DEVI <mutiasari@sttnas.ac.id>

Re: Measuring Urban Form Units: Alternative for Characterizing Urban Growth Pattern in Yogyakarta Urbanized Areas

3 messages

Eko Haryono <e.haryono@ugm.ac.id> Thu, Jul 25, 2019 at 5:05 AM
To: Mutiasari Kurnia Devi <mutiasari@sttnas.ac.id>

You must upload the revised manuscript trough your account in our website.

Chief editor

On Thu, Jul 25, 2019, 3:12 AM Mutiasari Kurnia Devi <mutiasari@sttnas.ac.id> wrote:

> Dear Editor-in-Chief of IJG,
>
> Through this mail, I would like to notify that we already revised our manuscripts based on reviewer's comments (manuscript attached). The changes that we made are indicated through the revision report which we also attached in this mail.
>
> We look forward to receive the feedbacks as well as the further decision for our manuscript very soon. Thank you for your attention.
>
> Best Regards,
> Mutiasari Kurnia Devi
> Urban and Regional Planning Department
> Institut Teknologi Nasional Yogyakarta
>
> ---
> Chief Editor
> Indonesian Journal of Geography
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Mutiasari Kurnia Devi <mutiasari@sttnas.ac.id> Wed, Jul 24, 2019 at 11:46 PM
To: Eko Haryono <e.haryono@ugm.ac.id>

Dear Editor-in-Chief of IJG,

Through this mail, I would like to notify that we already revised our manuscripts based on reviewer's comments (manuscript attached). The changes that we made are indicated through the revision report which we also attached in this mail.

We look forward to receive the feedbacks as well as the further decision for our manuscript very soon. Thank you for your attention.

Best Regards,
Mutiasari Kurnia Devi
Urban and Regional Planning Department
Institut Teknologi Nasional Yogyakarta

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2 attachments

Measuring Urban Form Unit_240719.doc
5509K

Revision Report.docx
16K

MUTIASARI KURNIA DEVI <mutiasari@sttnas.ac.id> Thu, Jul 25, 2019 at 12:41 PM
To: Eko Haryono <e.haryono@ugm.ac.id>

We have submitted the revised manuscript on OJS, however we couldn't attach the revision report there. As an alternative, we will upload the revision report as supplementary files on the summary page. Thank you

Best Regards,
Mutiasari Kurnia Devi
Urban and Regional Planning Department
Institut Teknologi Nasional Yogyakarta

On Thu, Jul 25, 2019 at 5:05 AM Eko Haryono <e.haryono@ugm.ac.id> wrote:

> You must upload the revised manuscript trough your account in our website.
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> Chief editor
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> On Thu, Jul 25, 2019, 3:12 AM Mutiasari Kurnia Devi <mutiasari@sttnas.ac.id> wrote:
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> > Mutiasari Kurnia Devi
> > Urban and Regional Planning Department
> > Institut Teknologi Nasional Yogyakarta
> >
> > ---
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--
Mutiasari Kurnia Devi
Department of Urban and Regional Planning
Sekolah Tinggi Teknologi Nasional Yogyakarta
Jl. Babarsari, Caturtunggal, Depok, Sleman 55281 Indonesia
Phone: +62 81325077025
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MUTIASARI KURNIA DEVI <mutiasari@sttnas.ac.id>

[IJG] Editor Decision: Revision Required

1 message

Eko Haryono <e.haryono@ugm.ac.id> Sun, Nov 24, 2019 at 9:31 PM
To: Mutiasari Kurnia Devi <mutiasari@sttnas.ac.id>
Cc: Lulu Mari Fitria <lulumari@sttnas.ac.id>, Muhammad Sani Roychansyah <saniroy@gmail.com>, Yori Herwangi <y.herwangi@gmail.com>

Dear Mutiasari Kurnia Devi,

I did not find that your latest version of your manuscript has been revised.
Please make in different text color in the revised passage.
Your maps (coordinates, legends, annotations are not readable).
Please use reference management software for citations. Use APA Style 6th version for the references.
You should cite at least one reference from the Indonesian journal of geography.

Best wishes,
Dr. Eko Haryono
Editor in Chief
Indonesian Journal of Geography,
Faculty of Geography, Universitas Gadjah Mada, Yogyakarta

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MUTIASARI KURNIA DEVI <mutiasari@sttnas.ac.id>

Measuring Urban Form Units: Alternative for Characterizing Urban Growth Pattern in Yogyakarta Urbanized Areas

1 message

Mutiasari Kurnia Devi <mutiasari@sttnas.ac.id> Tue, Dec 24, 2019 at 11:47 PM
To: Eko Haryono <e.haryono@ugm.ac.id>

Dear Editor in Chief of IJG,

I hope this find you well. According to the last feedbacks of our manuscript, we already submit the newest version of the article which has been revised through OJS. The changes that we made are indicated as blue colour in the file.

We look forward to receive the further decision for our manuscript very soon. Thank you for your attention.

Best Regards,
Mutiasari Kurnia Devi
Urban and Regional Planning Department
Institut Teknologi Nasional Yogyakarta

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MUTIASARI KURNIA DEVI <mutiasari@sttnas.ac.id>

[IJG] Editor Decision: Accept Manuscript

1 message

Eko Haryono <e.haryono@ugm.ac.id> Thu, May 28, 2020 at 10:11 AM
To: Mutiasari Kurnia Devi <mutiasari@sttnas.ac.id>
Cc: Lulu Mari Fitria <lulumari@sttnas.ac.id>, Muhammad Sani Roychansyah <saniroy@gmail.com>, Yori Herwangi <y.herwangi@gmail.com>

Dear Mutiasari Kurnia Devi,

Congratulations! After considering your responses to reviewer's comments, We have reached the decision regarding your submission to Indonesian Journal of Geography, "Measuring Urban Form Units: Alternative for Characterizing Urban Growth Pattern in Yogyakarta Urbanized Areas" to Accept your manuscript to be published in Indonesian Journal of Geography.

You will receive emails regarding the details of your publication. We may also request a technical edit of your manuscript if necessary.

Thank you for submitting to the Indonesian Journal of Geography and we look forward to receiving your manuscript in the future.

Best wishes,
Dr. Eko Haryono
Editor in Chief
Indonesian Journal of Geography,
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MUTIASARI KURNIA DEVI <mutiasari@sttnas.ac.id>

[IJG] Proofreading Request (Author) and author Fee

1 message

Winarsih Winarsih <wiwin_geo@ugm.ac.id> Tue, Aug 18, 2020 at 5:01 PM
To: Mutiasari Kurnia Devi <mutiasari@sttnas.ac.id>

Dear Mrs.Mutiasari Kurnia Devi,

Your submission "Measuring Urban Form Units: Alternative for Characterizing Urban Growth Pattern in Yogyakarta Urbanized Areas" to Indonesian Journal of Geography now needs to be proofread by following these steps.
1. Click on the Submission URL below.
2. Log into the journal and view PROOFING INSTRUCTIONS
3. Click on VIEW PROOF in Layout and proof the galley in the one or more formats used.
4. Enter corrections (typographical and format) in Proofreading Corrections.
5. Save and email corrections to Layout Editor and Proofreader.
6. Send the COMPLETE email to the editor.

Submission URL: https://jurnal.ugm.ac.id/ijg/author/submissionEditing/40599
Username: mutiasari

and....
Your manuscript has been accepted and will be published in the Indonesian Journal of Geography (on this year). Would you please pay the the contribution fee Rp 4.000.000 (four million rupiah) to the following bank account. Your contribution is highly appreciated in order to maintain the quality of IJG.

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Winarsih Winarsih
Faculty of Geography, Universitas Gadjah Mada
wiwin_geo@ugm.ac.id
Assistant Editor
Indonesian Journal of Geography and
Majalah Geografi

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MUTIASARI KURNIA DEVI <mutiasari@sttnas.ac.id>

[IJG] Proofreading Completed (Author)

1 message

Mutiasari Kurnia Devi <mutiasari@sttnas.ac.id> Wed, Aug 26, 2020 at 12:12 AM
To: Eko Haryono <e.haryono@ugm.ac.id>

Dear Eko Haryono,

I have completed proofreading the galleys for my manuscript, "Measuring Urban Form Units: Alternative for Characterizing Urban Growth Pattern in Yogyakarta Urbanized Areas," for Indonesian Journal of Geography. The galleys are now ready to have any final corrections made by the Proofreader and Layout Editor.

Best wishes,
Mutiasari Kurnia Devi

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Author
2020-08-26 12:06 AM

EDIT DELETE

Subject: Measuring Urban Form Units: Alternative for Characterizing Urban Growth Pattern in Yogyakarta Urbanized Areas

1. CHANGE

Author Affiliation

[1]Urban and Regional Planning Department, Sekolah Tinggi Teknologi Nasional Yogyakarta

---- to

[1]Urban and Regional Planning Department, **Institut** Teknologi Nasional Yogyakarta

2. CHANGE

Abstract

….. Yogyakarta Urbanized Area (YUA). In this paper, identified the characters of each part of YUA by examining its urban form unit. This paper assesses ……

---- to

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3. CHANGE

Abstract

….. the urban form typologies. Density, diversity, and accessibility were used to represent the urban form characteristic., the typologies are classified into three groups ……

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4. FORMATTING

Introduction

……. population density and land use cover are the key variables to explain more depth the typology of urban areas (Abrantes et al., 2019). Sustainable urban forms have been a concern in the context of developed cities which described as “new urbanism” or the “compact city” (Abe & Kato, 2017).

As urban sprawl triggers many negative implications towards environment, social, and economic,

there is a vision for many urban planners in the 21st century to create places with more compact design, more accessible to public transportation, and less driving The key principles …..

----- the structure of paragraph should be as below

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5. CHANGE

Introduction

….. development in YUA context. The study starts with a literature review of definitions of urban form and definitions of compactness and sprawl. After that, it the different dimensions of metropolitan forms, accompanied with appropriate quantitative indexes in which the degrees of compactness and sprawl are revealed.

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ISSN 2354-9114 (online), ISSN 0024-9521 (print)
Indonesian Journal of Geography Vol.52 , No. 1, 2020 (219 - 227)
DOI: http://dx.doi.org/10.22146/ijg.40599 website: https://jurnal.ugm.ac.id/ijg

INDONESIAN JOURNAL OF GEOGRAPHY

RESEARCH ARTICLE

Measuring Urban Form Units: Alternative for Characterizing Urban Growth Pattern in Yogyakarta Urbanized Areas

[1]Mutiasari Kurnia Devi, [1]Lulu Mari Fitria, [2]M. Sani Roychansyah and [2]Yori Herwangi
[1]Urban and Regional Planning Department, Sekolah Tinggi Teknologi Nasional Yogyakarta
[2]Architecture and Planning Department, Universitas Gadjah Mada, Indonesia

Received:
Accepted:

Keywords:
urban form;
urban growth;
agglomeration

Correspondent email:
mutiasari@sttnas.ac.id

Abstract. Yogyakarta is one of city in Indonesia which experience urban agglomeration called by Yogyakarta Urbanized Area (YUA). In this paper, identified the characters of each part of YUA by examining its urban form unit. This paper assesses the characteristics of urban forms distributed within YUA. Quantitative measurements were proposed for classifying the urban form typologies. Density, diversity, and accessibility were used to represent the urban form characteristic., the typologies are classified into three groups which are low compact, middle compact, and high compact. The result shows that the majority areas in YUA are grouped into middle compact typology where most of them are located in the city of Yogyakarta administrative area. Meanwhile, the areas, categorized as low compact typology, are in the hinterland area of Yogyakarta. High compact typology are concentrated in the centre of YUA where it has the highest activity concentration for the whole urban structure context. This study discovers that characterizing the urban growth patterns using quantitative method can distinguish urban form. At the end, this paper provides an important note about the distribution of urban form typology in the agglomeration area and, in the future, can be used to design urban policies, especially in the utilization of urban space.

1. Introduction

The majority of world's populations are predicted to live in cities. By 2030, nearly 60% of world population will live in cities (UNFPA, 2007). Drawing insights from this fact, many cities, especially in developing countries, will experience urbanisation at large scale, however, at the same time the urban infrastructure has not been able to accommodate the population. According to Statista (Statista, 2017), about 55% of Indonesia population live in urban area. In 2010, the urban population was about 50% and it went up to 53,5% in 2015. This trends will be continuously increasing until 2035. It is predicted that the urban population will hit 60% by 2025 and will reach 63,4% by 2030 (BPS, 2013). It gives a clear image that the rapid growth of urban population and urbanization is happening in a large scale. Therefore, the growth of urban population requires serious attention from stakeholders, in particularly urban planners. Increasing population which followed by rapid urbanisation has important implications for urban area expansion. This implication yields urban agglomeration within surrounded areas as the consequence. Not only that, but also rapid urbanisation causes a wide range of urban problems, including urban sprawl.

Sprawl is often defined by four land use characteristics: low density; scattered development (i.e. decentralised sprawl); commercial strip development; and, leapfrog development (Ewing, 1997). It can be described as an overall low density development or a scattered or leapfrog development with a daily commuting of its people relying on automobile (Uhel, 2006 cited in Abrantes et al., 2019; Galster et al., 2001; Kasanko et al., 2006). Higher environmental impacts are reported to be associated with low densities, one of sprawl development characteristics (Camagni, Cristina, & Rigamonti, 2002). In line with previous findings, Nechyba & Walsh (2004) mentioned that sprawl can be linked to environmental issues as lower-density development. In other words, sprawl can be associated as the increase in emissions per mile travelled related to traffic congestion and the increases in vehicle miles travelled. Urban sprawl also leads to cause loss of productive agricultural lands, open green spaces, as well as loss of surface water bodies (Bhat, Shafiq, Mir, & Ahmed, 2017). In addition to that, social sector is also reported to have negatively affected by urban sprawl. People who live farther from each other will have weak linkages within neighbours (Burchell et al., 1998 cited in (Nguyen, 2010) as well as social segregation (Camagni and Gibelli, 1997 cited in (Camagni et al., 2002)).

Handy (1996) defines urban form as a composite of characteristics related to land use patterns, transportation system, and urban design. Urban form can be further described conceptually as the spatial pattern of human activities including the physical configuration of a city along with land use patterns, population and housing densities, infrastructure and amenities, and transport and communication networks (Anderson et al., 1996 cited in (Tsai, 2005); Abrantes et al., 2019). In term of geographical scales, urban form can be viewed and classified into several levels, such as metropolitan area, city, and even neighbourhood. The reason for this classification is twofold.

First, some urban form variables operate only at certain levels, such as the job-housing balance variable. Secondly, urban form variables (such as density) may carry different meanings at different levels and may differently affect human activities, such as travel behaviour (Tsai, 2005). To sum up the concept of urban form, urban form is a result of the bringing together of many elements-concepts: the urban pattern (Jabareen, 2006).

Longstanding attempts to quantify urban sprawl that focuses on the growth of suburbs relative to central cities in which showing that suburbs have grown more rapidly than the central cities they surround (Chinitz, 1969). Song & Knaap (2004) measures urban form by utilizing street design and circulation systems, density, land use mix, accessibility, and pedestrian access to evaluate the development patterns in Portland, Oregon. Meanwhile, Tsai (2005) describes urban form by using three categories which are density, diversity, and spatial-structure pattern. In contrast, Chin (2002) points out three principal dimensions of urban sprawl such as urban spatial scale, population density decline, and scattered urbanisation. Among several variables that have been used to identify urban form, population density and land use cover are the key variables to explain more depth the typology of urban areas (Abrantes et al., 2019). Sustainable urban forms have been a concern in the context of developed cities which described as "new urbanism" or the "compact city" (Abe & Kato, 2017).

As urban sprawl triggers many negative implications towards environment, social, and economic,

there is a vision for many urban planners in the 21st century to create places with more compact design, more accessible to public transportation, and less driving The key principles which are proposed in order to create more sustainable urban form, are promoting walkability and connectivity, mixed land uses, and high density (Rukmana, 2018). Newman & Kenworthy (2000) found that the compact city emerges as the most fuel-efficient of urban forms. They conclude that urban form matters to improve urban air quality. Compactness also does not have a generally accepted definitions. Gordon & Richardson (1996) potray compactness as high-density or monocentric development. Ewing's definition (Ewing, 1997) was some concentration of employment and housing, as well as some mixture of land uses. Alternatively, Anderson et al. (Anderson, Kanaroglou, & Miller, 1996) defined both monocentric and polycentric forms as being compact. To conclude the definition, compactness refers to urban continuity (and connectivity), which suggest that future urban development shall take place adjacent to existing urban structures (Wheeler, 2002) as compactness brings the concentration of development (Tsai, 2005).

The studies on urban form have been drawing interests in international research area for the past decades. However, in Indonesia context, the lack of theoretical and empirical works to address urban structure using quantitative measures is still underdeveloped. In fact, understanding urban form can lead to better decisions on urban transportation, growth strategy, as well as the development of infrastructure (Bin Kashem, Chowdhury, Majumder, & Rahman, 2009). In recent years, a number of quantitative variables have been developed to characterise urban sprawl. However, there are some gaps in the definitions of compactness and sprawl, and in the appropriate quantitative variables. This paper aims to characterise quantitatively urban form in general and to distinguish compactness from sprawl particularly using urbanized area case. The findings can be taken to propose different types of urban policies and planning approaches based on the urban form typology as well as to attain sustainable travel. Moreover, by measuring the urban form unit, we can also reveal the trends of urban development in YUA context. The study starts with a literature review of definitions of urban form and definitions of compactness and sprawl. After that, it the different dimensions of metropolitan forms, accompanied with appropriate quantitative indexes in which the degrees of compactness and sprawl are revealed.

2. The Methods

Site Study

In terms of area coverage, this study was conducted in Yogyakarta Urbanized Area (YUA) with the object of research is the built environment, particularly urban form characteristic in that location. YUA covers 14 (fourteen) sub-districts in Yogyakarta City, 6 (six) sub-districts in Sleman Regency, and 3 (three) sub-districts in Bantul Regency.

Data Sets and Analysis

This paper developed a set of quantitative variables to characterise urban forms at the metropolitan level, and in particular, to distinguish compactness from "sprawl". The analysis follows reviewing and analysing former research on the definitions of urban form, compactness and sprawl, and corresponding quantitative variables. Density, diversity, and accessibility are often used to describe the urban form within region. Density is a critical typology in determining sustainable urban forms. It is the ratio of people or dwelling units to land area. Meanwhile diversity is a multidimensional phenomenon (Turner & Murray, 2001) that promotes further desirable urban features, including greater varieties of housing types, building densities, household sizes, ages, cultures, and incomes. Thus, diversity represents the social and cultural context of the urban form. Sometimes diversity is being relates to the mixed used in which in this context mixed land use indicates the diversity of functional land uses such as residential, commercial, industrial, institutional, and those related to transportation.

There are several ways to categorize the typology of urban form. Jabareen (2006) classifies urban form into four different types such as neo-traditional, compact city, urban containment, and eco city. The typology is described through several criteria such as density, diversity, mixed land use, compactness, sustainable transportation, passive solar design, and greening ecological design. Using different perspective, Jackson-Smith et al. (Jackson-Smith et al., 2016) further clustered the urban form that have been linked to its water system characteristics. For this paper, we categorized the urban form typology into three categories based on the level of its compactness: low compact, middle compact, and high compact typology.

To represent density, diversity, and accessibility in deeper context, six quantitative variables were developed to measure six dimensions of urban form: population density, richness index, bus service coverage area index, number of transit stops, built-area ratio, and land use variation. The data sets are display on the Table 1 below.

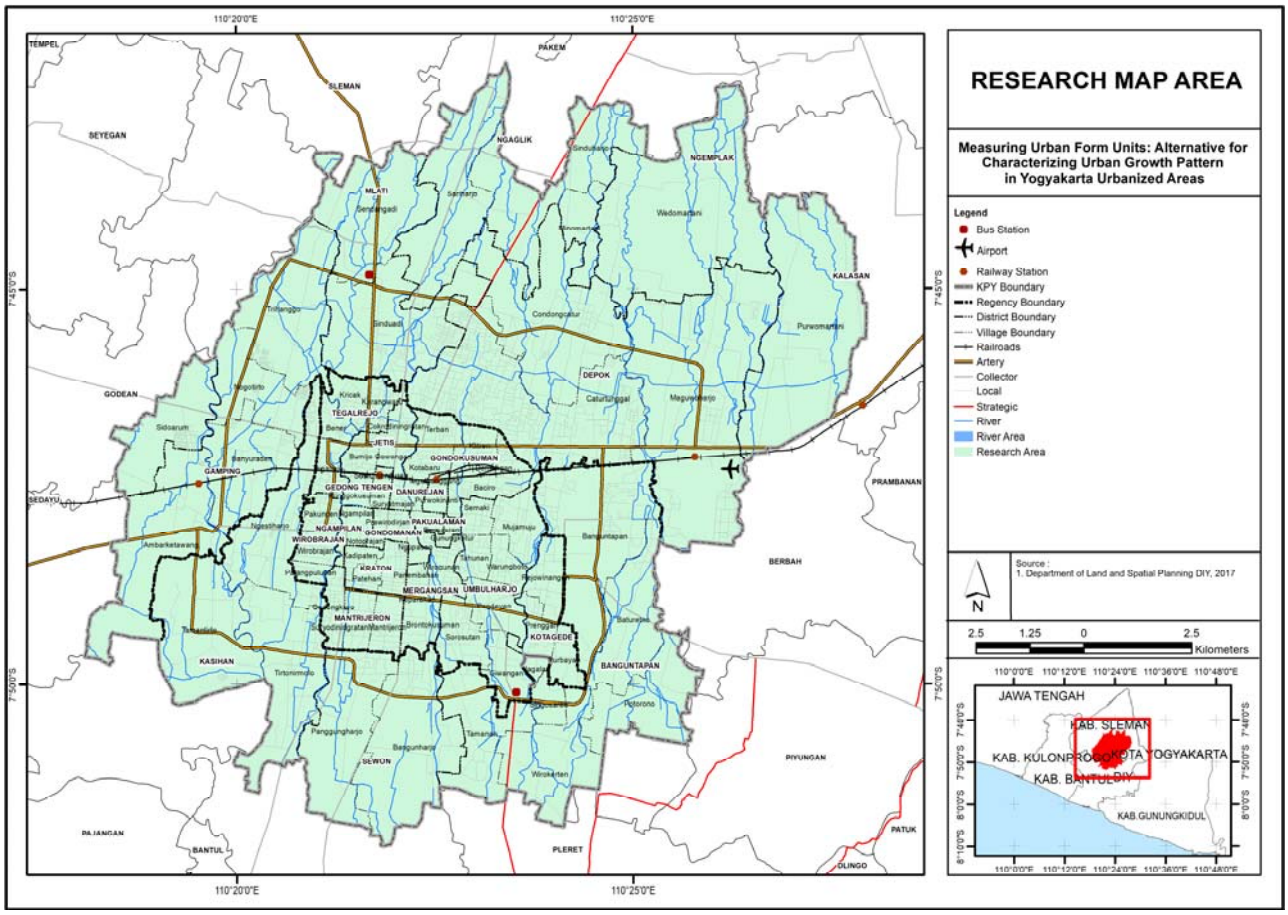

Figure 1. Research Area

Table 1. Data Sets

Variable	Operational
DENSITY Population density Built up area percentage	Total person per ha within the area Total built up area per total area
DIVERSITY Richness Index Land use variation	Ratio of its total land use groups Ratio of non-residential area per total area of its residential area
ACCESSIBILITY Number of transit stop Bus service coverage ratio	Total transit stops of TransJogja within the area Ratio between the length of TransJogja routes and total length of road within the area

Source: Analysis, 2018

The public transport service in Yogyakarta Special Province can be categorized into 4 type of services which are public transport (city bus and TransJogja), ojek, taxi, and non-motorized transportation (becak and andhong). TransJogja is expected to be the most reliable public transport services in Yogyakarta area which classified as Bus Rapid Transit (BRT) system. Accessibility towards public transportation service was measured through calculating the bus service coverage rate (BSCR) as the ratio between the length of TransJogja routes and total length of road. To represent the public transport service level in all Yogyakarta urbanized area, we divided the value of BSCR into three categories: low bus service coverage ratio (BSCR = < 0,1); middle bus service coverage ratio (BSCR = 0,1 – 0,3); high bus service coverage ratio (BSCR = > 0,3).

After we collecting the values of six variables, we classified the region into three categories which are low, middle, and high based on the interval class within the value. The classification of six variables in this study is shown in Table 2. The values of these variables were averaged and used to divide the urban forms into three domains (high compact, middle compact and low compact). High compact has high value of density, diversity and accessibility, whilst medium compact and low compact have medium and low value of these three factors accordingly.

Table 2. Interval Value Classification between Variables

Interval Class	Population density	Built-up area percentage	Richness index	Land use variation	Number of transit stop	Bus service coverage area
Low	<45	<68	<0,33	0	<1	<0,1
Middle	45-149	68-97	0,33-0,67	0-0,045	1-5	0,1-0,3
High	>149	>97	>0,67	>0,045	>5	>0,3

Source: Analysis, 2018

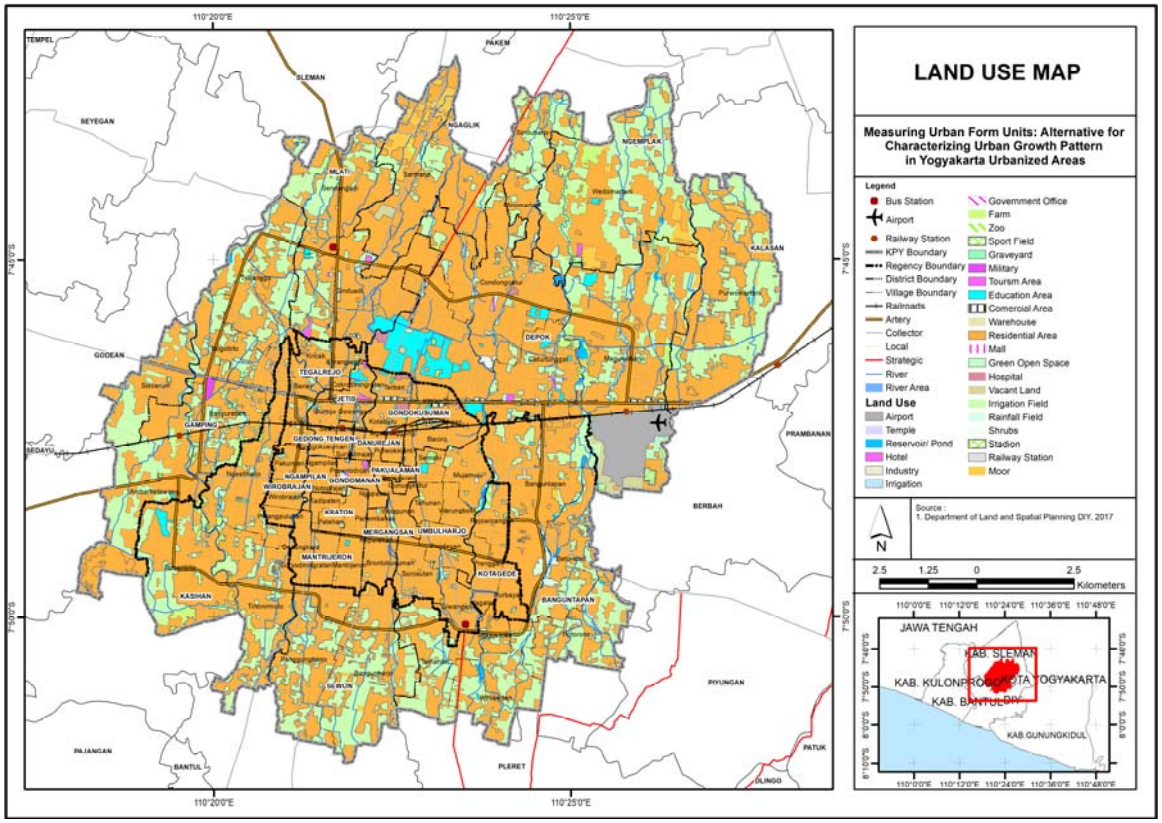

Figure 2. Land Use Map

3. Result and Discussion

Land Use Characteristics

DIY Agriculture Office (BPS, 2016) states that the conversion of agricultural land in DIY reaches 200 - 250 Ha per year, where most of it occurs in urban and periphery areas. In the city of Yogyakarta, agricultural land is only 56 hectares or only around 2% of the total city area of 3,250 ha. Subsequent land use in YUA is 5.14% of dry land / gardens / fields / yards, riverbanks in YUA reaches 4.17%, and the remaining 5.48% for other sectors such as education, trade and services, Public facilities, green open spaces, ponds / ponds and so on. Having this on mind, most of the area is dominated by densely populated residential areas in the central part of the city, while in the outer border (periphery) agricultural land remains stable as display on the Figure 2.

Looking at the land use distribution patterns in YUA, several lands greatly impact the patterns of community travel, namely settlements, offices, education, shopping centres, and trade and services. In the context of residential, it takes 66,37% of the total area of YUA. Mainly this residential area is centrally located in the centre of YUA since the region has good accessibility for transportation and public facilities.

Commercial Activity Characteristics

Yogyakarta Urban Growth follows a concentric pattern, where the City of Yogyakarta acts as a centres of growth. Growth centres for trade activities and services are developed from Jalan Malioboro to eastward (Jalan Solo) and partly to the north (Jalan Magelang). This development follows the city's growth and the improved road infrastructure. The centres for trading and economic activities in the Yogyakarta Urban Area occur by following the arterial and collector roads. Drawing idea from this, the total market is 175 markets, of which 27 markets are in Yogyakarta City, 8 markets are in the Bantul Regency, and as many as 140 markets are in Sleman Regency. In addition to the market presence, the trade sector is also dominated by 1777 shops, of which 890 shops are in Sleman Regency, 692 stores are in Yogyakarta City, and 195 stores are in Bantul Regency.

The number of hotels in Yogyakarta Urban Area is 306 buildings, of which 236 are in Yogyakarta City, 10 hotels are in Bantul Regency, and 60 hotels are in Sleman Regency. The most hotel facilities are in Gedong Tengen Subdistrict as many as 50 hotels, which are influenced by the Malioboro area as a tourism and trade centre of Yogyakarta City. The number of tertiary educational institutions in the city of Yogyakarta has reached 65. Meanwhile, the growth of education facilities is dominated by the northern region of the Yogyakarta Urban Area. The number of tertiary institutions in Sleman currently amounts to 30 private universities and 5 state universities.

Urban Form Classification

This section discusses the urban form classification through the measurement of density, diversity, and accessibility variable. In line with the aforementioned urban form variables, density is identified as population density and percentage of built-up area, diversity is identified as the Richness Index and variation in land use, and accessibility is identified as the number of public transport stops and ratio of coverage of public transportation services (Bus Service Coverage Rate/BSCR),

Results show that the majority of population density in YUA is still low. Figure 3 presents, high population density are concentrated in the centre of the area in which it is located in city of Yogyakarta administrative area. The activity concentration in which directed in the heart region of Yogyakarta can be related to high population density in this area. District of Danurejan, Gedongtengen, and Ngampilan are reported to have the highest density of population within YUA. The plausible reason to this finding is high concentration of residential in these areas. People are tend to reside closely to the public facilities. As the central government is located in Danurejan, this area provides good facilities, good connectivities, and many commercial activities which mostly people are looking for. Figure 3 also shows that high coverage of built-up area are also concentrated within centre area of YUA. Meanwhile, the suburban areas have low percentage of built-up area which means this area is still dominated by agricultural land use.

Table 3 describes the results of urban form typology within YUA. Most of the areas are categorized as middle compact typology characteristics, in which 13 areas are included in the low compact typology, 49 areas are included in the middle compact typology, and the remaining 9 areas are grouped in the high compact typology. Middle compact typology is dominated by region within city of Yogyakarta administrative area. Surprisingly, Bantul regency is not considered as high compact compare to the all parts of YUA. It is clear that multiple functions are often associated with higher densities and a greater mixed used activities. The lower its density values, the more scattering the activities as represent in the low compact area through its diversity value. In contrast, area with large variations of its activities have more compact urban form than areas with low variation have. Great accessibility in areas with large variation is inevitable.

Figure 4 describes high compact typology of urban form is concentrated in the centre of YUA. Caturtunggal and Sinduadi area, as a part of Sleman regency, are categorized as high compact areas. The existence of higher education within this area has triggered the emergence of new activities to support the function of the area. Rapid development in this area is also correlated with the higher densities as well as creating a multifunctional used within the area. Former research finds that Sleman regency is one of the areas where attracts people to come because of its function as the base for economy activities and as the base for educational facilities (Giyarsih, Arif, & Alfana, 2013). It is indeed that Yogyakarta is experiencing the spatial expansion into its hinterlands and peripheries in order to accommodate the growing urban population along with urban activities.

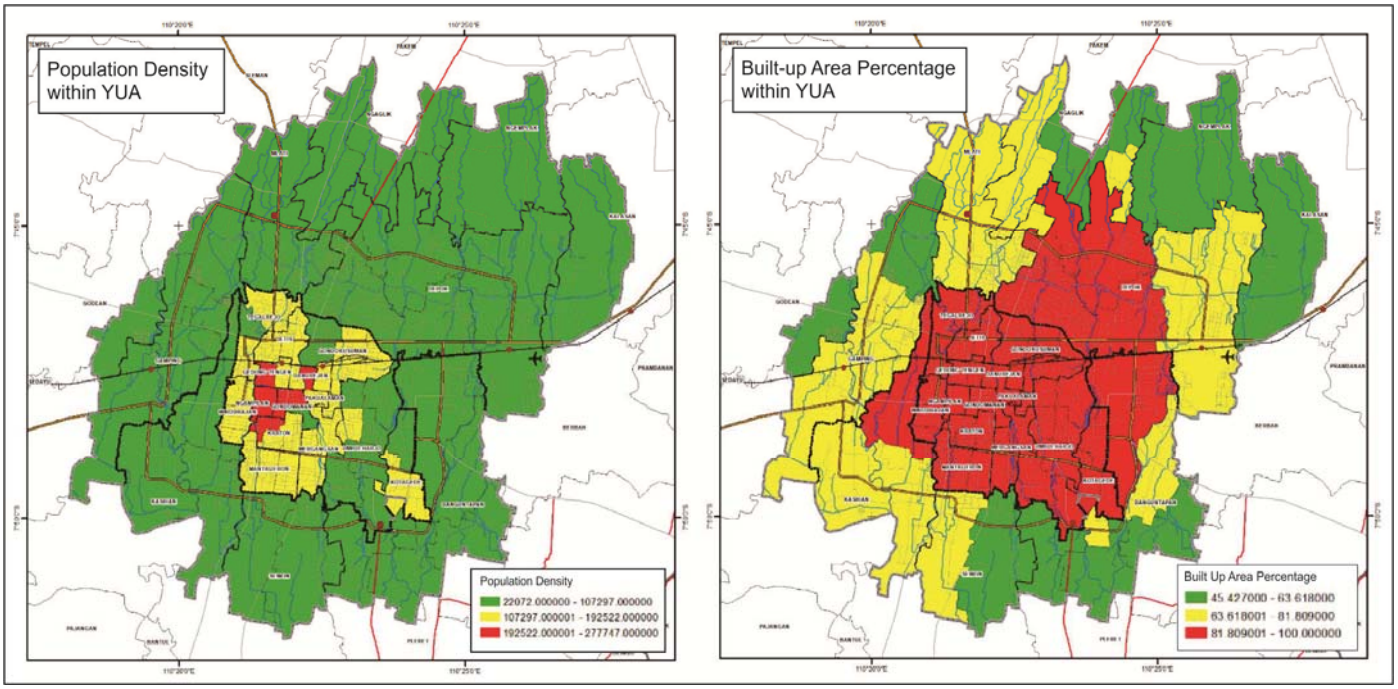

Figure 3. Density overview within YUA which seen through population and built-up area

Table 3. Urban form classification in Yogyakarta Urbanized Area

Urban Form Classification	Kabupaten/ Kota	Desa/ Kelurahan	DENSITY		DIVERSITY		ACCESIBILITY	
			Population Density	% Built-up Area	Richness Index	Land Use Variation	Transit Stops	Bus Service Coverage Rate
LOW COMPACT	Yogyakarta (3)	Panembahan, Patehan, Tahunan	136,068	97,453	0,278	0	0,667	0,009
	Sleman (5)	Sinduharjo, Minomartani, Wedomartani, Sidoarum, Purwomartani	42,331	58,984	0,600	0,011	0	0,006
	Bantul (5)	Wirokerten, Potorono, Tamanan, Singosaren, Bangunharjo	40,830	53,883	0,333	0	1,400	0,055
MIDDLE COMPACT	Yogyakarta (35)	Purbayan, Kadipaten, Suryodiningratan, Wirogunan, Brontokusuman, Wirobrajan, Keparakan, Bener, Warungboto, Sorosutan, Pakuncen, Prawirodirjan, Rejowinangun, Gedongkiwo, Gunungketur, Tegalrejo, Karangwaru, Pandeyan, Semaki, Giwangan, Patangpuluhan, Pringgokusuman, Ngupasan, Prenggan, Mantrijeron, Ngampilan, Notoprajan, Kricak, Muja-Muju, Tegal Panggung, Demangan, Baciro, Kotabaru, Cokrodiningratan, Purwokinanti	137,251	95,104	0,429	0,034	3,114	0,253
	Sleman (5)	Sariharjo, Nogotirto, Banyuraden, Maguwoharjo, Condongcatur	36,945	66,919	0,646	0,067	3,875	0,148
	Bantul (9)	Panggungharjo, Baturetno, Tirtonirmolo, Sendangadi, Trihanggo, Ambarketawang, Ngestiharjo, Tamantirto, Banguntapan	60,161	72,668	0,556	0,013	5	0,154
HIGH COMPACT	Yogyakarta (7)	Klitren, Bumijo, Gowongan, Suryatmajan, Bausasran, Sosromenduran, Terban	153,785	97,453	0,690	0,234	3	0,399
	Sleman (2)	Caturtunggal, Sinduadi	48,913	85,583	1	0,224	25	0,196
	Bantul (0)	-						

Source : Analysis, 2018

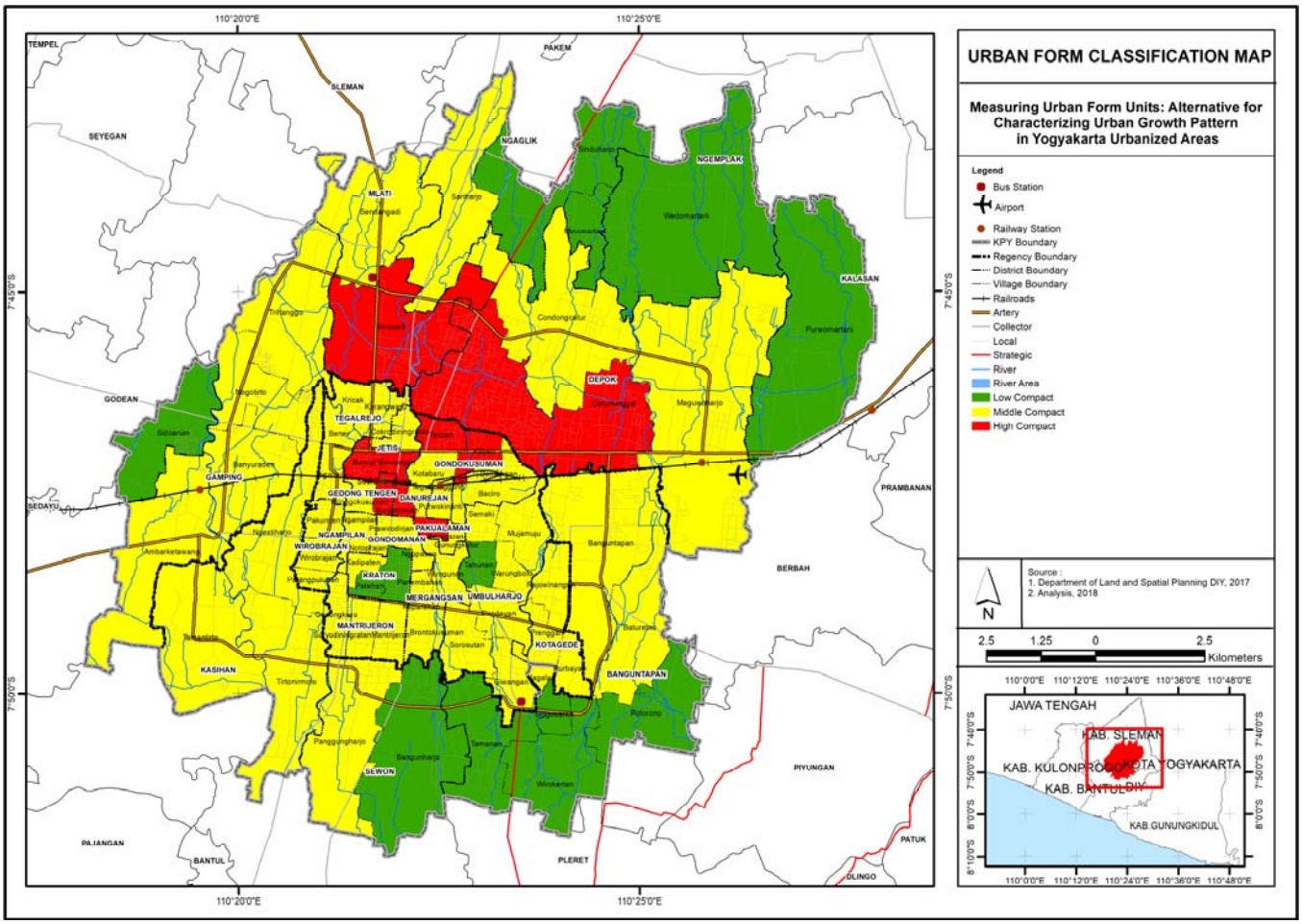

Figure 4. Classification of urban form typology in Yogyakarta Urbanized Area

Currently, the principal foundation for characterizing urban development and making urban comparisons is by using demographic-measure city population size (Stokes & Seto, 2019). Yuan et al. (Yuan, Song, Huang, Hong, & Huang, 2018) evaluate urban forms with six multiple dimensions which are population density, degree of centralization, mixed land use, street accessibility, shape complexity, and urban continuity. In the context of methodology approach, many studies use GIS and remote sensing methods to quantify and describe urban growth model (Almdhun, Mallak, Aburas, Md Said, & Ghadiri, 2018; Jiao, 2015; Shi, Sun, Zhu, Li, & Mei, 2012). Moreover, former study using Dublin city as the case study measures urban form changes by analysing street network design, land use mix, and density in community scale applying GIS functions (Nedovic-Budic, Knaap, Shahumyan, Williams, & Slaev, 2016). This study enriches the findings in characterizing urban expansion by using combination of variables in density, diversity, and accessibility. Results from this study confirm previous findings that urban expansion happens in a large scale. However, the expansion that is associated with sprawl in which characterized by low density, diversity, and accessibility in suburban area while the high concentration of activities is located in urban centre area. This high concentration of activities is associated with higher level of compactness which measured through its density, diversity, and accessibility.

4. Conclusion

This paper gives brief understanding on how to define urban form unit in the urban areas by quantifying the variables. The measurements of urban form units can be used to investigate other sustainability issues, particularly in transportation issues and quality of life. Therefore, this study can contribute significantly to the debate on building sustainable urban form in developing countries.

The major findings are summarized as, first, the urban growth of YUA is concentrated in the centre of YUA which shown through the characteristic of its high compact urban form. Another finding is, the agglomeration in the context of YUA mostly happen in Sleman regency which located in the north of the area. Although Sleman regency is considered as high compact area, higher education activities are the trigger to the emergence of rapid development within surrounded area. Last but not least, the majority of the area in YUA is classified as middle compact typology where most of them is in the city of Yogyakarta administrative area. Meanwhile, the area which categorized as low compact typology are located in the hinterland area of Yogyakarta. In the low compact and middle compact area, there should be policies to increase multifunctional use and accessibility within area in order to create more compact area development and sustainable urban form.

It is indeed that the indicators described in the paper have numbers of drawbacks that need to be taken into account for further development of this empirical work.

Moreover, there is also the opportunity to improve the methods for clustering the urban form typology as in this paper we used the basic statistical value in grouping the typology.

Acknowledgement

This research was fully funded by the Minister of Research, Technology, and Higher Education of Republic Indonesia, contract number 03.b/STTNAS/P3M/Pen.DRPM/III/2018.

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Measuring Urban Form Units: Alternative for Characterizing Urban Growth Pattern in Yogyakarta Urbanized Areas

1. ***Abstract*** *Urban area is always expanding into its surrounded area which then creating a well-known urban agglomeration area. Yogyakarta is one of city in Indonesia which experience urban agglomeration called by Yogyakarta Urbanized Area (YUA). YUA actually has different characteristic for its whole area. In this paper, we tried to identify the character of each part of YUA through measuring its urban form unit. We are concerned towards how does actually the characteristic of urban form distributed within YUA. A quantitative measure was proposed for classifying the urban form typology. Density, diversity, and accessibility were used to represent the urban form characteristic. In order to explain the urban form characteristic, we categorized the typology into three group which are low compact, middle compact, and high compact. The result show that the majority of the area in YUA is classified into middle compact typology where most of them are in the city of Yogyakarta administrative area. Meanwhile, the area which categorized as low compact typology are located in the hinterland area of Yogyakarta. High compact typology are concentrated in the centre of YUA in which it has the highest activity concentration for the whole urban structure context. At the end, this paper provides an important note about the distribution of urban form typology in the agglomeration area for constructing policy regarding the utilization of urban space.* **Please add conclusions to the Abstract**

Key words: urban form, urban growth, agglomeration

Abstrak *Daerah perkotaan selalu berkembang ke daerah sekitarnya, yang kemudian menciptakan area aglomerasi perkotaan. Yogyakarta adalah salah satu kota dengan aglomerasi perkotaan yang kemudian disebut sebagai Kawasan Perkotaan Yogyakarta (KPY). KPY sebenarnya memiliki karakteristik yang berbeda untuk seluruh wilayahnya. Dalam tulisan ini, kami mencoba untuk mengidentifikasi karakter masing-masing bagian dari KPY dengan mengukur unit dari bentuk perkotaannya. Dalam hal ini kami mencoba untuk menganalisis tentang bagaimana karakteristik bentuk-bentuk kota terdistribusi di wilayah KPY. Dalam mengklasifikasikan tipologi bentuk perkotaan, kami menggunakan metode pengukuran dengan pendekatan kuantitatif. Kepadatan, keragaman, dan aksesibilitas digunakan untuk mewakili karakteristik bentuk perkotaan. Untuk menjelaskan karakteristik bentuk perkotaan, kami mengkategorikan dalam tiga kelompok bentuk kota yaitu area dengan tingkat kekompakan rendah, menengah, dan tinggi. Hasil menunjukkan bahwa sebagian besar wilayah di KPY diklasifikasikan ke dalam tipologi tingkat kekompakan menengah dengan sebagian besar wilayah administrasi berada di Kota Yogyakarta. Sementara itu, daerah yang dikategorikan sebagai tipologi kekompakan rendah terletak di daerah pinggiran Yogyakarta. Tipologi area dengan kekompakan yang tinggi terkonsentrasi di pusat KPY di mana wilayah ini memiliki aktivitas konsentrasi tertinggi untuk keseluruhan konteks struktur perkotaan. Pada akhirnya, tulisan ini memberikan catatan penting tentang distribusi bentuk tipologi perkotaan di daerah aglomerasi untuk membangun kebijakan mengenai pemanfaatan ruang perkotaan.*

Kata kunci *:* urban form, urban growth, agglomeration

1. Introduction

The majority of world's population are predicted to live in cities. The expectation is that by 2030 nearly 60 percent of world's people will live in cities (UNFPA, 2000). In this context,

cities in developing countries will suffered the most as urbanisation will happened in the large scale while at the same time the urban infrastructure haven't been able to accommodate the population. According to the data that are released by Statista (2017), about 55 percent of Indonesia's population lived in urban areas. The high urbanization and rapid growth of the urban population in Indonesia are happened on a large scale. The percentage of the urban population in Indonesia, between 2010 and 2035, continues to increase. In 2010, it was almost 50% which then increased to 53,3% in 2015. However, it is predicted to be 60% by 2025 and even reaches 63,4% by 2030 (BPS, 2015). The growth of urban population requires serious attention from stakeholders, especially urban planners. Increasing population which followed by rapid urbanisation has important implications for the expanded of its urban area. In turn, this causes a typical what so called urban agglomeration within its surrounded area as a consequence. This rapid urbanisation caused a wide range of urban problems including urban sprawl as the urban activities are expanded within its surrounded area.

Sprawl is often defined by four land use characteristics: low density; scattered development (i.e. decentralised sprawl); commercial strip development; and, leapfrog development (Ewing, 1997). It can be described as an overall low density development or a scattered or leapfrog development with a daily commuting of its people relying on the automobile (Galster et al., 2001; Kasanko et al., 2006; Roo and Miller, 2000; Uhel, 2006 cited in Abrantes et al., 2017).

Handy (1996) defined urban form as a composite of characteristics related to land use patterns, transportation system, and urban design. Urban form can be further described conceptually as the spatial pattern of human activities including the physical configuration of a city as well as the land use patterns, population and housing densities, infrastructure and amenities, and transport and communication networks (Anderson et al., 1996 cited in Tsai, 2005; Abrantes, et al., 2017). Actually, from various geographical scales, urban form can be viewed and classified into such levels as metropolitan area, city, and even neighbourhood. The reason for this classification is twofold. First, some urban form variables operate only at certain levels, such as the job-housing balance variable. Secondly, urban form variables (such as density) may carry different meanings at different levels and may differently affect human activities, such as travel behaviour (Tsai, 2005). To sum up the concept of urban form, urban form is a result of the bringing together of many elements-concepts: the urban pattern (Jabareen, 2006).

Longstanding attempts to quantify urban sprawl focus on the growth of suburbs relative to central cities in which showing that suburbs have grown more rapidly than the central cities

they surround (Chinitz, 1965). Song and Knaap (2004) measures urban form by using street design and circulation systems, density, land use mix, accessibility, and pedestrian access to evaluate the development patterns in Portland, Oregon. Among several variables that been used to identify urban form, population density and land use cover are the key variables in which can further define the typology of urban areas (Abrantes et al., 2017).

As urban sprawl triggers many negative implications towards environment, social, and economic **(Give a concrete example of the negative impact of urban sprawl symptoms on environment, social, and economy)**

there is envision for many urban planners in the 21st century to create places with more compact design, more accessible to public transportation, and less driving The key principles which are proposed in order to create more sustainable urban form, are by promoting walkability and connectivity, mixed land uses, and high density (Rukmana, 2018). Newman and Kenworthy (2000) found that the compact city emerges as the most fuel-efficient of urban forms. He concluded that urban form does matter, and not just for urban air quality. Compactness also does not have a generally accepted definitions. Gordon and Richardson (1997) defined compactness as high-density or monocentric development. Ewing's definition (1997) was some concentration of employment and housing, as well as some mixture of land uses. Alternatively, Anderson et al. (1996) defined both monocentric and polycentric forms as being compact. To conclude the definition, compactness refers to urban continuity (and connectivity), which suggest that future urban development should take place adjacent to existing urban structures (Wheeler, 2002) as it brings the concentration of development (Tsai, 2005).

1. The study on urban form has been of growing interest in international research area for past decades. However, in Indonesia context, we still lack of theoretical and empirical works to address urban structure using quantitative measures. In fact, understanding urban form can lead to better decisions on urban transportation, growth strategy, as well as the development of infrastructure (Kashem, Chowdhury, Majumder, and Rahman, 2009). In recent years, a number of quantitative variables have been developed to characterise urban sprawl. However, some gaps still exist in the definitions of compactness and sprawl, and in appropriate quantitative variables. This paper aims to characterise quantitatively urban form in general and to distinguish compactness from sprawl in particular by using urbanized area case. It starts with a literature review of definitions of urban form and definitions of compactness and sprawl. Secondly, it defines theoretically different dimensions of metropolitan form, accompanied with appropriate quantitative indexes in which the degrees of compactness and sprawl revealed.**(Please add the research objectives here)**

2. The Methods

2.1. Site Study

In terms of area coverage, this study took place in the Yogyakarta Urbanized Area (YUA) with the object of research is the built environment, particularly urban form characteristic in that location. The YUA covers 14 (fourteen) sub-districts in Yogyakarta City, 6 (six) sub-districts in Sleman Regency, and 3 (three) sub-districts in Bantul Regency.

Remove the institution emblem from the map

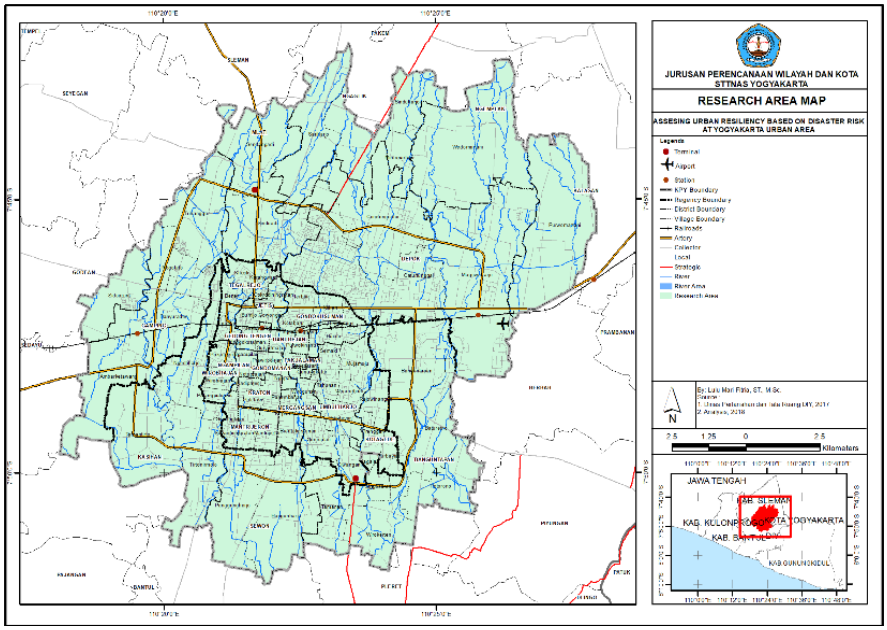

Figure 1. Research Area

The orientation on the map is upside down (must be reversed) so that it meets the cartographic rules

2.2. Data Sets and Analysis

This paper develops a set of quantitative variables to characterise urban forms at the metropolitan level, and in particular, to distinguish compactness from "sprawl". It first reviews and analyses past research on the definitions of urban form, compactness and sprawl, and corresponding quantitative variables. Density, diversity, and accessibility are often used to describe the urban form within region. Density is a critical typology in determining sustainable urban forms. It is the ratio of people or dwelling units to land area. Meanwhile diversity is a multidimensional phenomenon (Turner and Murray, 2001) that promotes further desirable urban features, including greater variety of housing types, building densities,

household sizes, ages, cultures, and incomes. Thus, diversity represents the social and cultural context of the urban form. Sometimes diversity is being relates to the mixed used in which in this context mixed land use indicates the diversity of functional land uses such as residential, commercial, industrial, institutional, and those related to transportation.

To represent density, diversity, and accessibility in deeper context, six quantitative variables are developed to measure six dimensions of urban form: population density, richness index, bus service coverage area index, number of transit stops, built-area ratio, and land use variation. The data sets are display on the Table 1 below.

Table 1. Data Sets

Variable	Operational
DENSITY	
- Population density	- Total person per ha within the area
- Built up area percentage	- Total built up area per total area
DIVERSITY	
- Richness Index	- Ratio of its total land use groups
- Land use variation	- Ratio of non-residential area per total area of its residential area
ACCESSIBILITY	
- Number of transit stop	- Total transit stops of TransJogja within the area
- Bus service coverage ratio	- Ratio between the length of TransJogja routes and total length of road within the area

Source: Analysis, 2018

Please explain how you combine different size and measurement units, as presented in Table 1

The public transport service in Yogyakarta Special Province can be categorized into 4 type of services which are public transport (city bus and TransJogja), ojek, taxi, and non-motorized transportation (becak and andhong). TransJogja is expected to be the most reliable public transport services in Yogyakarta area which classified as Bus Rapid Transit (BRT) system. Accessibility towards public transportation service was measured through calculating the bus service coverage rate (BSCR) as the ratio between the length of TransJogja routes and total length of road. To represent the public transport service level in all Yogyakarta urbanized area, we divided the value of BSCR into three categories: low bus service coverage ratio

(BSCR = < 0,1); middle bus service coverage ratio (BSCR = 0,1 – 0,3); high bus service coverage ratio (BSCR = > 0,3).

There are several ways to categorize the typology of urban form. Jabareen (2006) classified urban form into four different types which are neo-traditional, compact city, urban containment, and eco city. The typology is described through several criteria such as density, diversity, mixed land use, compactness, sustainable transportation, passive solar design, and greening ecological design. Using different perspective, Jackson-Smith et al. (2016) further clustered the urban form that have been linked to its water system characteristics. For this paper, we categorized the urban form typology into three categories based on the level of its compactness: low compact, middle compact, and high compact typology. The categorization is set upon the average values of all the density, diversity, and accessibility.

3. Result and Discussion

3.1. Land Use Characteristics

DIY Agriculture Office (2016) states that the conversion of agricultural land in DIY reaches 200 - 250 Ha per year, where most of it occurs in urban and periphery areas. In the city of Yogyakarta alone, agricultural land is only 56 hectares or only around 2% of the total city area of 3,250 ha. Subsequent land use in KPY is for 5.14% of dry land / gardens / fields / yards, riverbanks in KPY reaches 4.17%, and the remaining 5.48% for other sectors such as education, trade and services, Public facilities, green open spaces, ponds / ponds and so on. It is seen that most of the area is dominated by densely populated residential areas in the central part of the city, while in the outer border (periphery) there is still agricultural land as display on the Figure 2.

Of the land use distribution patterns that exist in the Yogyakarta Urbanized Area, several land use functions greatly influence the patterns of community travel, namely settlements, offices, education, shopping centres, and trade and services. The majority of land use distribution in YUA is residential which comprising 66,37% of the total area of YUA. The distribution of this residential area is centrally located in the city centre of YUA as this region has good accessibility for the transportation as well as the public facilities.

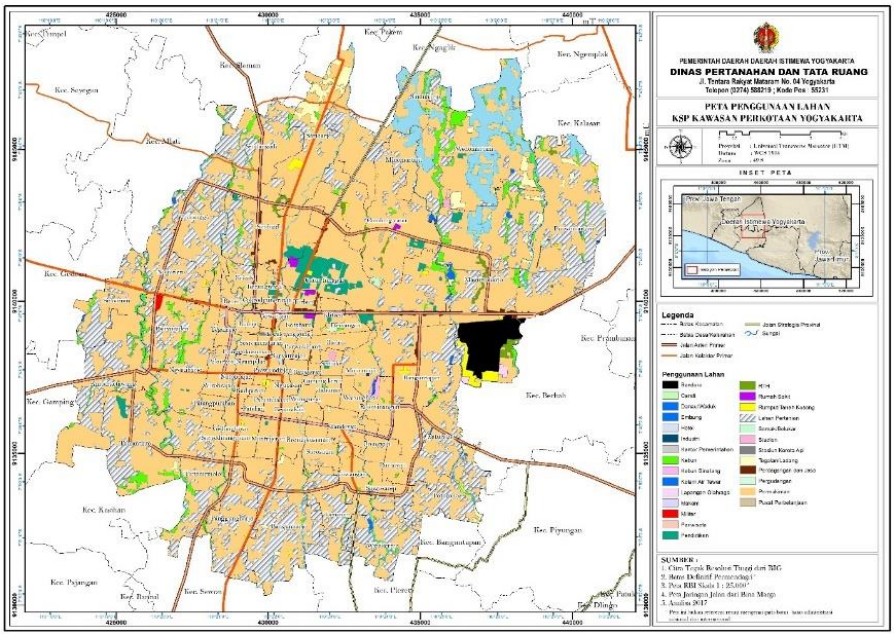

Figure 2. Land Use Map

The maps must be arranged in English

3.2. Commercial Activity Characteristics

Yogyakarta Urban Growth follows a concentric pattern, where the City of Yogyakarta acts as a centres of growth. Growth centres for trade activities and services developed from Jalan Malioboro and developed eastward (Jalan Solo) and partly to the north (Jalan Magelang) following the city's growth along with improved road infrastructure. The centres for the development of trade and economic activities in the Yogyakarta Urban Area have character, which is growing following the arterial and collector roads. Based on the analysis, it is found that the total market is 175 markets, of which 27 markets are in Yogyakarta City, 8 markets are in the Bantul Regency, and as many as 140 markets are in Sleman Regency. In addition to the market presence, the trade sector is also dominated by 1777 shops, of which 890 shops are in Sleman Regency, 692 stores are in Yogyakarta City, and 195 stores are in Bantul Regency.

The number of hotels in Yogyakarta Urban Area is 306 buildings, of which 236 are in Yogyakarta City, 10 hotels are in Bantul Regency, and 60 hotels are in Sleman Regency. The most hotel facilities are in Gedong Tengen Subdistrict as many as 50 hotels, which are influenced by the Malioboro area as a tourism and trade centre of Yogyakarta City. The number of tertiary educational institutions in the city of Yogyakarta has reached 65. Meanwhile, the growth of education facilities is dominated by the northern region of the

Yogyakarta Urban Area. The number of tertiary institutions in Sleman currently amounts to 30 private universities and 5 state universities.

3.3. Urban Form Classification

This section discussed the urban form classification through the measurement of density, diversity, and accessibility variable. Based on the urban form variable used as mentioned in the methodology section, namely density identified from population density and percentage of built-up area, diversity identified from the Richness Index and variation in land use, and accessibility identified from the number of public transport stops and ratio of coverage of public transportation services (Bus Service Coverage Rate/BSCR), it can be grouped into research areas based on the characteristics of the urban typology form that is owned.

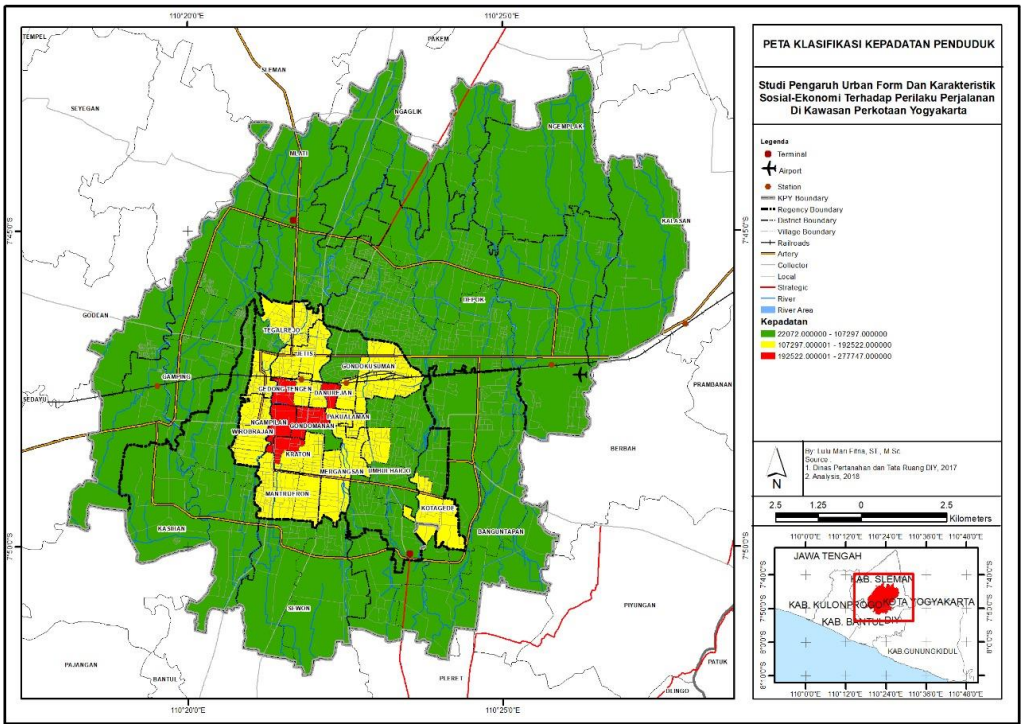

Figure 3. Distribution of population density within YUA

The maps must be arranged in English

Results show that the majority of population density in YUA is still low. According to Figure 3, high population density are concentrated in the centre of the area in which it is located in city of Yogyakarta administrative area. The activity concentration in which directed in the heart region of Yogyakarta can be related to high population density in this area. District of Danurejan, Gedongtengen, and Ngampilan are reported to have the highest density of population within YUA. High concentration of residential in these areas are one of the reason

to this condition. People are tend to reside close to the public facility. As central government is located in Danurejan, this area provide good facilities as well as connectivity into commercial activities in which supported people daily needs.

Table 2. Urban form classification in Yogyakarta Urbanized Area

No.	Regency	Sub District	Village	DENSITY		DIVERSITY		ACCESIBILITY		Urban Form Typology
				Population Density	% Built Area	Richness Index	Land Use Variation	Transit Stop Number	Bus Service Coverage Rate	
1	Bantul	Banguntapan	Wirokerten	42,799	48,123	0,33333	0	0	0	LOW COMPACT
2	Bantul	Banguntapan	Potorono	35,674	45,427	0,33333	0	0	0	
3	Bantul	Banguntapan	Tamanan	39,892	52,377	0,33333	0	1	0,0877	
4	Bantul	Banguntapan	Singosaren	40,924	72,978	0,33333	0	0	0	
5	Sleman	Ngaglik	Sinduharjo	33,528	59,864	0,5	0,0038	0	0	
6	Sleman	Ngaglik	Minomartani	81,094	73,506	0,33333	0	0	0	
7	Sleman	Ngemplak	Wedomartani	22,072	45,983	0,66667	0,0058	0	0	
8	Sleman	Godean	Sidoarum	44,844	62,569	0,5	0,0347	0	0	
9	Yogyakarta	Kraton	Panembahan	143,983	100	0,16667	0	0	0	
10	Yogyakarta	Kraton	Patehan	150,476	95,753	0,33333	0	0	0	
11	Yogyakarta	Umbulharjo	Tahunan	113,745	96,606	0,33333	0	2	0,0271	
12	Bantul	Sewon	Bangunharjo	44,863	50,509	0,33333	0	6	0,1863	
13	Sleman	Kalasan	Purwomartani	30,116	52,999	1	0,0125	0	0,0321	
14	Yogyakarta	Kotagede	Purbayan	134,123	99,632	0,33333	0	1	0,0722	MIDDLE COMPACT
15	Yogyakarta	Kraton	Kadipaten	194,121	100,000	0,16667	0	0	0	
16	Yogyakarta	Mantrijeron	Suryodiningratan	120,433	96,129	0,33333	0	3	0,1462	
17	Yogyakarta	Mergangsan	Wirogunan	130,146	93,955	0,33333	0	5	0,2162	
18	Yogyakarta	Mergangsan	Brontokusuman	112,447	96,818	0,33333	0	2	0,2274	
19	Yogyakarta	Wirobrajan	Wirobrajan	138,358	95,918	0,33333	0	1	0,1535	
20	Bantul	Sewon	Panggungharjo	61,702	68,923	0,33333	0	2	0,1049	
21	Bantul	Banguntapan	Baturetno	32,547	65,036	0,83333	0,0255	2	0,0707	
22	Bantul	Kasihan	Tirtonirmolo	53,850	66,954	0,33333	0	6	0,1225	
23	Sleman	Mlati	Sendangadi	35,393	64,520	0,66667	0,0208	1	0,1294	
24	Sleman	Gamping	Trihanggo	31,345	52,080	0,5	0,0021	4	0,2024	
25	Sleman	Gamping	Ambarketawang	34,089	64,052	0,5	0,0013	2	0,1965	
26	Yogyakarta	Mergangsan	Keparakan	187,861	96,174	0,33333	0	3	0,1785	
27	Yogyakarta	Tegalrejo	Bener	82,888	86,307	0,5	0,0414	1	0,0470	
28	Yogyakarta	Umbulharjo	Warungboto	106,583	99,009	0,33333	0	1	0,2430	
29	Yogyakarta	Umbulharjo	Sorosutan	86,675	93,181	0,33333	0	8	0,1827	
30	Yogyakarta	Wirobrajan	Pakuncen	172,853	96,575	0,18182	0	2	0,1859	
31	Sleman	Ngaglik	Sariharjo	32,069	68,974	0,5	0,0061	2	0,1009	
32	Sleman	Gamping	Nogotirto	50,136	65,307	0,5	0,0279	5	0,1410	
33	Sleman	Gamping	Banyuraden	40,939	66,411	0,66667	0,0775	1	0,1189	
34	Yogyakarta	Gondomanan	Prawirodirjan	198,770	92,964	0,33333	0	3	0,3346	
35	Yogyakarta	Kotagede	Rejowinangun	100,286	88,034	0,33333	0	7	0,3174	
36	Yogyakarta	Mantrijeron	Gedongkiwo	155,409	97,432	0,33333	0	1	0,1571	

37	Yogyakarta	Pakualaman	Gunungketur	148,334	99,349	0,33333	0,0065	1	0,2257	
38	Yogyakarta	Tegalrejo	Tegalrejo	109,697	91,277	0,66667	0,0436	3	0,2153	
39	Yogyakarta	Tegalrejo	Karangwaru	135,140	95,620	0,66667	0,0471	0	0,2131	
40	Yogyakarta	Umbulharjo	Pandeyan	85,481	95,285	0,33333	0	8	0,3432	
41	Yogyakarta	Umbulharjo	Semaki	84,968	88,292	0,5	0,0907	5	0,2686	
42	Yogyakarta	Umbulharjo	Giwangan	57,762	86,088	0,33333	0	6	0,4038	
43	Yogyakarta	Wirobrajan	Patangpuluhan	164,245	97,541	0,33333	0	1	0,2387	
44	Bantul	Kasihan	Ngestiharjo	80,651	82,764	0,66667	0,0092	5	0,1451	
45	Bantul	Kasihan	Tamantirto	42,469	68,489	0,5	0,0359	8	0,2813	
46	Yogyakarta	Gedongtengen	Pringgokusu man	268,732	98,163	0,33333	0	1	0,4248	
47	Yogyakarta	Gondomanan	Ngupasan	83,435	95,713	0,66667	0,1710	2	0,2751	
48	Yogyakarta	Kotagede	Prenggan	108,632	98,064	0,33333	0	9	0,3239	
49	Yogyakarta	Mantrijeron	Mantrijeron	114,471	99,129	0,5	0,0163	1	0,3010	
50	Yogyakarta	Ngampilan	Ngampilan	223,449	98,699	0,33333	0	3	0,4621	
51	Yogyakarta	Ngampilan	Notoprajan	218,461	97,126	0,33333	0	3	0,4642	
52	Yogyakarta	Tegalrejo	Kricak	156,531	89,139	0,5	0,0479	3	0,0837	
53	Yogyakarta	Umbulharjo	Muja muju	67,226	83,933	0,5	0,0146	6	0,2794	
54	Bantul	Banguntapan	Banguntapan	89,746	83,842	0,66667	0,0068	7	0,2007	
55	Yogyakarta	Danurejan	Tegal panggung	277,747	99,023	0,5	0	1	0,3797	
56	Yogyakarta	Gondokusuman	Demangan	115,468	95,352	0,83333	0,1894	1	0,2223	
57	Yogyakarta	Gondokusuman	Baciro	109,677	99,771	0,5	0,0066	6	0,2576	
58	Yogyakarta	Gondokusuman	Kotabaru	37,017	94,842	0,83333	0,1478	4	0,4201	
59	Yogyakarta	Jetis	Cokrodining ratan	133,368	95,145	0,66667	0,3503	6	0,3051	
60	Yogyakarta	Pakualaman	Purwokinanti	182,982	98,974	0,5	0,0011	1	0,3005	
61	Sleman	Depok	Maguwoharjo	22,392	68,365	1	0,3695	10	0,1441	
62	Sleman	Depok	Condong catur	49,199	85,647	0,83333	0,0308	6	0,1485	
63	Yogyakarta	Gondokusuman	Klitren	134,800	99,975	0,66667	0,1782	2	0,3679	
64	Yogyakarta	Jetis	Bumijo	176,973	94,590	0,83333	0,1437	4	0,1783	
65	Yogyakarta	Jetis	Gowongan	191,521	94,313	0,5	0,4051	3	0,3808	
67	Sleman	Depok	Catur tunggal	45,530	90,659	1	0,2804	33	0,1665	
68	Sleman	Mlati	Sinduadi	52,297	80,507	1	0,1683	17	0,2260	HIGH COMPACT
69	Yogyakarta	Danurejan	Suryatmajan	162,562	97,235	0,66667	0,1401	2	0,5804	
70	Yogyakarta	Danurejan	Bausasran	152,850	100,000	0,5	0,1350	2	0,4820	
71	Yogyakarta	Gedongtengen	Sosromenduran	150,610	100,000	0,66667	0,2008	2	0,3203	
72	Yogyakarta	Gondokusuman	Terban	107,178	96,058	1	0,4343	6	0,4852	

Source : Analysis, 2018

Table 3 show the result of urban form typology within YUA. Most of the areas are categorized as middle compact typology characteristics, in which 13 areas are included in the low compact typology, 49 areas are included in the middle compact typology, and the remaining 9 areas are grouped in the high compact typology. Middle compact typology is comprised of city of Yogyakarta administrative area. Surprisingly, Bantul regency is not considered as high compact for its whole YUA part. It is clear that multiple functions are

often associated with higher densities as well as a greater mixed used activities exist. As the densities get lower, the activity is more spread out as represent in the low compact area through its diversity value. In contrast, area with large variation of its activities will have more compact urban form where also supported by great accessibility.

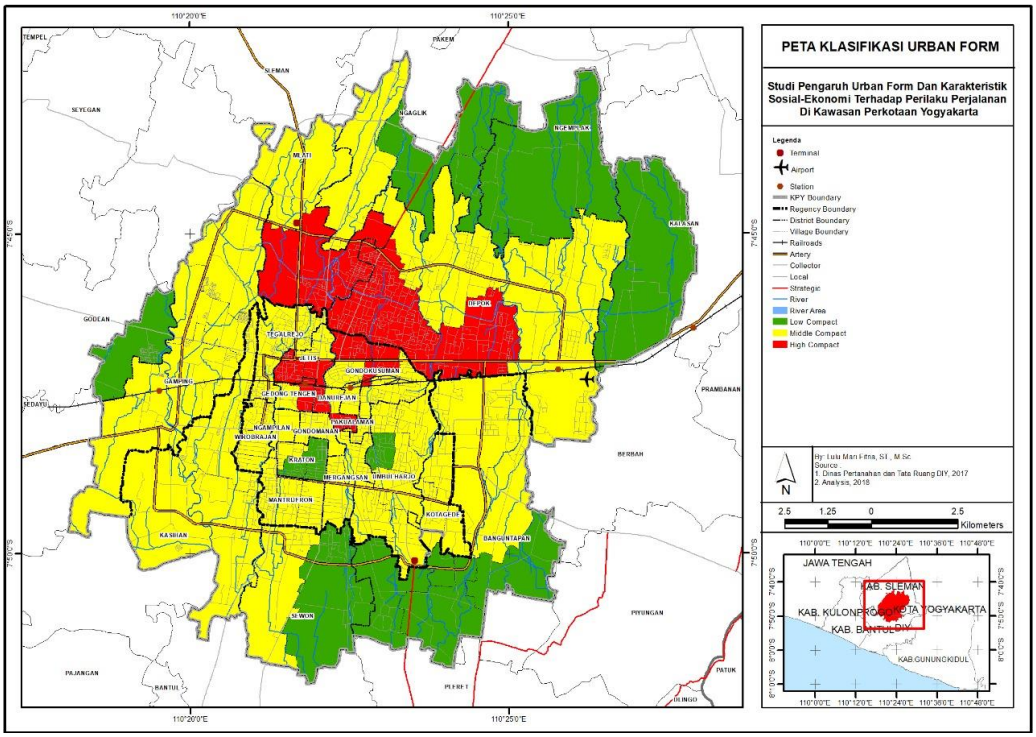

Figure 4. Classification of urban form typology in Yogyakarta Urbanized Area

The maps must be arranged in English

Through Figure 4, high compact typology of urban form is concentrated in the centre of YUA. Caturtunggal and Sinduadi area, as a part of Sleman regency, is categorized as high compact area. The existence of higher education within this area has triggered the emergence of new activities to support the function of the area. Rapid development in this area is also correlated with the higher densities as well as creating a multifunctional used within the area.

The results of this study must be linked to the results of previous studies (a theoretical dialogue must be carried out)

4. Conclusion

This paper gives brief understanding on how to define urban form unit in the urban areas by using simple quantitative measures. The measure of urban form units could be used to investigate other sustainability issues, particularly in relating to transportation issues and quality of life. Therefore, it can contribute significantly to the debate on building sustainable urban form in developing countries. It is indeed that the indicators described in the paper

have numbers of drawbacks that need to be taken into account for further development of this empirical work. Moreover, there is also the opportunity to improve the methods for clustering the urban form typology as in this paper we used the basic statistical value in grouping the typology.

The conclusions must refer to the purpose of the study

Acknowledgement

This research was fully funded by the Minister of Research, Technology, and Higher Education of Republic Indonesia. We would like to express our gratitude for all who has contributed in this research. **(The acknowledgments must be specifically addressed to individualsor institutions and mention their respective contributions to the study.**

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Measuring Urban Form Units: Alternative for Characterizing Urban Growth Pattern in Yogyakarta Urbanized Areas

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Abstract *Yogyakarta is one of cities in Indonesia which experiences urban agglomeration called by Yogyakarta Urbanized Area (YUA). We identified the character of each part of YUA through measuring its urban form unit. We are concerned towards how does actually the characteristic of urban form distributed within YUA. A quantitative measure was proposed for classifying the urban form typology. Density, diversity, and accessibility were used to represent the urban form characteristic. We categorized the typology into three group which are low compact, middle compact, and high compact. The result show that the majority of the area in YUA is classified into middle compact typology where most of them are in the city of Yogyakarta administrative area. Meanwhile, the area which categorized as low compact typology are located in the hinterland area of Yogyakarta. High compact typology are concentrated in the centre of YUA in which it has the highest activity concentration for the whole urban structure context. This study shows that characterizing the urban growth pattern with this method can distinguish urban form with different typology. At the end, this paper provides an important note about the distribution of urban form typology in the agglomeration area for constructing policy regarding the utilization of urban space.*

Key words: urban form, urban growth, agglomeration

Abstrak *Yogyakarta adalah salah satu kota dengan aglomerasi perkotaan yang kemudian disebut sebagai Kawasan Perkotaan Yogyakarta (KPY). Kami mengidentifikasi karakter masing-masing bagian dari KPY dengan mengukur unit dari bentuk perkotaannya. Dalam hal ini kami mencoba untuk menganalisis bagaimana karakteristik bentuk-bentuk kota yang terdistribusi di wilayah KPY. Dalam mengklasifikasikan tipologi bentuk perkotaan, kami menggunakan metode pengukuran dengan pendekatan kuantitatif. Kepadatan, keragaman, dan aksesibilitas digunakan untuk mewakili karakteristik bentuk perkotaan. Kami mengkategorikan dalam tiga kelompok bentuk kota yaitu area dengan tingkat kekompakan rendah, menengah, dan tinggi. Hasil menunjukkan bahwa sebagian besar wilayah di KPY diklasifikasikan ke dalam tipologi tingkat kekompakan menengah yang sebagian besar wilayah administrasinya berada di Kota Yogyakarta. Sementara itu, daerah yang dikategorikan sebagai tipologi kekompakan rendah terletak di daerah pinggiran Yogyakarta. Tipologi area dengan kekompakan yang tinggi terkonsentrasi di pusat KPY di mana wilayah ini memiliki aktivitas konsentrasi tertinggi untuk keseluruhan konteks struktur perkotaan. Studi ini menunjukkan bahwa pengelompokan pola pertumbuhan perkotaan dengan metode ini dapat membedakan bentuk kota dengan tipologi yang berbeda Pada akhirnya, tulisan ini memberikan catatan penting tentang distribusi bentuk tipologi perkotaan di daerah aglomerasi untuk membangun kebijakan mengenai pemanfaatan ruang perkotaan.*

Kata kunci : bentuk kota, pertumbuhan kota, aglomerasi

1. Introduction

The majority of world's population are predicted to live in cities. The expectation is that by 2030 nearly 60 percent of world's people will live in cities (UNFPA, 2007). In this context, cities in developing countries will suffered the most as urbanisation will happened in the large scale while at the same time the urban infrastructure haven't been able to accommodate the population. According to the data that are released by Statista (2017), about 55 percent of Indonesia's population lived in urban areas. The high urbanization and rapid growth of the urban population in Indonesia are happened on a large scale. The percentage of the urban population in Indonesia, between 2010 and 2035, continues to increase. In 2010, it was almost 50% which then increased to 53,3% in 2015. However, it is predicted to be 60% by 2025 and even reaches 63,4% by 2030 (BPS, 2015). The growth of urban population requires serious attention from stakeholders, especially urban planners. Increasing population which followed by rapid urbanisation has important implications for the expanded of its urban area. In turn, this causes a typical what so called urban agglomeration within its surrounded area as a consequence. This rapid urbanisation caused a wide range of urban problems including urban sprawl as the urban activities are expanded within its surrounded area.

Sprawl is often defined by four land use characteristics: low density; scattered development (i.e. decentralised sprawl); commercial strip development; and, leapfrog development (Ewing, 1997). It can be described as an overall low density development or a scattered or leapfrog development with a daily commuting of its people relying on the automobile (Galster et al., 2001; Kasanko et al., 2006; Roo and Miller, 2000; Uhel, 2006 cited in Abrantes et al., 2017). Higher environmental impacts were reported to be associated with low densities which is one of sprawl development characteristic (Camagni et al., 2002). In line with previous findings, Nechyba and Walsh (2004) mentioned that sprawl can be linked to environmental issues as lower-density development is associated with increases in emissions per mile travelled related to traffic congestion and increases in vehicle miles travelled. Moreover, urban sprawl has also reported to cause loss of productive agricultural lands, open green spaces, as well as loss of surface water bodies (Bhat et al., 2017). Social sector is also reported to have negatively affected by urban sprawl. People who live farther away from each other will have weak linkages within neighbours (Burchell et al. cited in Nguyen, 2010) as well as social segregation (Camagni and Gibelli cited in Camagni et al., 2002).

Handy (1996) defined urban form as a composite of characteristics related to land use patterns, transportation system, and urban design. Urban form can be further described conceptually as the spatial pattern of human activities including the physical configuration of a city as well as the land use patterns, population and housing densities, infrastructure and amenities, and transport and communication networks (Anderson et al., 1996 cited in Tsai, 2005; Abrantes, et al., 2017). Actually, from various geographical scales, urban form can be viewed and classified into such levels as metropolitan area, city, and even neighbourhood. The reason for this classification is twofold. First, some urban form variables operate only at certain levels, such as the job-housing balance variable. Secondly, urban form variables (such as density) may carry different meanings at different levels and may differently affect human activities, such as travel behaviour (Tsai, 2005). To sum up the concept of urban form, urban form is a result of the bringing together of many elements-concepts: the urban pattern (Jabareen, 2006).

Longstanding attempts to quantify urban sprawl focus on the growth of suburbs relative to central cities in which showing that suburbs have grown more rapidly than the central cities they surround (Chinitz, 1965). Song and Knaap (2004) measures urban form by using street design and circulation systems, density, land use mix, accessibility, and pedestrian access to evaluate the development patterns in Portland, Oregon. Meanwhile, Tsai (2005) tried to describe urban form by using three categories which are density, diversity, and the spatial-structure pattern. In contrast, Chin (2002) pointed out three principal dimensions of urban sprawl which are urban spatial scale, population density decline, and scattered urbanisation. Among several variables that been used to identify urban form, population density and land use cover are the key variables in which can further define the typology of urban areas (Abrantes et al., 2017).

Sustainable urban forms have been concern in the context of developed cities which described as “new urbanism” or the “compact city” (Abe and Kato, 2017). As urban sprawl triggers many negative implications towards environment, social, and economic, there is envision for many urban planners in the 21st century to create places with more compact design, more accessible to public transportation, and less driving. The key principles which are proposed in order to create more sustainable urban form, are by promoting walkability and connectivity, mixed land uses, and high density (Rukmana, 2018). Newman and Kenworthy (2000) found that the compact city emerges as the most fuel-efficient of urban

forms. He concluded that urban form does matter, and not just for urban air quality. Compactness also does not have a generally accepted definitions. Gordon and Richardson (1997) defined compactness as high-density or monocentric development. Ewing's definition (1997) was some concentration of employment and housing, as well as some mixture of land uses. Alternatively, Anderson et al. (1996) defined both monocentric and polycentric forms as being compact. To conclude the definition, compactness refers to urban continuity (and connectivity), which suggest that future urban development should take place adjacent to existing urban structures (Wheeler, 2002) as it brings the concentration of development (Tsai, 2005).

The study on urban form has been of growing interest in international research area for past decades. However, in Indonesia context, we still lack of theoretical and empirical works to address urban structure using quantitative measures. In fact, understanding urban form can lead to better decisions on urban transportation, growth strategy, as well as the development of infrastructure (Kashem et al., 2009). In recent years, a number of quantitative variables have been developed to characterise urban sprawl. However, some gaps still exist in the definitions of compactness and sprawl, and in appropriate quantitative variables. This paper aims to characterise quantitatively urban form in general and to distinguish compactness from sprawl in particular by using urbanized area case. The findings can be used to propose different types of urban policies and planning approaches based on the urban form typology as well as to attain sustainable travel. Moreover, by measuring the urban form unit, we can also reveal the trends of urban development in YUA context. The study starts with a literature review of definitions of urban form as well as definitions of compactness and sprawl. After that, we define theoretically different dimensions of metropolitan form, accompanied with appropriate quantitative indexes in which the degrees of compactness and sprawl revealed.

2. The Methods

2.1. Site Study

In terms of area coverage, this study took place in the Yogyakarta Urbanized Area (YUA) with the object of research is the built environment, particularly urban form characteristic in that location. The YUA covers 14 (fourteen) sub-districts in Yogyakarta City, 6 (six) sub-districts in Sleman Regency, and 3 (three) sub-districts in Bantul Regency.

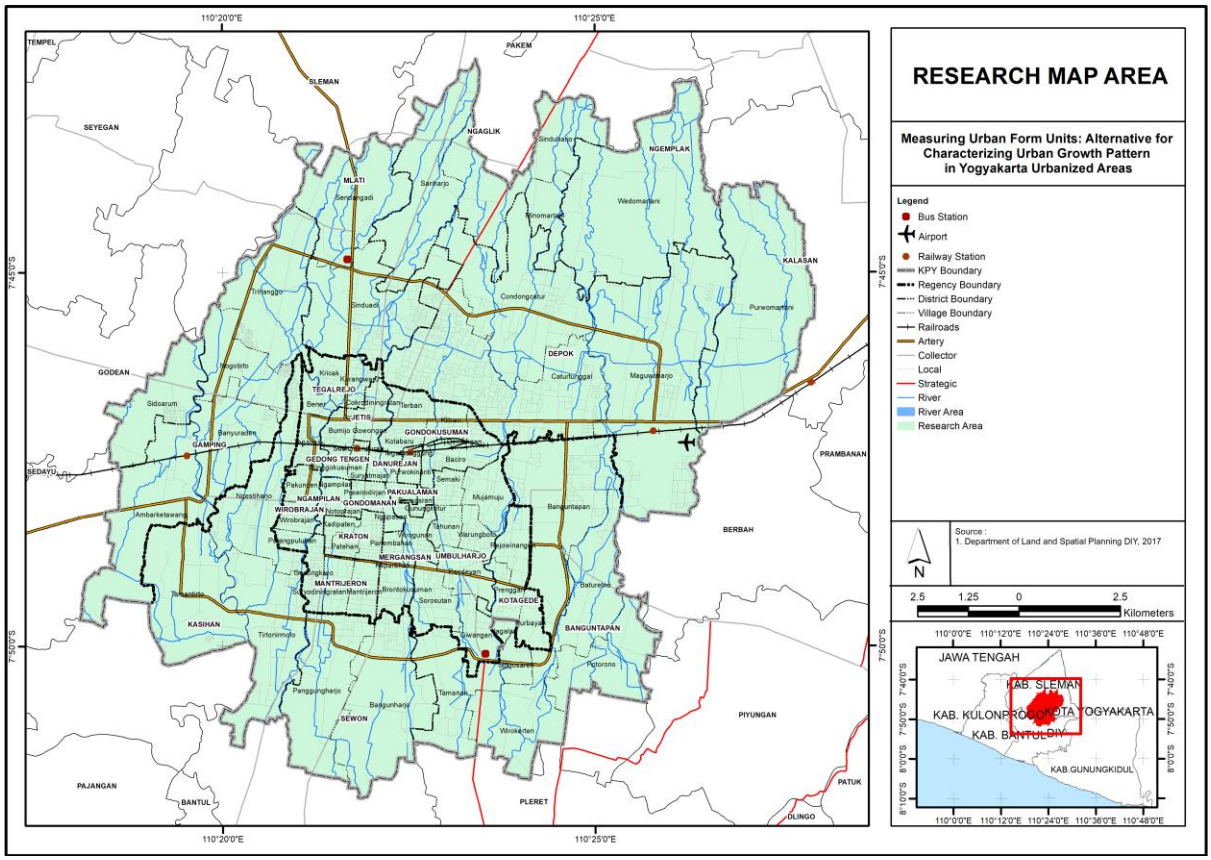

Figure 1. Research Area

2.2. Data Sets and Analysis

This paper develops a set of quantitative variables to characterise urban forms at the metropolitan level, and in particular, to distinguish compactness from "sprawl". It first reviews and analysis past research on the definitions of urban form, compactness and sprawl, and corresponding quantitative variables. Density, diversity, and accessibility are often used to describe the urban form within region. Density is a critical typology in determining sustainable urban forms. It is the ratio of people or dwelling units to land area. Meanwhile diversity is a multidimensional phenomenon (Turner and Murray, 2001) that promotes further desirable urban features, including greater variety of housing types, building densities, household sizes, ages, cultures, and incomes. Thus, diversity represents the social and cultural context of the urban form. Sometimes diversity is being relates to the mixed used in which in this context mixed land use indicates the diversity of functional land uses such as residential, commercial, industrial, institutional, and those related to transportation.

There are several ways to categorize the typology of urban form. Jabareen (2006) classified urban form into four different types which are neo-traditional, compact city, urban

containment, and eco city. The typology is described through several criteria such as density, diversity, mixed land use, compactness, sustainable transportation, passive solar design, and greening ecological design. Using different perspective, Jackson-Smith et al. (2016) further clustered the urban form that have been linked to its water system characteristics. For this paper, we categorized the urban form typology into three categories based on the level of its compactness: low compact, middle compact, and high compact typology.

To represent density, diversity, and accessibility in deeper context, six quantitative variables are developed to measure six dimensions of urban form: population density, richness index, bus service coverage area index, number of transit stops, built-area ratio, and land use variation. The data sets are display on the Table 1 below.

Table 1. Data Sets

Variable	Operational
DENSITY	
- Population density	- Total person per ha within the area
- Built up area percentage	- Total built up area per total area
DIVERSITY	
- Richness Index	- Ratio of its total land use groups
- Land use variation	- Ratio of non-residential area per total area of its residential area
ACCESSIBILITY	
- Number of transit stop	- Total transit stops of TransJogja within the area
- Bus service coverage ratio	- Ratio between the length of TransJogja routes and total length of road within the area

Source: Analysis, 2018

The public transport service in Yogyakarta Special Province can be categorized into 4 type of services which are public transport (city bus and TransJogja), ojek, taxi, and non-motorized transportation (becak and andhong). TransJogja is expected to be the most reliable public transport services in Yogyakarta area which classified as Bus Rapid Transit (BRT) system. Accessibility towards public transportation service was measured through calculating the bus service coverage rate (BSCR) as the ratio between the length of TransJogja routes and total length of road. To represent the public transport service level in all Yogyakarta urbanized area, we divided the value of BSCR into three categories: low bus service coverage ratio

(BSCR = < 0,1); middle bus service coverage ratio (BSCR = 0,1 – 0,3); high bus service coverage ratio (BSCR = > 0,3).

After we gather the values of six variables, we classified the region into three categories which are low, middle, and high based on the interval class within the value. The classification of six variables in this study is shown in Table 2 below. The values of these variables were averaged and used to divide the urban forms into three domains (high compact, middle compact and low compact). High compact has high value of density, diversity and accessibility, whilst medium compact and low compact have medium and low value of these three factors accordingly.

Table 2. Interval Value Classification between Variables

Interval Class	Population density	Built-up area percentage	Richness index	Land use variation	Number of transit stop	Bus service coverage area
Low	<45	<68	<0,33	0	<1	<0,1
Middle	45-149	68-97	0,33-0,67	0-0,045	1-5	0,1-0,3
High	>149	>97	>0,67	>0,045	>5	>0,3

Source: Analysis, 2018

3. Result and Discussion

3.1. Land Use Characteristics

DIY Agriculture Office (2016) states that the conversion of agricultural land in DIY reaches 200 - 250 Ha per year, where most of it occurs in urban and periphery areas. In the city of Yogyakarta alone, agricultural land is only 56 hectares or only around 2% of the total city area of 3,250 ha. Subsequent land use in KPY is for 5.14% of dry land / gardens / fields / yards, riverbanks in KPY reaches 4.17%, and the remaining 5.48% for other sectors such as education, trade and services, Public facilities, green open spaces, ponds / ponds and so on. It is seen that most of the area is dominated by densely populated residential areas in the central part of the city, while in the outer border (periphery) there is still agricultural land as display on the Figure 2.

Of the land use distribution patterns that exist in the Yogyakarta Urbanized Area, several land use functions greatly influence the patterns of community travel, namely settlements, offices, education, shopping centres, and trade and services. The majority of land use distribution in

YUA is residential which comprising 66,37% of the total area of YUA. The distribution of this residential area is centrally located in the city centre of YUA as this region has good accessibility for the transportation as well as the public facilities.

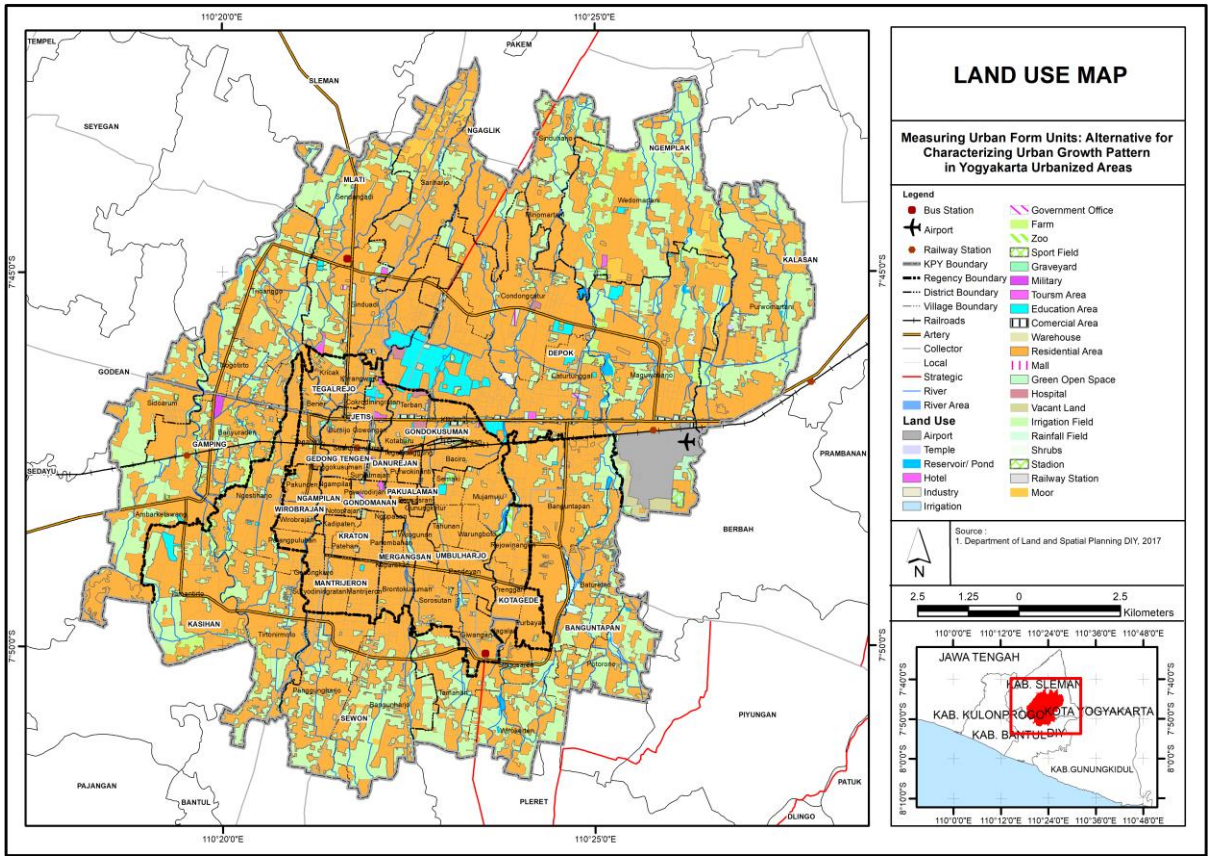

Figure 2. Land Use Map

3.2. Commercial Activity Characteristics

Yogyakarta Urban Growth follows a concentric pattern, where the City of Yogyakarta acts as a centres of growth. Growth centres for trade activities and services developed from Jalan Malioboro and developed eastward (Jalan Solo) and partly to the north (Jalan Magelang) following the city's growth along with improved road infrastructure. The centres for the development of trade and economic activities in the Yogyakarta Urban Area have character, which is growing following the arterial and collector roads. Based on the analysis, it is found that the total market is 175 markets, of which 27 markets are in Yogyakarta City, 8 markets are in the Bantul Regency, and as many as 140 markets are in Sleman Regency. In addition to the market presence, the trade sector is also dominated by 1777 shops, of which 890 shops are in Sleman Regency, 692 stores are in Yogyakarta City, and 195 stores are in Bantul Regency.

The number of hotels in Yogyakarta Urban Area is 306 buildings, of which 236 are in Yogyakarta City, 10 hotels are in Bantul Regency, and 60 hotels are in Sleman Regency. The most hotel facilities are in Gedong Tengen Subdistrict as many as 50 hotels, which are influenced by the Malioboro area as a tourism and trade centre of Yogyakarta City. The number of tertiary educational institutions in the city of Yogyakarta has reached 65. Meanwhile, the growth of education facilities is dominated by the northern region of the Yogyakarta Urban Area. The number of tertiary institutions in Sleman currently amounts to 30 private universities and 5 state universities.

3.3. Urban Form Classification

This section discussed the urban form classification through the measurement of density, diversity, and accessibility variable. Based on the urban form variable used as mentioned in the methodology section, density is identified from population density and percentage of built-up area, diversity is identified from the Richness Index and variation in land use, and accessibility is identified from the number of public transport stops and ratio of coverage of public transportation services (Bus Service Coverage Rate/BSCR).

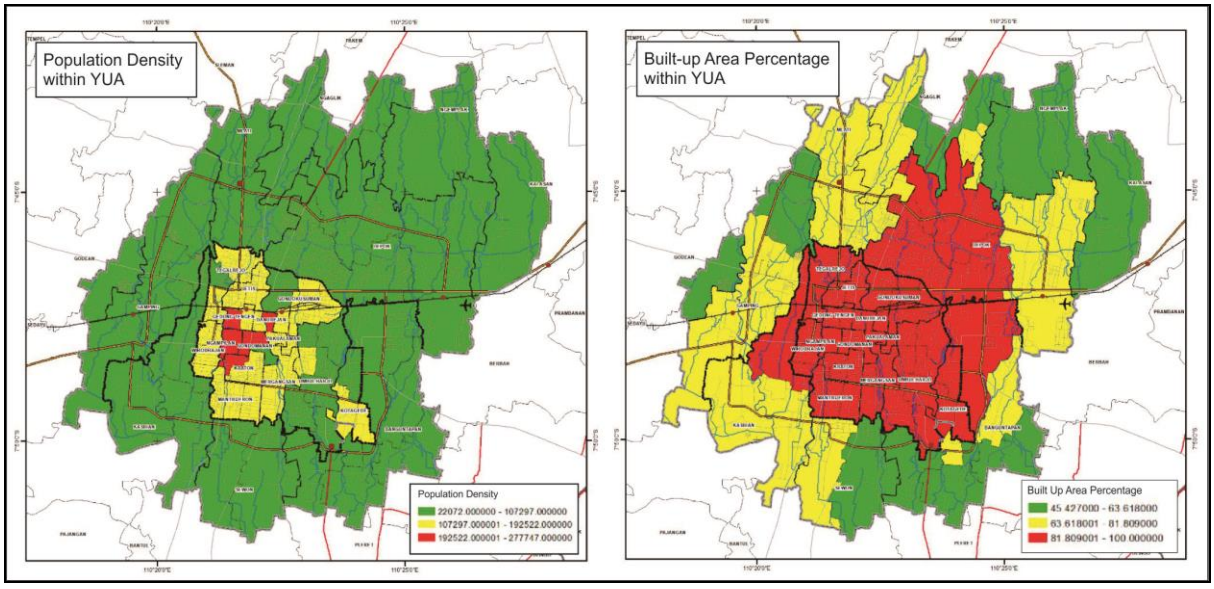

Figure 3. Density overview within YUA which seen through population and built-up area

Results show that the majority of population density in YUA is still low. According to Figure 3, high population density are concentrated in the centre of the area in which it is located in city of Yogyakarta administrative area. The activity concentration in which directed in the heart region of Yogyakarta can be related to high population density in this area. District of Danurejan, Gedongtengen, and Ngampilan are reported to have the highest density of

population within YUA. High concentration of residential in these areas are one of the reason to this condition. People are tend to reside close to the public facility. As central government is located in Danurejan, this area provide good facilities as well as connectivity into commercial activities in which supported people daily needs. High coverage of built-up area also concentrated within centre area of YUA which can be seen through Figure 3. Meanwhile, the suburban area have low percentage of built-up area which mean this area is still dominated by agricultural land use.

Table 3. Urban form classification in Yogyakarta Urbanized Area

Urban Form Classification	Kabupaten/ Kota	Desa/ Kelurahan	DENSITY		DIVERSITY		ACCESIBILITY	
			Population Density	% Built-up Area	Richness Index	Land Use Variation	Transit Stops	Bus Service Coverage Rate
LOW COMPACT	Yogyakarta (3)	Panembahan, Patehan, Tahunan	136,068	97,453	0,278	0	0,667	0,009
	Sleman (5)	Sinduharjo, Minomartani, Wedomartani, Sidoarum, Purwomartani	42,331	58,984	0,600	0,011	0	0,006
	Bantul (5)	Wirokerten, Potorono, Tamanan, Singosaren, Bangunharjo	40,830	53,883	0,333	0	1,400	0,055
MIDDLE COMPACT	Yogyakarta (35)	Purbayan, Kadipaten, Suryodiningratan, Wirogunan, Brontokusuman, Wirobrajan, Keparakan, Bener, Warungboto, Sorosutan, Pakuncen, Prawirodirjan, Rejowinangun, Gedongkiwo, Gunungketur, Tegalrejo, Karangwaru, Pandeyan, Semaki, Giwangan, Patangpuluhan, Pringgokusuman, Ngupasan, Prenggan, Mantrijeron, Ngampilan, Notoprajan, Kricak, Muja-Muju, Tegal Panggung, Demangan, Baciro, Kotabaru, Cokrodiningratan, Purwokinanti	137,251	95,104	0,429	0,034	3,114	0,253
	Sleman (5)	Sariharjo, Nogotirto, Banyuraden, Maguwoharjo, Condongcatur	36,945	66,919	0,646	0,067	3,875	0,148
	Bantul (9)	Panggungharjo, Baturetno, Tirtonirmolo, Sendangadi, Trihanggo, Ambarketawang, Ngestiharjo, Tamantirto, Banguntapan	60,161	72,668	0,556	0,013	5	0,154
HIGH COMPACT	Yogyakarta (7)	Klitren, Bumijo, Gowongan, Suryatmajan, Bausasran, Sosromenduran, Terban	153,785	97,453	0,690	0,234	3	0,399
	Sleman (2)	Caturtunggal, Sinduadi	48,913	85,583	1	0,224	25	0,196
	Bantul (0)	-						

Source : Analysis, 2018

Table 3 show the result of urban form typology within YUA. Most of the areas are categorized as middle compact typology characteristics, in which 13 areas are included in the low compact typology, 49 areas are included in the middle compact typology, and the remaining 9 areas are grouped in the high compact typology. Middle compact typology is dominated by region within Yogyakarta city administrative. Surprisingly, Bantul regency is not considered as high compact for its whole YUA part. It is clear that multiple functions are often associated with higher densities as well as a greater mixed used activities exist. As the densities get lower, the activity is more spread out as represent in the low compact area through its diversity value. In contrast, area with large variation of its activities will have more compact urban form where also supported by great accessibility.

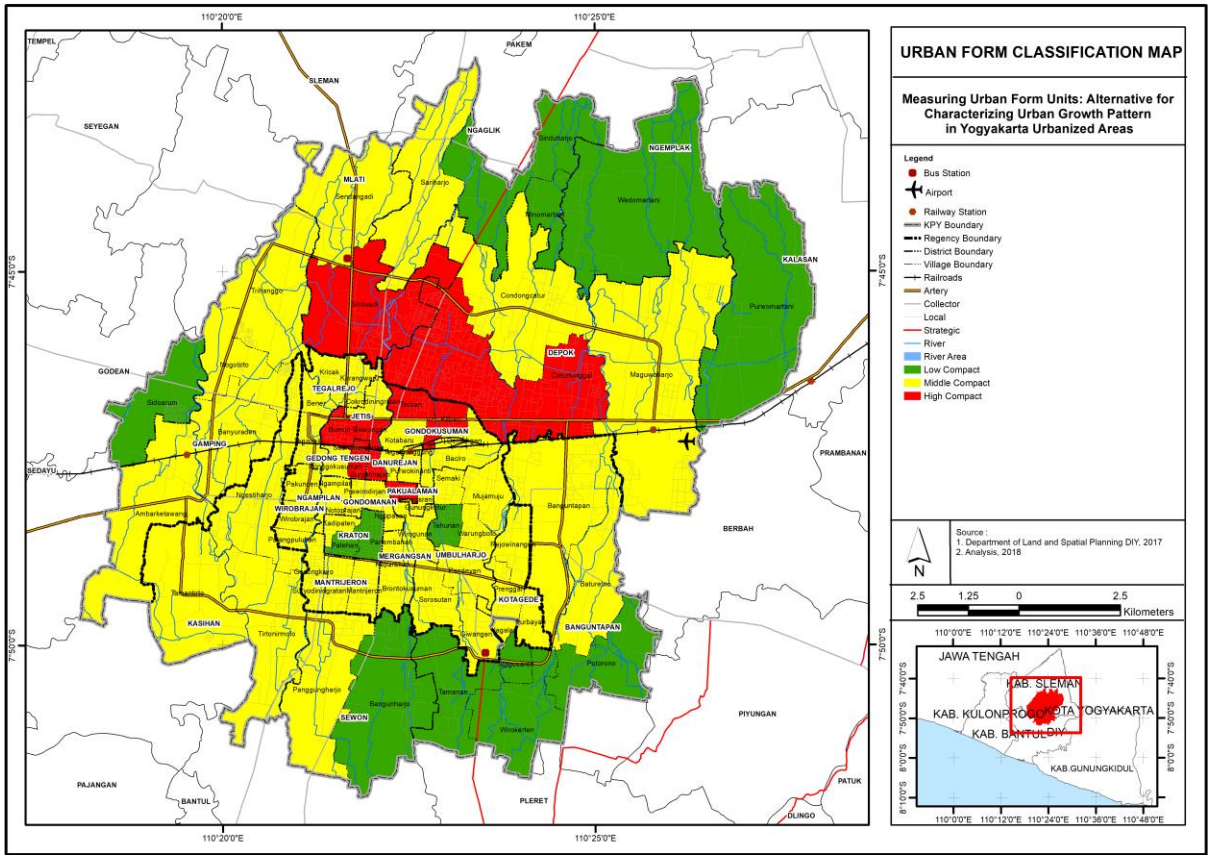

Figure 4. Classification of urban form typology in Yogyakarta Urbanized Area

Through Figure 4, high compact typology of urban form is concentrated in the centre of YUA. Caturtunggal and Sinduadi area, as a part of Sleman regency, is categorized as high compact area. The existence of higher education within this area has triggered the emergence of new activities to support the function of the area. Rapid development in this area is also correlated with the higher densities as well as creating a multifunctional used within the area.

It is indeed that Yogyakarta is experiencing the spatial expansion into its hinterlands and peripheries in order to accommodate the growing urban population as well as urban activities.

Currently, the principal foundation for characterizing urban development and making urban comparisons is by using demographic-measure city population size (Stokes et al., 2018). Yuan et al. (2017) evaluated urban form through six multiple dimensions which are population density, degree of centralization, mixed land use, street accessibility, shape complexity, and urban continuity. In the context of methodology approach, many studies used GIS and remote sensing methods to quantify and describe urban growth model (Shi et al., 2012; Jiao, 2015; Almdhun, 2018). Moreover, study using Dublin city as case study are tried to measure urban form changes through street network design, land use mix, and density in community scale by using GIS functions (Nedovic-Budic et al., 2016). This study enrich the findings in characterizing urban expansion by using combination of variables in density, diversity, and accessibility. Results from this study confirm previous findings that urban expansion happens in a large scale. However, the expansion is associated with sprawl in which characterized by low density, diversity, and accessibility in suburban area while the high concentration of activities is located in urban centre area. This high concentration of activities is associated with higher level of compactness which measured through its density, diversity, and accessibility.

4. Conclusion

This paper gives brief understanding on how to define urban form unit in the urban areas by using simple quantitative measures. The measure of urban form units could be used to investigate other sustainability issues, particularly in relating to transportation issues and quality of life. Therefore, it can contribute significantly to the debate on building sustainable urban form in developing countries.

The major findings are summarized as, first, the urban growth of YUA are concentrated in the centre of its area which shown through the characteristic of its high compact urban form. Second, the agglomeration in the context of YUA are mostly happened in Sleman regency which located in the north of the area. Higher education activities have become a trigger to the emergence of the rapid development within surrounded area even it is considered as high compact area. Lastly, the majority of the area in YUA is classified as middle compact typology where most of them are in the city of Yogyakarta administrative area. Meanwhile,

the area which categorized as low compact typology are located in the hinterland area of Yogyakarta. In the low compact and middle compact area, there should be policies to increase multifunctional use and accessibility within area in order to create more compact area development as well as sustainable urban form.

It is indeed that the indicators described in the paper have numbers of drawbacks that need to be taken into account for further development of this empirical work. Moreover, there is also the opportunity to improve the methods for clustering the urban form typology as in this paper we used the basic statistical value in grouping the typology.

Acknowledgement

This research was fully funded by the Minister of Research, Technology, and Higher Education of Republic Indonesia, contract number 03.b/STTNAS/P3M/Pen.DRPM/III/2018

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Revision Report

Paper ID: 40599

Paper title: Measuring Urban Form Units: Alternative for Characterizing Urban Growth Pattern in Yogyakarta Urbanized Areas

Corresponding author: Mutiasari Kurnia Devi

No.	Section Line no./ figure/table	Reviewer's comment/request/question	Your resulting revision
1	Abstract Page 1 Line 23	Please add conclusions to the Abstract	The abstract is revised and the conclusion is added as suggested
2	Introduction Page 3 Line 7	Give a concrete example of the negative impact of urban sprawl symptoms on environment, social, and economy	It was mentioned in Page 2 Line 23
3	Introduction Page 3 Line 37	Please add the research objectives here	The objectives of the study already put on the Page 4 Line 17
4	The Methods Site Study Figure 1	Remove the institution emblem from the map The orientation on the map is upside down (must be reversed) so that it meets the cartographic rules	It was removed and changed

5	The Methods Data Sets and Analysis Page 5 Line 13	Please explain how you combine different size and measurement units, as presented in Table 1	It was added in Page 7 Line 4 and shown through Table 2
6	Result and Discussion Land Use Classification Figure 2	The maps must be arranged in English	It was changed in English
7	Result and Discussion Urban Form Classification Figure 3	The maps must be arranged in English	It was changed
8	Result and Discussion Urban Form Classification Figure 4	The maps must be arranged in English	It was changed
9	Result and Discussion Urban Form Classification Page 11 Line 14	The results of this study must be linked to the results of previous studies (a theoretical dialogue must be carried out)	We tried to put theoretical dialogue as suggested in Page 12 Line 4
10	Conclusion Page 11 Line 5	The conclusions must refer to the purpose of the study	The conclusion which refer to the purpose of study were put in Page 12 Line 28

11	Acknowledg ement Page 12 Line 11	The acknowledgments must be specifically addressed to individualsor institutions and mention their respective contributions to the study.	It was corrected
12	References	The list of references contained in the Bibilography/References must be exactly the same as those cited in the text	It was corrected

Measuring Urban Form Units: Alternative for Characterizing Urban Growth Pattern in Yogyakarta Urbanized Areas

1. ***Abstract*** ~~*Urban area is always expanding into its surrounded area which then creating a well-known urban agglomeration area.*~~ *Yogyakarta is one of city in Indonesia which experience urban agglomeration called by Yogyakarta Urbanized Area (YUA).* ~~*YUA actually has different characteristic for its whole area.*~~ *In this paper, we* ~~*tried to identify*~~ *identified the characters of each part of YUA* ~~*through measuring*~~ *by examining its urban form unit. This paper assesses the characteristics of urban forms distributed within YUA. Quantitative measurements were proposed for classifying the urban form typologies. Density, diversity, and accessibility were used to represent the urban form characteristic.* ~~*In order to explain the urban form characteristics,*~~ *the typologies are classified into three groups which are low compact, middle compact, and high compact. The result shows that the majority areas in YUA are grouped into middle compact typology where most of them are located in the city of Yogyakarta administrative area. Meanwhile, the areas, categorized as low compact typology, are in the hinterland area of Yogyakarta. High compact typology are concentrated in the centre of YUA where it has the highest activity concentration for the whole urban structure context. This study discovers that characterizing the urban growth patterns using quantitative method can distinguish urban form. At the end, this paper provides an important note about the distribution of urban form typology in the agglomeration area and, in the future, can be used to design urban policies, especially in the utilization of urban space*. **Please add conclusions to the Abstract**

Key words: urban form, urban growth, agglomeration

Abstrak ~~*Daerah perkotaan selalu berkembang ke daerah sekitarnya, yang kemudian menciptakan area aglomerasi perkotaan.*~~ *Yogyakarta adalah salah satu kota dengan aglomerasi perkotaan yang kemudian disebut sebagai Kawasan Perkotaan Yogyakarta (KPY).* ~~*KPY sebenarnya memiliki karakteristik yang berbeda untuk seluruh wilayahnya.*~~ *Dalam tulisan ini, kami* ~~*mencoba untuk*~~ *mengidentifikasi karakter masing-masing bagian dari KPY dengan mengukur unit dari bentuk perkotaannya. Dalam hal ini kami mencoba untuk menganalisis* ~~*tentang*~~ *bagaimana karakteristik bentuk-bentuk kota terdistribusi di wilayah KPY. Dalam mengklasifikasikan tipologi bentuk perkotaan, kami menggunakan metode pengukuran dengan pendekatan kuantitatif. Kepadatan, keragaman, dan aksesibilitas digunakan untuk mewakili karakteristik bentuk perkotaan.* ~~*Untuk menjelaskan karakteristik bentuk perkotaan,*~~ *kami mengkategorikan dalam tiga kelompok bentuk kota yaitu area dengan tingkat kekompakan rendah, menengah, dan tinggi. Hasil menunjukkan bahwa sebagian besar wilayah di KPY diklasifikasikan ke dalam tipologi tingkat kekompakan menengah dengan sebagian besar wilayah administrasi berada di Kota Yogyakarta. Sementara itu, daerah yang dikategorikan sebagai tipologi kekompakan rendah terletak di daerah pinggiran Yogyakarta. Tipologi area dengan kekompakan yang tinggi terkonsentrasi di pusat KPY di mana wilayah ini memiliki aktivitas konsentrasi tertinggi untuk keseluruhan konteks struktur perkotaan. Studi ini menunjukkan bahwa pengelompokan pola pertumbuhan perkotaan dengan metode ini dapat membedakan bentuk kota dengan tipologi yang berbeda. Pada akhirnya, tulisan ini memberikan catatan penting tentang distribusi bentuk tipologi perkotaan di daerah aglomerasi untuk membangun kebijakan mengenai pemanfaatan ruang perkotaan.*

Kata kunci *:* bentuk kota, pertumbuhan kota, aglomerasi ~~urban form, urban growth, agglomeration~~

1. Introduction

The majority of world's populations are predicted to live in cities. By 2030, nearly 60% of world population will live in cities (UNFPA, 2007). Drawing insights from this fact, many cities, especially in developing countries, will experience urbanisation at large scale, however, at the same time the urban infrastructure has not been able to accommodate the population. According to Statista (Statista, 2017), about 55% of Indonesia population live in urban area. In 2010, the urban population was about 50% and it went up to 53,5% in 2015. This trends will be continuously increasing until 2035. It is predicted that the urban population will hit 60% by 2025 and will reach 63,4% by 2030 (BPS, 2013). It gives a clear image that the rapid growth of urban population and urbanization is happening in a large scale. Therefore, the growth of urban population requires serious attention from stakeholders, in particularly urban planners. Increasing population which followed by rapid urbanisation has important implications for urban area expansion. This implication yields urban agglomeration within surrounded areas as the consequence. Not only that, but also rapid urbanisation causes a wide range of urban problems, including urban sprawl.

Sprawl is often defined by four land use characteristics: low density; scattered development (i.e. decentralised sprawl); commercial strip development; and, leapfrog development (Ewing, 1997). It can be described as an overall low density development or a scattered or leapfrog development with a daily commuting of its people relying on automobile (Uhel, 2006 cited in Abrantes et al., 2019; Galster et al., 2001; Kasanko et al., 2006). Higher environmental impacts are reported to be associated with low densities, one of sprawl development characteristics (Camagni, Cristina, & Rigamonti, 2002). In line with previous findings, Nechyba & Walsh (2004) mentioned that sprawl can be linked to environmental issues as lower-density development. In other words, sprawl can be associated as the increase in emissions per mile travelled related to traffic congestion and the increases in vehicle miles travelled. Urban sprawl also leads to cause loss of productive agricultural lands, open green spaces, as well as loss of surface water bodies (Bhat, Shafiq, Mir, & Ahmed, 2017). In addition to that, social sector is also reported to have negatively affected by urban sprawl. People who live farther from each other will have weak linkages within neighbours (Burchell et al., 1998 cited in (Nguyen, 2010) as well as social segregation (Camagni and Gibelli, 1997 cited in (Camagni et al., 2002)).

Handy (1996) defines urban form as a composite of characteristics related to land use patterns, transportation system, and urban design. Urban form can be further described conceptually as the spatial pattern of human activities including the physical configuration of

a city along with land use patterns, population and housing densities, infrastructure and amenities, and transport and communication networks (Anderson et al., 1996 cited in (Tsai, 2005); Abrantes et al., 2019). In term of geographical scales, urban form can be viewed and classified into several levels, such as metropolitan area, city, and even neighbourhood. The reason for this classification is twofold. First, some urban form variables operate only at certain levels, such as the job-housing balance variable. Secondly, urban form variables (such as density) may carry different meanings at different levels and may differently affect human activities, such as travel behaviour (Tsai, 2005). To sum up the concept of urban form, urban form is a result of the bringing together of many elements-concepts: the urban pattern (Jabareen, 2006).

Longstanding attempts to quantify urban sprawl that focuses on the growth of suburbs relative to central cities in which showing that suburbs have grown more rapidly than the central cities they surround (Chinitz, 1969). Song & Knaap (2004) measures urban form by utilizing street design and circulation systems, density, land use mix, accessibility, and pedestrian access to evaluate the development patterns in Portland, Oregon. Meanwhile, Tsai (2005) describes urban form by using three categories which are density, diversity, and spatial-structure pattern. In contrast, Chin (2002) points out three principal dimensions of urban sprawl such as urban spatial scale, population density decline, and scattered urbanisation. Among several variables that have been used to identify urban form, population density and land use cover are the key variables to explain more depth the typology of urban areas (Abrantes et al., 2019).

Sustainable urban forms have been a concern in the context of developed cities which described as “new urbanism” or the “compact city” (Abe & Kato, 2017).

As urban sprawl triggers many negative implications towards environment, social, and economic, **(Give a concrete example of the negative impact of urban sprawl symptoms on environment, social, and economy)**

there is a vision for many urban planners in the 21st century to create places with more compact design, more accessible to public transportation, and less driving The key principles which are proposed in order to create more sustainable urban form, are promoting walkability and connectivity, mixed land uses, and high density (Rukmana, 2018). Newman & Kenworthy (2000) found that the compact city emerges as the most fuel-efficient of urban forms. They conclude that urban form matters to improve urban air quality. Compactness also does not have a generally accepted definitions. Gordon & Richardson (1996) potray compactness as high-density or monocentric development. Ewing’s definition (Ewing, 1997)

was some concentration of employment and housing, as well as some mixture of land uses. Alternatively, Anderson et al. (Anderson, Kanaroglou, & Miller, 1996) defined both monocentric and polycentric forms as being compact. To conclude the definition, compactness refers to urban continuity (and connectivity), which suggest that future urban development shall take place adjacent to existing urban structures (Wheeler, 2002) as compactness brings the concentration of development (Tsai, 2005).

1. The studies on urban form have been drawing interests in international research area for the past decades. However, in Indonesia context, the lack of theoretical and empirical works to address urban structure using quantitative measures is still underdeveloped. In fact, understanding urban form can lead to better decisions on urban transportation, growth strategy, as well as the development of infrastructure (Bin Kashem, Chowdhury, Majumder, & Rahman, 2009). In recent years, a number of quantitative variables have been developed to characterise urban sprawl. However, there are some gaps in the definitions of compactness and sprawl, and in the appropriate quantitative variables. This paper aims to characterise quantitatively urban form in general and to distinguish compactness from sprawl particularly using urbanized area case. The findings can be taken to propose different types of urban policies and planning approaches based on the urban form typology as well as to attain sustainable travel. Moreover, by measuring the urban form unit, we can also reveal the trends of urban development in YUA context. ~~It~~ The study starts with a literature review of definitions of urban form and definitions of compactness and sprawl. ~~Secondly~~ After that, ~~it~~ the different dimensions of metropolitan forms, accompanied with appropriate quantitative indexes in which the degrees of compactness and sprawl are revealed. **(Please add the research objectives here)**

2. The Methods

2.1. Site Study

In terms of area coverage, this study was conducted in Yogyakarta Urbanized Area (YUA) with the object of research is the built environment, particularly urban form characteristic in that location. YUA covers 14 (fourteen) sub-districts in Yogyakarta City, 6 (six) sub-districts in Sleman Regency, and 3 (three) sub-districts in Bantul Regency.

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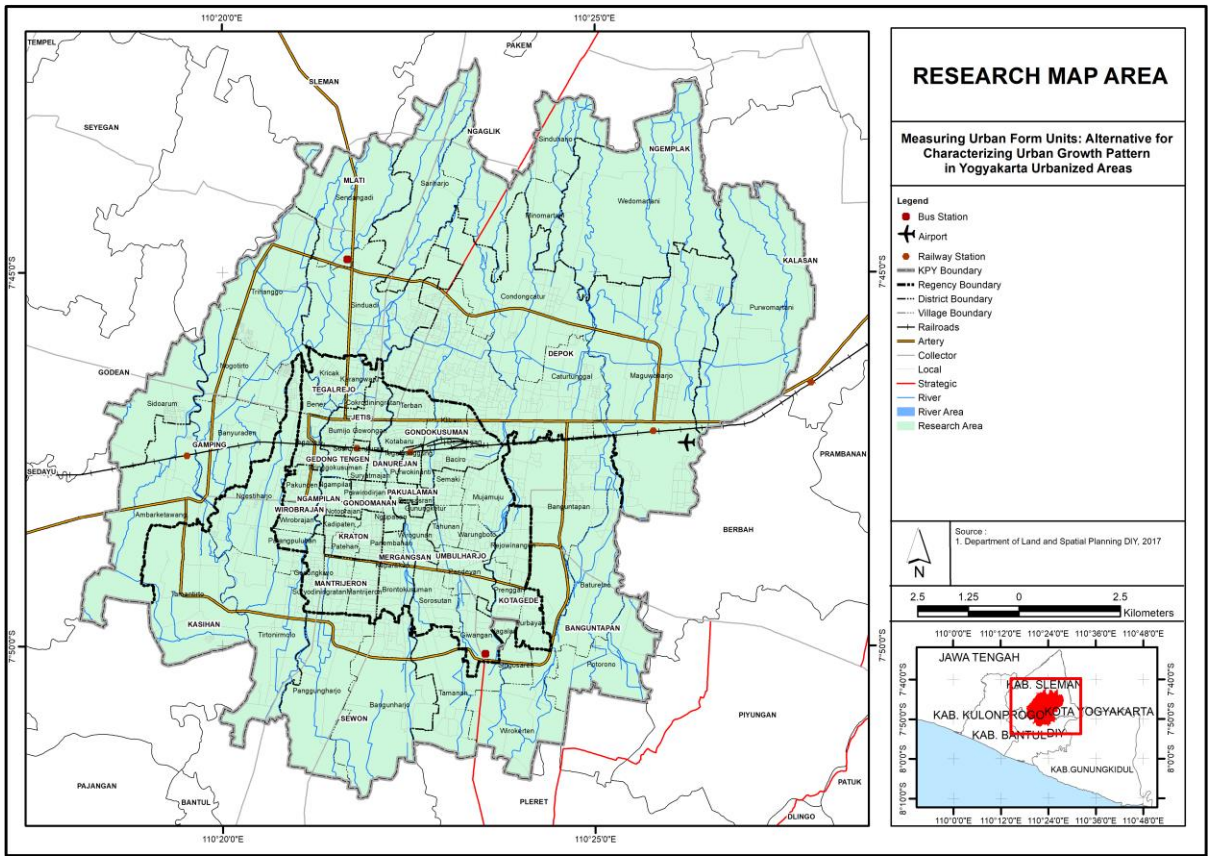

Figure 1. Research Area

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2.2. Data Sets and Analysis

This paper developed a set of quantitative variables to characterise urban forms at the metropolitan level, and in particular, to distinguish compactness from "sprawl". The analysis follows reviewing and analysing former research on the definitions of urban form, compactness and sprawl, and corresponding quantitative variables. Density, diversity, and accessibility are often used to describe the urban form within region. Density is a critical typology in determining sustainable urban forms. It is the ratio of people or dwelling units to land area. Meanwhile diversity is a multidimensional phenomenon (Turner & Murray, 2001) that promotes further desirable urban features, including greater varieties of housing types, building densities, household sizes, ages, cultures, and incomes. Thus, diversity represents the social and cultural context of the urban form. Sometimes diversity is being relates to the mixed used in which in this context mixed land use indicates the diversity of functional land uses such as residential, commercial, industrial, institutional, and those related to transportation.

There are several ways to categorize the typology of urban form. Jabareen (2006) classifies urban form into four different types such as neo-traditional, compact city, urban containment, and eco city. The typology is described through several criteria such as density, diversity, mixed land use, compactness, sustainable transportation, passive solar design, and greening ecological design. Using different perspective, Jackson-Smith et al. (Jackson-Smith et al., 2016) further clustered the urban form that have been linked to its water system characteristics. For this paper, we categorized the urban form typology into three categories based on the level of its compactness: low compact, middle compact, and high compact typology.

To represent density, diversity, and accessibility in deeper context, six quantitative variables were developed to measure six dimensions of urban form: population density, richness index, bus service coverage area index, number of transit stops, built-area ratio, and land use variation. The data sets are display on the Table 1 below.

Table 1. Data Sets

Variable	Operational
DENSITY	
- Population density	- Total person per ha within the area
- Built up area percentage	- Total built up area per total area
DIVERSITY	
- Richness Index	- Ratio of its total land use groups
- Land use variation	- Ratio of non-residential area per total area of its residential area
ACCESSIBILITY	
- Number of transit stop	- Total transit stops of TransJogja within the area
- Bus service coverage ratio	- Ratio between the length of TransJogja routes and total length of road within the area

Source: Analysis, 2018

Please explain how you combine different size and measurement units, as presented in Table 1

The public transport service in Yogyakarta Special Province can be categorized into 4 type of services which are public transport (city bus and TransJogja), ojek, taxi, and non-motorized transportation (becak and andhong). TransJogja is expected to be the most reliable public transport services in Yogyakarta area which classified as Bus Rapid Transit (BRT) system.

Accessibility towards public transportation service was measured through calculating the bus service coverage rate (BSCR) as the ratio between the length of TransJogja routes and total length of road. To represent the public transport service level in all Yogyakarta urbanized area, we divided the value of BSCR into three categories: low bus service coverage ratio (BSCR = < 0,1); middle bus service coverage ratio (BSCR = 0,1 – 0,3); high bus service coverage ratio (BSCR = > 0,3).

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After we collecting the values of six variables, we classified the region into three categories which are low, middle, and high based on the interval class within the value. The classification of six variables in this study is shown in Table 2. The values of these variables were averaged and used to divide the urban forms into three domains (high compact, middle compact and low compact). High compact has high value of density, diversity and accessibility, whilst medium compact and low compact have medium and low value of these three factors accordingly.

Table 2. Interval Value Classification between Variables

Interval Class	Population density	Built-up area percentage	Richness index	Land use variation	Number of transit stop	Bus service coverage area
Low	<45	<68	<0,33	0	<1	<0,1
Middle	45-149	68-97	0,33-0,67	0-0,045	1-5	0,1-0,3
High	>149	>97	>0,67	>0,045	>5	>0,3

Source: Analysis, 2018

3. Result and Discussion

3.1. Land Use Characteristics

DIY Agriculture Office (BPS, 2016) states that the conversion of agricultural land in DIY reaches 200 - 250 Ha per year, where most of it occurs in urban and periphery areas. In the

city of Yogyakarta, agricultural land is only 56 hectares or only around 2% of the total city area of 3,250 ha. Subsequent land use in YUA is 5.14% of dry land / gardens / fields / yards, riverbanks in YUA reaches 4.17%, and the remaining 5.48% for other sectors such as education, trade and services, Public facilities, green open spaces, ponds / ponds and so on. Having this on mind, most of the area is dominated by densely populated residential areas in the central part of the city, while in the outer border (periphery) agricultural land remains stable as display on the Figure 2.

Looking at the land use distribution patterns in YUA, several lands greatly impact the patterns of community travel, namely settlements, offices, education, shopping centres, and trade and services. In the context of residential, it takes 66,37% of the total area of YUA. Mainly this residential area is centrally located in the centre of YUA since the region has good accessibility for transportation and public facilities.

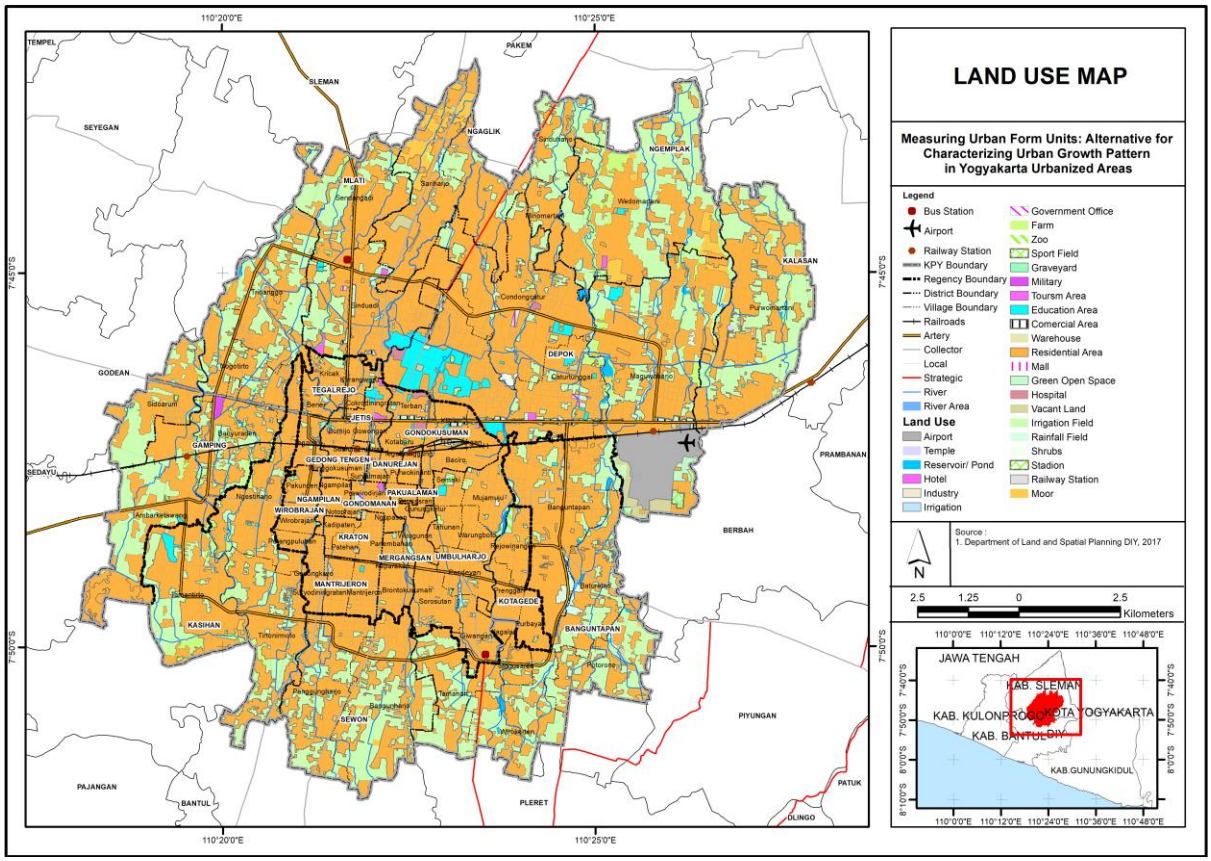

Figure 2. Land Use Map

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3.2. Commercial Activity Characteristics

Yogyakarta Urban Growth follows a concentric pattern, where the City of Yogyakarta acts as a centres of growth. Growth centres for trade activities and services are developed from Jalan Malioboro to eastward (Jalan Solo) and partly to the north (Jalan Magelang). This development follows the city's growth and the improved road infrastructure. The centres for trading and economic activities in the Yogyakarta Urban Area occur by following the arterial and collector roads. Drawing idea from this, the total market is 175 markets, of which 27 markets are in Yogyakarta City, 8 markets are in the Bantul Regency, and as many as 140 markets are in Sleman Regency. In addition to the market presence, the trade sector is also dominated by 1777 shops, of which 890 shops are in Sleman Regency, 692 stores are in Yogyakarta City, and 195 stores are in Bantul Regency.

The number of hotels in Yogyakarta Urban Area is 306 buildings, of which 236 are in Yogyakarta City, 10 hotels are in Bantul Regency, and 60 hotels are in Sleman Regency. The most hotel facilities are in Gedong Tengen Subdistrict as many as 50 hotels, which are influenced by the Malioboro area as a tourism and trade centre of Yogyakarta City. The number of tertiary educational institutions in the city of Yogyakarta has reached 65. Meanwhile, the growth of education facilities is dominated by the northern region of the Yogyakarta Urban Area. The number of tertiary institutions in Sleman currently amounts to 30 private universities and 5 state universities.

3.3. Urban Form Classification

This section discusses the urban form classification through the measurement of density, diversity, and accessibility variable. In line with the aforementioned urban form variables, ~~namely~~ density is identified as population density and percentage of built-up area, diversity is identified as the Richness Index and variation in land use, and accessibility is identified as the number of public transport stops and ratio of coverage of public transportation services (Bus Service Coverage Rate/BSCR), ~~it can be grouped into research areas based on the characteristics of the urban typology form that is owned.~~

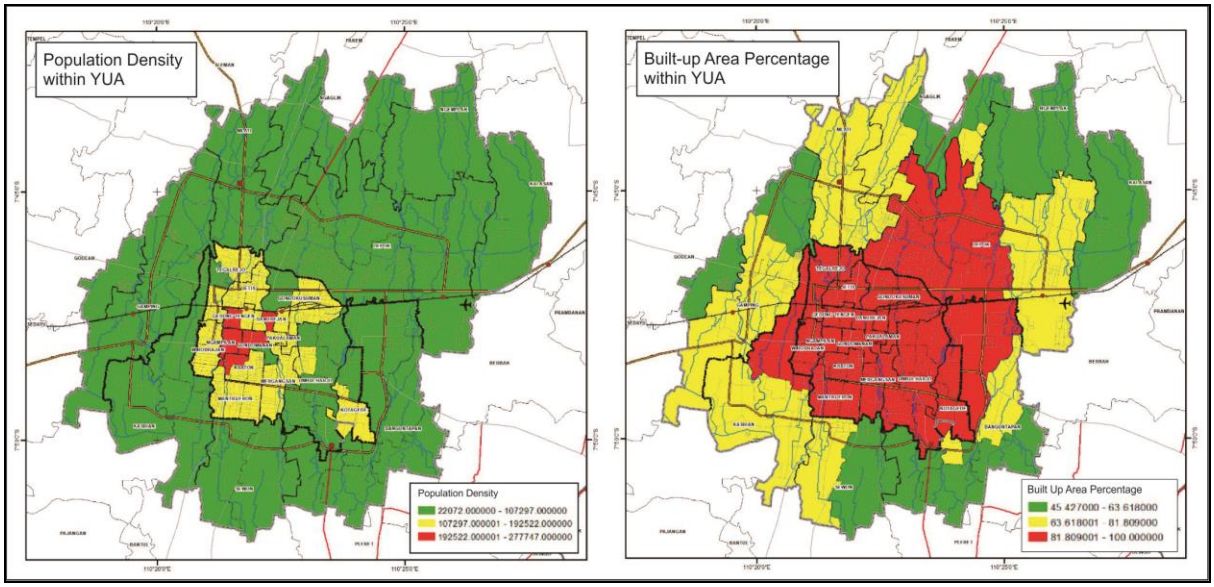

Figure 3. Density overview within YUA which seen through population and built-up area

The maps must be arranged in English

Results show that the majority of population density in YUA is still low. Figure 3 presents, high population density are concentrated in the centre of the area in which it is located in city of Yogyakarta administrative area. The activity concentration in which directed in the heart region of Yogyakarta can be related to high population density in this area. District of Danurejan, Gedongtengen, and Ngampilan are reported to have the highest density of population within YUA. The plausible reason to this finding is high concentration of residential in these areas. People are tend to reside closely to the public facilities. As the central government is located in Danurejan, this area provides good facilities, good connectivities, and many commercial activities which mostly people are looking for. Figure 3 also shows that high coverage of built-up area are also concentrated within centre area of YUA. Meanwhile, the suburban areas have low percentage of built-up area which means this area is still dominated by agricultural land use.

Table 2. Urban form classification in Yogyakarta Urbanized Area

No.	Regency	Sub District	Village	DENSITY		DIVERSITY		ACCESIBILITY		Urban Form Typology
				Population Density	% Built Area	Richness Index	Land Use Variation	Transit Stop Number	Bus Service Coverage Rate	
1	Bantul	Banguntapan	Wirokerten	42,799	48,123	0,33333	0	0	0	
2	Bantul	Banguntapan	Potorono	35,674	45,427	0,33333	0	0	0	
3	Bantul	Banguntapan	Tamanan	39,892	52,377	0,33333	0	1	0,0877	
4	Bantul	Banguntapan	Singosaren	40,924	72,978	0,33333	0	0	0	
5	Sleman	Ngaglik	Sinduharjo	33,528	59,864	0,5	0,0038	0	0	
6	Sleman	Ngaglik	Minomartani	81,094	73,506	0,33333	0	0	0	
7	Sleman	Ngemplak	Wedomartani	22,072	45,983	0,66667	0,0058	0	0	LOW COMPACT
8	Sleman	Godean	Sidoarum	44,844	62,569	0,5	0,0347	0	0	
9	Yogyakarta	Kraton	Panembahan	143,983	100	0,16667	0	0	0	
10	Yogyakarta	Kraton	Patehan	150,476	95,753	0,33333	0	0	0	
11	Yogyakarta	Umbulharjo	Tahunan	113,745	96,606	0,33333	0	2	0,0271	
12	Bantul	Sewon	Bangunharjo	44,863	50,509	0,33333	0	6	0,1863	
13	Sleman	Kalasan	Purwomartani	30,116	52,999	1	0,0125	0	0,0321	
14	Yogyakarta	Kotagede	Purbayan	134,123	99,632	0,33333	0	1	0,0722	
15	Yogyakarta	Kraton	Kadipaten	194,121	100,000	0,16667	0	0	0	
16	Yogyakarta	Mantrijeron	Suryodiningratan	120,433	96,129	0,33333	0	3	0,1462	
17	Yogyakarta	Mergangsan	Wirogunan	130,146	93,955	0,33333	0	5	0,2162	
18	Yogyakarta	Mergangsan	Brontokusuman	112,447	96,818	0,33333	0	2	0,2274	
19	Yogyakarta	Wirobrajan	Wirobrajan	138,358	95,918	0,33333	0	1	0,1535	
20	Bantul	Sewon	Panggungharjo	61,702	68,923	0,33333	0	2	0,1049	
21	Bantul	Banguntapan	Baturetno	32,547	65,036	0,83333	0,0255	2	0,0707	
22	Bantul	Kasihan	Tirtonirmolo	53,850	66,954	0,33333	0	6	0,1225	
23	Sleman	Mlati	Sendangadi	35,393	64,520	0,66667	0,0208	1	0,1294	
24	Sleman	Gamping	Trihanggo	31,345	52,080	0,5	0,0021	4	0,2024	
25	Sleman	Gamping	Ambarketawang	34,089	64,052	0,5	0,0013	2	0,1965	
26	Yogyakarta	Mergangsan	Keparakan	187,861	96,174	0,33333	0	3	0,1785	
27	Yogyakarta	Tegalrejo	Bener	82,888	86,307	0,5	0,0414	1	0,0470	MIDDLE COMPACT
28	Yogyakarta	Umbulharjo	Warungboto	106,583	99,009	0,33333	0	1	0,2430	
29	Yogyakarta	Umbulharjo	Sorosutan	86,675	93,181	0,33333	0	8	0,1827	
30	Yogyakarta	Wirobrajan	Pakuncen	172,853	96,575	0,18182	0	2	0,1859	
31	Sleman	Ngaglik	Sariharjo	32,069	68,974	0,5	0,0061	2	0,1009	
32	Sleman	Gamping	Nogotirto	50,136	65,307	0,5	0,0279	5	0,1410	
33	Sleman	Gamping	Banyuraden	40,939	66,411	0,66667	0,0775	1	0,1189	
34	Yogyakarta	Gondomanan	Prawirodirjan	198,770	92,964	0,33333	0	3	0,3346	
35	Yogyakarta	Kotagede	Rejowinangun	100,286	88,034	0,33333	0	7	0,3174	
36	Yogyakarta	Mantrijeron	Gedongkiwo	155,409	97,432	0,33333	0	1	0,1571	
37	Yogyakarta	Pakualaman	Gunungketur	148,334	99,349	0,33333	0,0065	1	0,2257	
38	Yogyakarta	Tegalrejo	Tegalrejo	109,697	91,277	0,66667	0,0436	3	0,2153	
39	Yogyakarta	Tegalrejo	Karangwaru	135,140	95,620	0,66667	0,0471	0	0,2131	
40	Yogyakarta	Umbulharjo	Pandeyan	85,481	95,285	0,33333	0	8	0,3432	
41	Yogyakarta	Umbulharjo	Semaki	84,968	88,292	0,5	0,0907	5	0,2686	

42	Yogyakarta	Umbulharjo	Giwangan	57,762	86,088	0,33333	0	6	0,4038	
43	Yogyakarta	Wirobrajan	Patangpuluhan	164,245	97,541	0,33333	0	1	0,2387	
44	Bantul	Kasihan	Ngestiharjo	80,651	82,764	0,66667	0,0092	5	0,1451	
45	Bantul	Kasihan	Tamantirto	42,469	68,489	0,5	0,0359	8	0,2813	
46	Yogyakarta	Gedongtengen	Pringgokusuman	268,732	98,163	0,33333	0	1	0,4248	
47	Yogyakarta	Gondomanan	Ngupasan	83,435	95,713	0,66667	0,1710	2	0,2751	
48	Yogyakarta	Kotagede	Prenggan	108,632	98,064	0,33333	0	9	0,3239	
49	Yogyakarta	Mantrijeron	Mantrijeron	114,471	99,129	0,5	0,0163	1	0,3010	
50	Yogyakarta	Ngampilan	Ngampilan	223,449	98,699	0,33333	0	3	0,4621	
51	Yogyakarta	Ngampilan	Notoprajan	218,461	97,126	0,33333	0	3	0,4642	
52	Yogyakarta	Tegalrejo	Kricak	156,531	89,139	0,5	0,0479	3	0,0837	
53	Yogyakarta	Umbulharjo	Muja muju	67,226	83,933	0,5	0,0146	6	0,2794	
54	Bantul	Banguntapan	Banguntapan	89,746	83,842	0,66667	0,0068	7	0,2007	
55	Yogyakarta	Danurejan	Tegal panggung	277,747	99,023	0,5	0	1	0,3797	
56	Yogyakarta	Gondokusuman	Demangan	115,468	95,352	0,83333	0,1894	1	0,2223	
57	Yogyakarta	Gondokusuman	Baciro	109,677	99,771	0,5	0,0066	6	0,2576	
58	Yogyakarta	Gondokusuman	Kotabaru	37,017	94,842	0,83333	0,1478	4	0,4201	
59	Yogyakarta	Jetis	Cokrodiningratan	133,368	95,145	0,66667	0,3503	6	0,3051	
60	Yogyakarta	Pakualaman	Purwokinanti	182,982	98,974	0,5	0,0011	1	0,3005	
61	Sleman	Depok	Maguwoharjo	22,392	68,365	1	0,3695	10	0,1441	
62	Sleman	Depok	Condong catur	49,199	85,647	0,83333	0,0308	6	0,1485	
63	Yogyakarta	Gondokusuman	Klitren	134,800	99,975	0,66667	0,1782	2	0,3679	
64	Yogyakarta	Jetis	Bumijo	176,973	94,590	0,83333	0,1437	4	0,1783	
65	Yogyakarta	Jetis	Gowongan	191,521	94,313	0,5	0,4051	3	0,3808	
67	Sleman	Depok	Catur tunggal	45,530	90,659	1	0,2804	33	0,1665	
68	Sleman	Mlati	Sinduadi	52,297	80,507	1	0,1683	17	0,2260	HIGH COMPACT
69	Yogyakarta	Danurejan	Suryatmajan	162,562	97,235	0,66667	0,1401	2	0,5804	
70	Yogyakarta	Danurejan	Bausasran	152,850	100,000	0,5	0,1350	2	0,4820	
71	Yogyakarta	Gedongtengen	Sosromenduran	150,610	100,000	0,66667	0,2008	2	0,3203	
72	Yogyakarta	Gondokusuman	Terban	107,178	96,058	1	0,4343	6	0,4852	

Source : Analysis, 2018

Table 3. Urban form classification in Yogyakarta Urbanized Area

Urban Form Classification	Kabupaten/ Kota	Desa/ Kelurahan	DENSITY		DIVERSITY		ACCESIBILITY	
			Population Density	% Built-up Area	Richness Index	Land Use Variation	Transit Stops	Bus Service Coverage Rate
LOW COMPACT	Yogyakarta (3)	Panembahan, Patehan, Tahunan	136,068	97,453	0,278	0	0,667	0,009
	Sleman (5)	Sinduharjo, Minomartani, Wedomartani, Sidoarum, Purwomartani	42,331	58,984	0,600	0,011	0	0,006
	Bantul (5)	Wirokerten, Potorono, Tamanan, Singosaren, Bangunharjo	40,830	53,883	0,333	0	1,400	0,055
MIDDLE COMPACT	Yogyakarta (35)	Purbayan, Kadipaten, Suryodiningratan, Wirogunan, Brontokusuman, Wirobrajan, Keparakan, Bener, Warungboto, Sorosutan, Pakuncen, Prawirodirjan, Rejowinangun, Gedongkiwo, Gunungketur, Tegalrejo, Karangwaru, Pandeyan, Semaki, Giwangan, Patangpuluhan, Pringgokusuman, Ngupasan, Prenggan, Mantrijeron, Ngampilan, Notoprajan, Kricak, Muja-Muju, Tegal Panggung, Demangan, Baciro, Kotabaru, Cokrodiningratan, Purwokinanti	137,251	95,104	0,429	0,034	3,114	0,253
	Sleman (5)	Sariharjo, Nogotirto, Banyuraden, Maguwoharjo, Condongcatur	36,945	66,919	0,646	0,067	3,875	0,148
	Bantul (9)	Panggungharjo, Baturetno, Tirtonirmolo, Sendangadi, Trihanggo, Ambarketawang, Ngestiharjo, Tamantirto, Banguntapan	60,161	72,668	0,556	0,013	5	0,154
HIGH COMPACT	Yogyakarta (7)	Klitren, Bumijo, Gowongan, Suryatmajan, Bausasran, Sosromenduran, Terban	153,785	97,453	0,690	0,234	3	0,399
	Sleman (2)	Caturtunggal, Sinduadi	48,913	85,583	1	0,224	25	0,196
	Bantul (0)	-						

Source : Analysis, 2018

Table 3 describes the results of urban form typology within YUA. Most of the areas are categorized as middle compact typology characteristics, in which 13 areas are included in the low compact typology, 49 areas are included in the middle compact typology, and the remaining 9 areas are grouped in the high compact typology. Middle compact typology is

~~comprised of~~ dominated by region within city of Yogyakarta administrative area. Surprisingly, Bantul regency is not considered as high compact compare to the all parts of YUA. It is clear that multiple functions are often associated with higher densities and a greater mixed used activities. The lower its density values, the more scattering the activities as represent in the low compact area through its diversity value. In contrast, area with large variations of its activities have more compact urban form than areas with low variation have. Great accessibility in areas with large variation is inevitable.

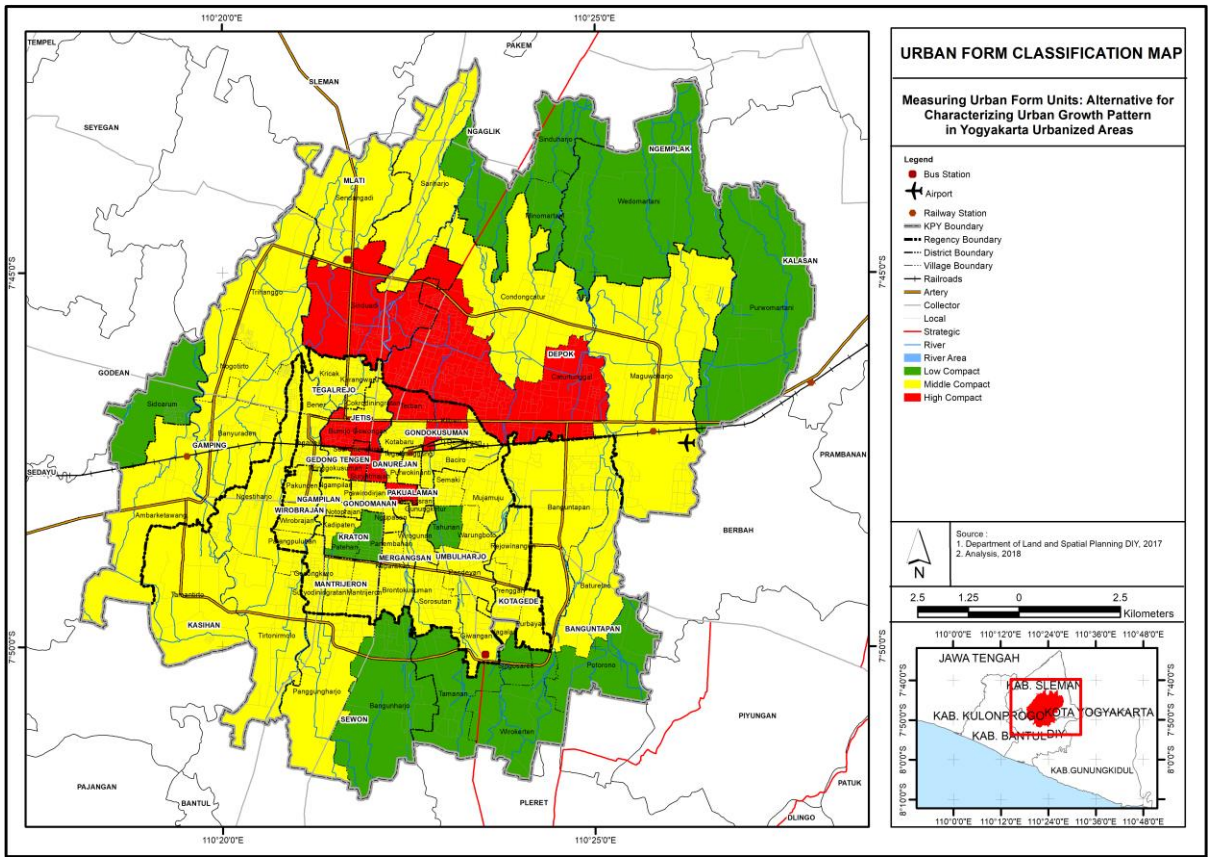

Figure 4. Classification of urban form typology in Yogyakarta Urbanized Area

The maps must be arranged in English

Figure 4 describes high compact typology of urban form is concentrated in the centre of YUA. Caturtunggal and Sinduadi area, as a part of Sleman regency, are categorized as high compact areas. The existence of higher education within this area has triggered the emergence of new activities to support the function of the area. Rapid development in this area is also correlated with the higher densities as well as creating a multifunctional used within the area. Former research finds that Sleman regency is one of the areas where attracts people to come because of its function as the base for economy activities and as the base for educational facilities (Giyarsih, Arif, & Alfana, 2013). It is indeed that Yogyakarta is

experiencing the spatial expansion into its hinterlands and peripheries in order to accommodate the growing urban population along with urban activities.

The results of this study must be linked to the results of previous studies (a theoretical dialogue must be carried out)

Currently, the principal foundation for characterizing urban development and making urban comparisons is by using demographic-measure city population size (Stokes & Seto, 2019). Yuan et al. (Yuan, Song, Huang, Hong, & Huang, 2018) evaluate urban forms with six multiple dimensions which are population density, degree of centralization, mixed land use, street accessibility, shape complexity, and urban continuity. In the context of methodology approach, many studies use GIS and remote sensing methods to quantify and describe urban growth model (Almdhun, Mallak, Aburas, Md Said, & Ghadiri, 2018; Jiao, 2015; Shi, Sun, Zhu, Li, & Mei, 2012). Moreover, former study using Dublin city as the case study measures urban form changes by analysing street network design, land use mix, and density in community scale applying GIS functions (Nedovic-Budic, Knaap, Shahumyan, Williams, & Slaev, 2016). This study enriches the findings in characterizing urban expansion by using combination of variables in density, diversity, and accessibility. Results from this study confirm previous findings that urban expansion happens in a large scale. However, the expansion that is associated with sprawl in which characterized by low density, diversity, and accessibility in suburban area while the high concentration of activities is located in urban centre area. This high concentration of activities is associated with higher level of compactness which measured through its density, diversity, and accessibility.

4. Conclusion

This paper gives brief understanding on how to define urban form unit in the urban areas by quantifying the variables. The measurements of urban form units can be used to investigate other sustainability issues, particularly in transportation issues and quality of life. Therefore, this study can contribute significantly to the debate on building sustainable urban form in developing countries.

The major findings are summarized as, first, the urban growth of YUA is concentrated in the centre of YUA which shown through the characteristic of its high compact urban form. Another finding is, the agglomeration in the context of YUA mostly happen in Sleman regency which located in the north of the area. Although Sleman regency is considered as high compact area, higher education activities are the trigger to the emergence of rapid

development within surrounded area. Last but not least, the majority of the area in YUA is classified as middle compact typology where most of them is in the city of Yogyakarta administrative area. Meanwhile, the area which categorized as low compact typology are located in the hinterland area of Yogyakarta. In the low compact and middle compact area, there should be policies to increase multifunctional use and accessibility within area in order to create more compact area development and sustainable urban form.

It is indeed that the indicators described in the paper have numbers of drawbacks that need to be taken into account for further development of this empirical work. Moreover, there is also the opportunity to improve the methods for clustering the urban form typology as in this paper we used the basic statistical value in grouping the typology.

The conclusions must refer to the purpose of the study

Acknowledgement

This research was fully funded by the Minister of Research, Technology, and Higher Education of Republic Indonesia, contract number 03.b/STTNAS/P3M/Pen.DRPM/III/2018

~~This research was fully funded by the Minister of Research, Technology, and Higher Education of Republic Indonesia. We would like to express our gratitude for all who has contributed in this research~~. **(The acknowledgments must be specifically addressed to individualsor institutions and mention their respective contributions to the study.**

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