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Evaluation of carrying capacity based on land capability of Kulon Progo Regency as an input for spatial planning in the new aerotropolis era

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***Abstract**. The new aerotropolis era due to airport construction in Kulon Progo has stimulated regional development and changed the image of the area from rural to urban-oriented. The negative impact of rapid growth, such as urban sprawl, can be mitigated through sustainable spatial planning. Therefore, this study aims to evaluate the carrying capacity based on the land capability of both existing and official land use plans. The matching criteria method was used to conduct the capability evaluation. According to the analysis results, 56,13% of the Kulon Progo area was dominated by moderate to low land capability classes (V-VIII), with the main inhibiting factor as slopes. Furthermore, the evaluation of conformity with land use/land cover (LULC) in 2020 showed most land uses were in not conform (NC) and conditionally conform (CC) status. The area of land use that did not conform with its carrying capacity was 8.286,44 ha which was distributed in the southern part. Meanwhile, an evaluation of the official land use plan of the area showed 57% of the plan conform (C) with land capability. Therefore, the carrying capacity of the land in Kulon Progo is in reasonably good condition. However, planning interventions should be carried out for areas with no conform status.*

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INTRODUCTION

Kulon Progo is currently undergoing a development transition towards a new aerotropolis era with the construction of Yogyakarta International Airport. Aerotropolis is a development concept that combines land use and transportation aspects with an agglomeration of activities located in the airport area (Banai 2017). This development has positively influenced the growth of Gross Domestic Regional Product (GDRP) since 2018, which increased to 10,83% (BPS Kulon Progo 2021). Also, the construction sector has experienced positive growth and contributed the most to the GDRP in 2019 (BPS Kulon Progo 2021). This growth is correlated with the increase in built-up, which is a land cover indication of an urban-oriented activity. The emergence of a new airport has changed the value in the region from the rural to urban perspective (Pratiwi and Rahardjo 2018), with the main activities in the form of services and trade (Rustiadi *et al.* 2009). The rapid growth in built-up and the lack of land use planning probably creates the urban sprawl, which consequently has an impact on the inefficient use of resources (He *et al.* 2017; Andari *et al.* 2022; Fuadina *et al.* 2021).

The rapid economic growth in Kulon Progo needs to consider the sustainability aspect attentively. Spatial planning is essential in realizing sustainability by preventing excessive growth, such as urban sprawl (Wilson and Chakraborty 2013; Bovet *et al.* 2018). Law No. 26 of 2007 concerning Spatial Planning states that the use of space needs to consider the carrying capacity. According to Law No. 32 of 2009, the carrying capacity is the ability of the environment to support the activities of human life and other creatures. Meanwhile, a land capability is one approach for its analysis. It is also an assessment of land's characteristics, such as topography, drainage, soil texture, erosion, adequate soil depth, certain factors like rocks, and flooding threat (Hardjowigeno and Widiatmaka 2007).

The carrying capacity evaluation of the existing land use/land cover (LULC) and official land-use planning is important to be conducted in the early phase of the aerotropolis development era. The more comprehensive study was conducted by Litasari *et al.* (2022) to build the policy recommendation to spatial planning in Kulon Progo. However, this study is concern on preliminary diagnostic of spatial performance using land capability. This is to ensure that the land can be utilized according to the carrying capacity (Sharififar *et al.* 2013; Liu *et al.* 2018; Zhang *et al.* 2018). The evaluation of the existing condition reflects the actual condition, which becomes an important input for formulating spatial planning policies in the future (Widjayatnika *et al.* 2017; Pravitasari *et al.* 2020, 2021; Jaya *et al.*, 2021). Moreover, the evaluation of the official planning provides a quality of planning overview in realizing sustainability. Therefore, recommendations for spatial planning can be drawn up to actualize sustainable development. This study aims to evaluate the carrying capacity based on land capability for both existing and official land use planning as input in formulating sustainable spatial planning policies.

METHODS

Study Area

This study was conducted in the Kulon Progo Regency, which is the location for the construction of Yogyakarta International Airport. It is one of the regencies in Yogyakarta Special Province. Astronomically, it is located at 7°38'42"-7°59'3" South Latitude and 110°1'37"- 110°16'26" East Longitude. Magelang Regency borders with Kulon Progo in the north, Bantul and Sleman in the east, the Indian Ocean in the south, and Purworejo Regency in the west. This study location consists of 12 district administrations and 88 villages. It is also divided into three clusters based on its topographic characteristics (North, East, and South), which is presented in Figure 1.

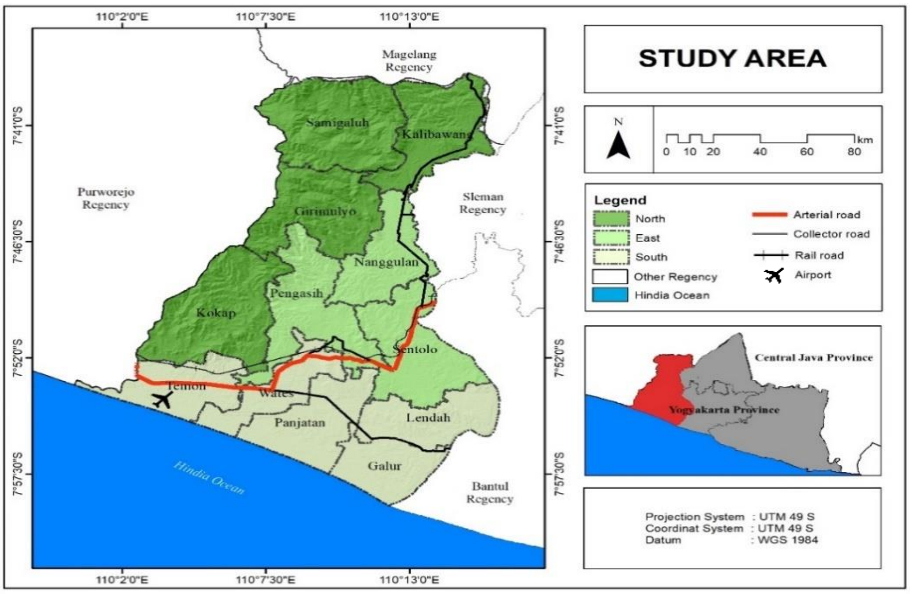

Figure 1 Study area

Data Collection

Soil map unit data as a unit of land capability analysis were obtained from the Indonesian Center for Agricultural Land Resources Research and Development (ICALRD) with a scale of 1:50.000. Meanwhile, LULC data were obtained by processing Landsat 8 imagery in the 2020 recording year with a 30 m spatial resolution. This image was processed using supervised classification to obtain the data. The data LULC was analyzed by Litasari *et al.* (2021). The ground check was conducted on December 3rd –10th, 2020. The location distribution of ground checkpoints can be seen in Figure 2. Moreover, the official land use planning map 2012 – 2032 of Kulon Progo was obtained by accessing http://bappeda.jogjaprov.go.id/dataku/peta.

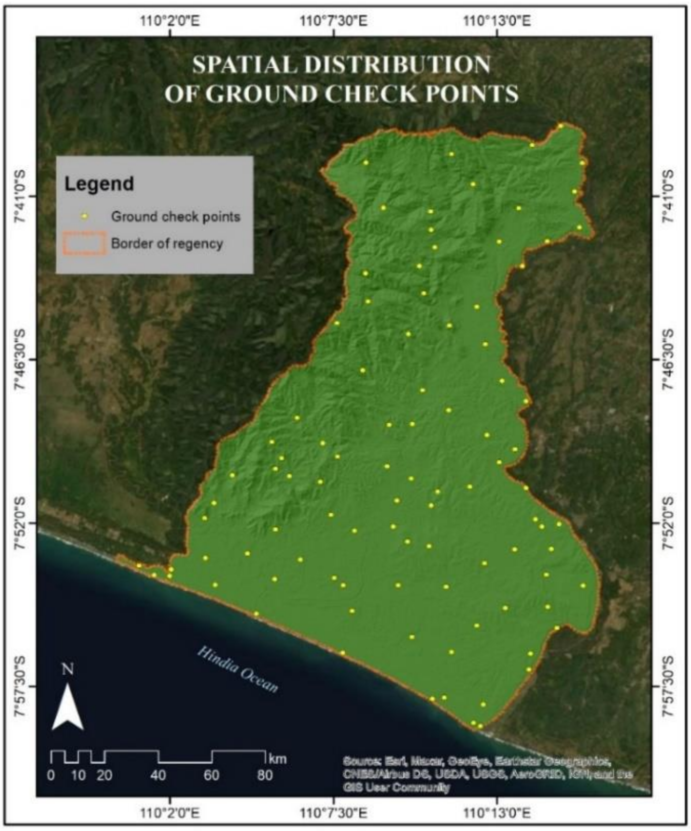

Figure 2 Distribution of ground check points

Data Analysis

The land capability evaluation was carried out by analyzing the soil map unit, which amounted to 46 units by using matching criteria that was adopted from the analysis of Litasari *et al.* (2022). This method is an analysis which matches land capability requirements with the actual characteristics (Amalia, 2015). Table 1 represented the criteria for determining the land capability class.

The results of the land capability analysis were subsequently analyzed for their conformity with the actual land use in 2020 and the official land use planning 2012–2032. The degree of conformity is divided into three, namely conform (C), conditionally conform (CC), and not conform (NC). The conform indicated that the existing LULC or official land use planning was in accordance with the land capability. The conditionally conform criteria indicated that the actual LULC or official land use planning exceeded their carrying capacity, although they can still be tolerated but require certain interventions in their utilization. Meanwhile, the criteria that do not conform indicated that the actual LULC or official land use planning exceeded their carrying capacity (Widiatmaka *et al.* 2015; Sadesmesli *et al.* 2017).

Table 1 Criteria of land capability

No	Inhibiting Factors	Land Capability Class							
		I	II	III	IV	V	VI	VII	VIII
1	Soil texture (t)[1)]								
	a. Upper layer	t_2/t_3	t_1/t_4	t_1/t_4	(*)	(*)	(*)	(*)	t_5
	b. Lower layer	t_2/t_3	t_1/t_4	t_1/t_4	(*)	(*)	(*)	(*)	t_5
2	Slope(%)[2)]	l_0	l_1	l_2	l_3	(*)	l_4	l_5	l_6
3	Drainage[3)]	d_0/d_1	d_2	d_3	d_4	(**)	(*)	(*)	(*)
4	Soil effective depth[4)]	k_0	k_0	k_1	k_2	(*)	k_3	(*)	(*)
5	Erosion[5)]	e_0	e_1	e_1	e_2	(*)	e_3	e_4	(*)
6	Rock[6)]	b_0	b_0	b_0	b_1	b_2	(*)	(*)	b_3
7	Flood[7)]	o_0	o_1	o_2	o_3	o_4	(*)	(*)	(*)

Source*:* Hardjowigeno and Widiatmaka (2007); Widiatmaka *et al.* (2015).
*can have any of the inhibiting factor properties of the lower class, **the surface is always flooded.
[1)]soil texture: t_1: fine, t_2: medium fine, t_3: medium, t_4: medium-coarse, t_5: coarse; [2)]slope: l_0: (0-3%), l_1: (3-8%), l_2: (8-15%), l_3: (15-30%), l_4: (30-45%), l_5: (45-65%), l_6: (>65%); [3)]drainage: d_0: good, d_1: rather good, d_2: rather poor, d_3: poor, d_4: very poor; [4)]soil depth: k_0: deep, k_1: moderate, k_2: shallow, k_3: very shallow; [5)]erosion: e_0, there is no erosion, e_1: light, e_2: moderate, e_3: heavy, e_4: very heavy; [6)]rocks: b_0: not exist or slight, b_1: moderate, b_2: abundant, b_3: very abundant; [7)]flood: o_0: never happened, o_1: seldom o_2: sometimes, o_3: frequent, o_4: very frequent.

RESULT AND DISCUSSION

The land capability analysis only utilized four of the seven criteria specified in Hardjowigeno and Widiatmaka (2007). Three criteria, which are, the state of erosion, rock, and flooding, were not included due to limited data. Table 2 showed the analysis result of land capability classes in Kulon Progo. This classes are categorized as follows, land with high to medium capability (class I-IV) and land with moderate to low capability (class V-VIII), according to Widiatmaka *et al.* (2015).

Table 2 Land capability class in Kulon Progo Regency

No	Class	Sub-class	Area (ha)	Area (%)
High to medium capability (Class I-IV)				
1	I	I-t,l,d,k	2.426,04	4,32
		I-l,d,k	529,70	0,92
2	II	II-k,d	2.507,27	4,37
		II-l,k	529,30	0,92
		II-t,l,k	776,60	1,35
3	III	III-t	9.066,65	15,82
		III-l	173,27	0,30
		III-t,l	141,60	0,25
4	IV	IV-l	2.672,51	4,66
		IV-k	2.898,07	5,06
		IV-l,k	3.217,68	5,61
Sum			24.938,70	43,50
Moderate to low capability (Class V-VIII)				
5	VI	VI-l	1.276,45	2,23
		VI-k	5.218,42	9,10
		VI-l.k	172,59	0,30
6	VII	VII-l	1.8305,56	31,93
7	VIII	VIII-t	6.340,06	11,06

No	Class	Sub-class	Area (ha)	Area (%)
		VIII-l	865,62	1,51
Sum			32.178,70	56,13
No data			208,72	0,36
TOTAL			57.326,13	100,00

The Kulon Progo area was mostly classified as a moderate to low land capability. Class VII had the most land capability in the area where the main inhibiting factor was a slope. Class VII was distributed over the Menoreh Hills area in the western part, extending to the north of the Regency. Meanwhile, class VIII was concentrated in the southern part, with the main inhibiting factor as soil texture. The main inhibiting factor for class VIII, which was distributed in other areas was the slope. Class III, with texture as an inhibiting factor dominated in the high to medium capability group of classes. In comparison, the percentage of classes I and II was less compared to the others. Land with high to medium capability was distributed in the eastern cluster of Kulon Progo. This area has a relatively flat to wavy topography. The spatial distribution of land capability classes in this location is shown in Figure 3.

The conformity evaluation results of land capability with existing LULC in 2020 showed that most land uses was still in the conform and conditionally conform categories. The land use that was not in line with the land capability was 8.286,44 ha or approximately 14,45% of the total area. Table 3 presents details of the conformity evaluation from land capability with LULC 2020 in the regency.

LULC which did not conform with the carrying capacity distributed in the southern cluster of Kulon Progo. This area had a coarse texture which was the main inhibiting factor. Therefore it was included in class VIII. Soil texture affect the intrution of contaminant vapor concentration attenuation that probably caused human exposure at area where the building build top of contamination (Yao *et al.*, 2017). Coarse texture soil also have bad performance in filtering materials that caused ground water pollution (Hardjowigeno and Widiatmaka 2007). In addition, the texture is a component that can not be changed through the land management process (Hardjowigeno and Widiatmaka 2007). Therefore, the areas are not recommended for intensive cultivation activities.

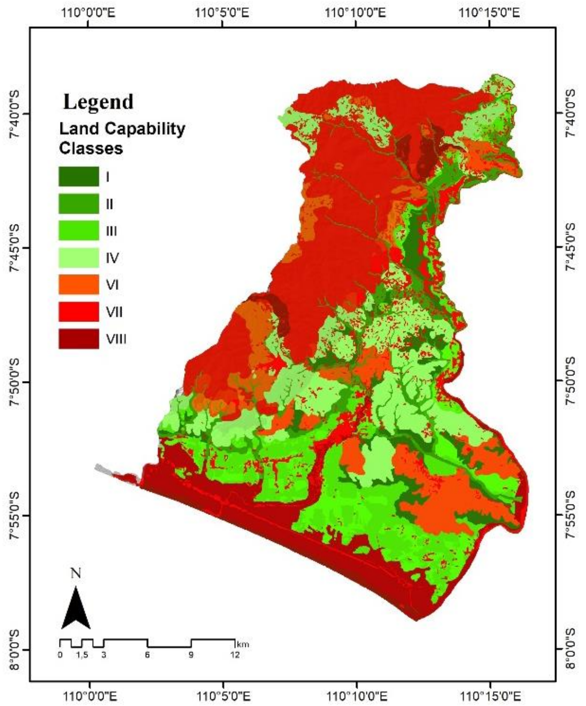

Figure 3 Land capability of Kulon Progo Regency

Table 3 Conformity evaluation of land capability and land use/land cover 2020

LCC*	LULC**	LCC-LULC	Area (ha)	Area (%)
I	F, MG, WA, DA, OA, S	C	2.955,74	5,16
II	F, MG, WB, WA, DA	C	3.739,00	6,52
	OA, S	CC	74,18	0,13
III	F, MG	C	4.642,31	8,10
	WA, DA, OA, S	CC	4.739,20	8,27
IV	F, WB	C	1.380,08	2,41
	MG, WA, DA, OA, S	CC	7.408,19	12,92
VI	F, WB	C	1.678,77	2,93
	MG	CC	4.679,08	8,16
	WA, DA, OA, S	NC	309,61	0,54
VII	F, WB	C	10.838,31	18,91
	MG	CC	5.819,18	10,15
	WA, DA, OA, S, BS	NC	1.648,07	2,87
VIII	F, WB	C	876,92	1,53
	MG, WA, DA, OA, S, BS	NC	6.328,76	11,04
	No data		208,72	0,36
		TOTAL	57.326,13	100

*LCC = Land capability classes, **LULC = land use/land cover, F = forest, WB = water body, MG = mixed garden, WA = wetland agriculture, DA = dry-land agriculture, OA = opened area, S = settlement, BS = built up non settlement.

Conversely, the southern cluster will become a new growth center with the airport construction. Several infrastructure development programs will also be built in this cluster to accommodate regional growth opportunities. Some of the priority infrastructure for acceleration stated in the Governor's decree of Yogyakarta Special Province No. 163/KEP/2017 include the construction of the Tanjung Adikarta Port, the development in the southern coast of Kulon Progo, the construction and development of a new airport area, as well as the construction of the Wates International Hospital. Moreover, the impact of settlement growth which was also predicted will occur with the shifting land value of the strategic area. The development of the area with urban-characterized activities emergence will increase the water demand. Therefore, development in the southern region should be conducted by considering its carrying capacity. The map for conformity evaluation of land capability and existing land use in 2020 is presented in Figure 4.

Conformity evaluation of land capability with the official land use planning in 2012–2032 showed that 57,06% of the plan conforms with land capability, and 18,65% conditionally conformed. Meanwhile, the official land use planning that did not conform with the land capability was 13.694,26 ha or 23,89%. The details of the conformity evaluation are shown in Table 4.

The official land-use planning with NC status was spatially distributed in the southern and eastern parts of Kulon Progo. The land-use allocation of the official land use planning in the Menoreh Hills area was in reasonable conform (C) status. Figure 5 showed the spatial distribution conformity evaluation of land capability with the official land use planning.

The recapitulation of conformity between land capability with the actual land use in 2020 and the official land use planning of 2012–2032 showed that the carrying capacity of the official planning was better than the actual land use. However, land use that did not conform was more common in official planning. This indicated that the actual land use did not exceed its carrying capacity. However, it will be exceeded in some areas when land use occurs according to the plan. Therefore, it is necessary to revise several land uses in the official planning to direct allocation conformally with their carrying capacity.

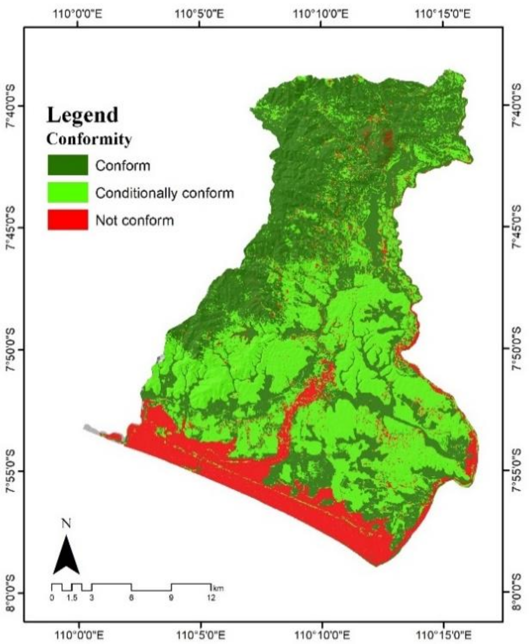

Figure 4 Conformity evaluation of land capability with existing land use/land cover 2020

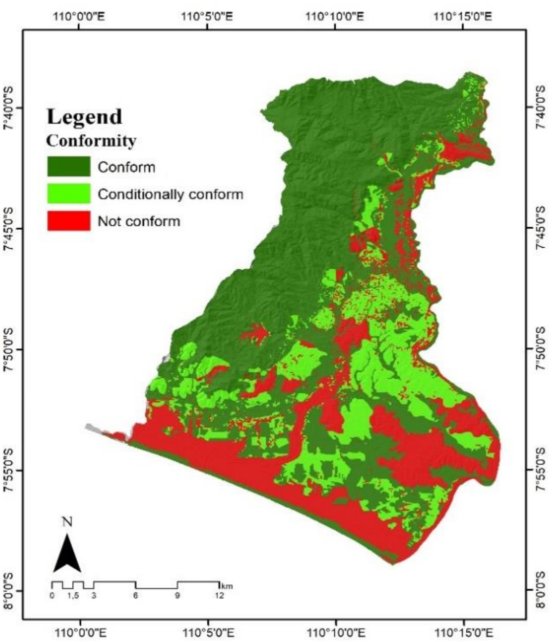

Figure 5 Conformity evaluation of land capability and official land use planning 2012–2032

Table 4 Conformity evaluation of land capability and official land use planning 2012–2032

LCC	LUA*	LCC-LUA	Area (ha)	Area (%)
I	PF, RA, RB, LB, SF, HP, IF, WA, DA, RS, US, TA, IN	C	2.955,55	5,16
II	PF, SF, HP, KRA, RB, LB, IF, WA, DA, RS	C	3.481,84	6,07
	US, TA, IN	CC	325,22	0,57
III	RA, RB, SF, IF, WA, DA	C	5.887,16	10,27
	RS, US, TA, IN	CC	3.537,41	6,17
IV	PF, PA, RA, RB, LB, SF, HP	C	3.098,32	5,40
	WA, DA, IF, RS, US, IN	CC	5.686,94	9,92
VI	PF, RA, RB, LB, PA	C	2.203,75	3,84
	SF, HP	CC	319,62	0,56
	WA, DA, IF, RS, US, TA, IN	NC	4.136,49	7,22
VII	PF, RA, RB, LB, SA, SP, PA	C	13.380,89	23,34
	SF	CC	0,00	0,00
	HP, WA, DA, IF, RS, US, TA, IN	NC	4.069,88	7,10
VIII	SA, RA, RB, SP	C	1.705,53	2,98
	SF, WA, DA, IF, RS, US, TA, IN	NC	5.487,89	9,57
	No data		1.049,62	1,83
		TOTAL	57.326,13	100

*LUA = Land use allocation, PF = protected forest, RA = reservoir area, RB = river border, LB = lake border, SF = social forest, HP = production forest, IF = inland fishing, WA= wetland agriculture, DA = dryland agriculture, RS = rural settlement, US = urban settlement, TA = trading area, IN = industry

On the other hand, the degree conformity of the conditional conform status on actual land use was greater than the official planning. This indicated the need to enforce land-use regulations based on official land use planning. Conformity recapitulation of land capability with actual and official land-use planning can be seen in Table 5. The actual land use and official planning in Kulon Progo Regency are in fairly good condition. However, the actual and official planning included in the conditionally conform and non-conform status requires policy intervention to utilize land use, considering its carrying capacity.

Table 5 Recapitulation of conformity

Conformity	LCC vs LULC		LCC vs LUA	
	ha	**%**	**ha**	**%**
C	26.111,13	45,55	32.713,05	57, 06
CC	22.719,83	39,63	10.690,46	18,65
NC	8.286,44	14,45	13.694,26	23,89

C = conform, CC = conditionally conform, NC = not conform, LCC = land capability classes, LULC = land-use/land cover, LUA = land use allocation

CONCLUSION

The carrying capacity based on land capability in Kulon Progo is in fairly good condition as most of the existing areas, as well as the official land-use planning, had conditions that conformed and conditionally conform with the land capability. However, the southern region of this regency, which will be the center of new growth, had low carrying capacity based on a land capability perspective. The main inhibiting factor of the area included the soil texture, which is difficult to intervene using land management. Therefore, policy intervention is required, especially in the southern region of Kulon Progo, to sustainably carry out the planned development as a new growth center.

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