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MODELLING OF DOMESTIC WATER DEMAND USING SPATIAL DATA POPULATION FOR CISADANE UPSTREAM WATERSHED

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Abstract

In Indonesia, water resources management planning has done based on river area. But the problem is the calculation still based on population data with administrative boundary. This is caused by the lack of population data with watershed or river area boundary. Geographical Information System (GIS) is a tools to analyze, visualize and interpret data with spatial and geographic data. For this research, GIS is used to generate population data with watershed and river area boundary,then the result will used for domestic water demand calculation for Cisadane upstream watershed. For all district in Cisadane Upstream Watershed, the largest district in entire watershed are Cibungbulang, Leuwiliang and Nanggung. But the most dense population are Ciomas, Ciampea and Cibungbulang. The calculation using watershed boundary resulting significant difference from district boundary. With spatial data population using watershed boundary, domestic water demand calculation result can be more accurate than using all district population data.

Keywords : *Cisadane; GIS; Population; Spatial*

Abstrak

Di Indonesia, perencanaan pengelolaan sumber daya air dilakukan berdasarkan wilayah sungai. Namun masalahnya adalah perhitungannya masih berdasarkan data kependudukan dengan batas administrasi. Hal ini disebabkan oleh kurangnya data populasi dengan batas daerah aliran sungai atau sungai. Sistem Informasi Geografis (SIG) adalah alat untuk menganalisis, memvisualisasikan dan menginterpretasi data dengan data spasial dan geografis. Untuk penelitian ini, SIG digunakan untuk menghasilkan data populasi dengan batas daerah aliran sungai dan sungai, kemudian hasilnya akan digunakan untuk perhitungan kebutuhan air domestik untuk DAS Cisadane. Untuk semua kabupaten di Cisadane Hulu DAS, distrik terbesar di seluruh DAS adalah Cibungbulang, Leuwiliang dan Nanggung. Namun populasi yang paling padat adalah Ciomas, Ciampea dan Cibungbulang. Perhitungan menggunakan batas DAS menghasilkan perbedaan yang signifikan dari batas kabupaten. Dengan populasi data spasial menggunakan batas DAS, hasil perhitungan permintaan air domestik dapat lebih akurat daripada menggunakan semua data penduduk kabupaten.

Kata Kunci: *Cisadane; GIS; Populasi; Spasial*

Introduction

Water resources management is one of important issue, facing all problem related to water such as: flood, drought, water quality, etc. In Indonesia, water resources management planning has done based on river area. River area is an unitary area of water resources management in one or more watersheds and / or small islands less than or equal to 2,000 km^2(Indonesia Ministry of Public Works and Public Housing, 2015). Therefore all water resources planning and analysis should be done by river area or watershed boundary.

Based on Indonesia regulation, water resources management planning has been written on document planning for each river area. The document consist of

5 main part of water resources management: water resources conservation, water resources usability, controlling of water damaged power, water resources information system and community empowerment, that integrate to realize water resources sustainability. For ensure that water resources management planning for each river area has represented the condition, the analysis (such as: hydrology and hydraulic analysis, water demand calculation, etc) must be doing with real condition. For domestic water demand calculation (especially in Indonesia), the calculation still based on population data with administrative boundary. This is caused by the lack of population data with watershed or river area boundary.

Geographical Information System (GIS) is a tools to analyze, visualize and interpret data with spatial and geographic data. There are several menu/tools that used to analyze water resources data, such as: thiessen polygon, watershed generating menu, etc (Pa Hidayat and Andajani, n.d.). For this research, GIS is used to generate population data with watershed and river area boundary,then the result will used for domestic water demand calculation. This research use Cisadane upstream watershed as a case study, located in West Java Province in Indonesia.

Literature Review

Domestic Water Demand Calculation Method

Domestic water demand calculation was done by multiplying the projected population number by the appropriate per capita usage number (Georgia Environmental Protection Division, 2007).

Domestic water demand$_i$ = projected population$_i$ x water usage number
i = projected year

Based on (Georgia Environmental Protection Division, 2007), if watershed/river area boundary is different from any established city or county boundary, there are several condition:

a) Known and documented population being served outside the Subdistrict boundaries; and
b) Projected additional population being served outside of the Subdistrictity boundary. This could be based on: proportional areas comparing population percentages to surface area or proportional population distribution (that is used for this research).

For water usage number, based on Indonesia Ministry of Public Works and Housing regulation, is classified by type of area (rural area until metropolis):

a) Rural area : 60 liter / per capita / day
b) Small city : 90 liter / per capita / day
c) Medium city : 110 liter / per capita / day
d) Large city : 130 liter / per capita / day
e) Metropolis : 150 liter / per capita / day.

GIS Application For Water Resources Analysis

Geographic Information System is a tools to analyze, visualize and interpret data with spatial and geographic data. Nowadays, many research on engineering field especially on water resources engineering using GIS as a tools. There are several research that used GIS for water resources engineering field, such as:

a) GIS was used to developed various spatial data such as land-use layers and hydrological layers to apply fundamental concept of the proposed water management modeling of the Chirchik river basin Uzbekistan and overview of hydrological model using Geomorphology Based Hydrological Model (GBHM) (Pachri et al., 2013)
b) GIS was used to assessing water pollution by the use of Landsat data and GIS for at Burullus Lake, Egypt. Multi-spectral Burullus Lake is the second largest lake along the Mediterranean Sea and represents one of the most sub- jected lakes to pollution at the delta's coastline. (El-Zeiny and El-Kafrawy, 2017)
c) GIS was used to develop soil erosion model calculation in Citepus Watershed area in Bandung-Indonesia.GIS is for forming watershed boundary, hydrology analysis and MUSLE calculation to get annual soil loss rate value (Pa Hidayat and Andajani, 2018)

For this research, GIS application is used for overlay watershed boundary with Subdistrictity boundary to generate population data with watershed and river area boundary,then the result will used for domestic water demand calculation.

Research Methodology

Data Collection

For data analysis, there are several data needed, consist of:

- Topography map
  Topography used to generate watershed boundary using watershed tools in GIS. This research is used Shuttle Radar Topography Mission (SRTM) as the topography input.
- Subdistrict area
  Cisadane upstream watershed consist of 17 subdistrict: Bogor Selatan, Bogor Barat, Bogor Tengah, Caringin, Ciampea, Ciawi, Cibungbulang, Cigudeg, Cijeruk, Ciomas, Cisarua, Dramaga, Leuwiliang, Megamendung, Nanggung and Rumpin.
- Population data for each district
  Population data for selected year (2016) in each district that is used from local government of Indonesia.

Watershed Boundary Analysis

Wateshed boundary analysis was done by GIS, used raster topography as the input, and through flow direction and flow accumulation process.

Generating Population Data With Watershed Boundary

Population data for selected year for each district is inserted in GIS by each label featured.

Domestic Water Demand Calculation (With Subdistrict and Watershed Boundary)

Domestic water demand calculation was done by multiplying the projected population number by the appropriate per capita usage number. There are 2 condition for domestic water demand calculation, using population data with Subdistrict boundary and using population data with watershed boundary.

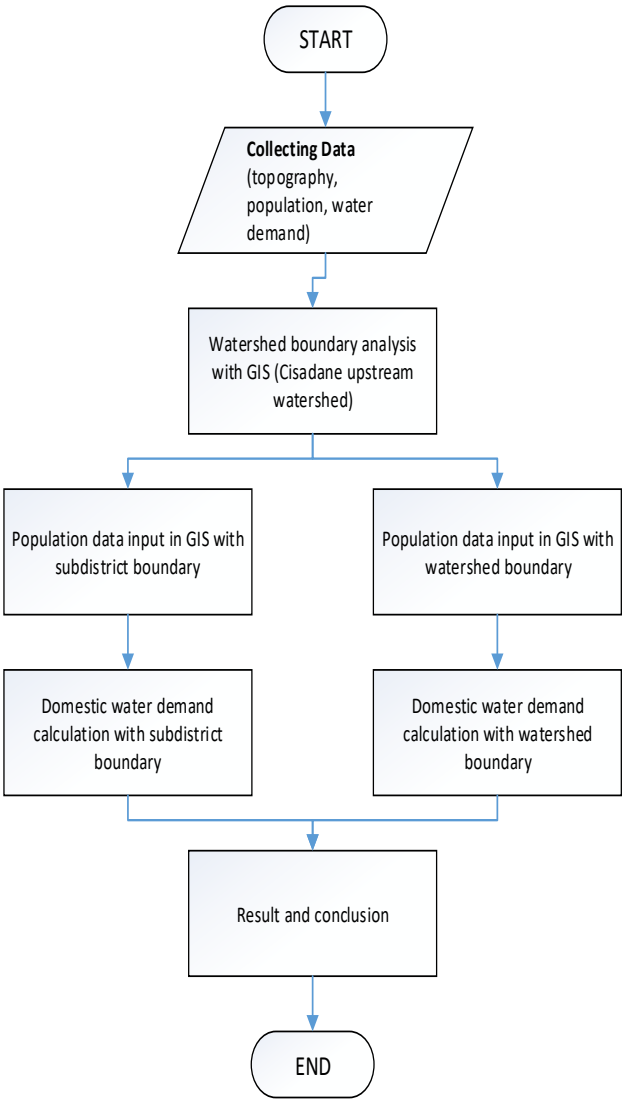


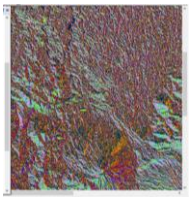
Figure 1
Research Flowchart

Result and Discussion

Watershed and District Boundary Analysis

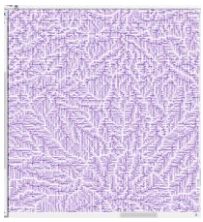
Citepus upstream watershed was generated by watershed tools in ArcGIS, using SRTM raster as the input. The watershed generating process consist of 3 step: Flow direction, flow accumulation and stream analysis. Flow direction analysis aim to create flow direction from each cell to its steepest downslope neighbor, by using SRTM raster as the input. Flow accumulation analysis is used to create a raster of accumulated flow into each cell, by using flow direction result. Then Surface analysis is used to converts a raster representing a linear network to features representing the linear network. Watershed boundary process and result can be seen on Fig.2 and Fig.3.

(a) Raster Topography Data



(b) Flow Direction Result

(c) Flow Accumulation Result



(d) Stream Result

Figure 2
Watershed Boundary Analysis Process

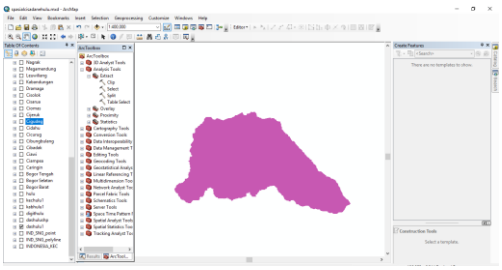


Figure 3
Watershed Boundary Result

After watershed boundary was generated, then overlay watershed boundary layer with sub district boundary layer. The result can be seen on Fig 4. Each sub district is calculated the area and used for the next calculation.

(a) District area

(b) Overlay result

Figure 4
District and Watershed Boundary Overlay Process

Domestic Water Demand Calculation

For this research, domestic water demand calculation consist of 2 method: using sub district area and using watershed area. For all district in Cisadane Upstream Watershed, the largest district in entire watershed are Cibungbulang, Leuwiliang and Nanggung. But the most dense population are Ciomas, Ciampea and Cibungbulang. The calculation using watershed boundary resulting significant difference from district boundary. Domestic water demand calculation result and comparison can be seen on Table 1 and Table 2.

Table 1
Domestic Water Demand Calculation Result (using watershed boundary)

Sub-District	Total Area	Population	Total district area in entire watershed	Percentage areas compared to watershed	Population each district with watershed boundary	Water Usage number	Domestic Water Demand
	km^2	person	km^2	%	person	l/capita/day	m^3/day
Bogor Barat	32.85	236,302	0.62	1.88	4,443	90	400
Bogor Selatan	30.81	199,248	0.19	0.61	1,219	90	110
Bogor Tengah	8.13	104,682	0.27	3.37	3,526	90	317
Caringin	57.29	124,584	57.24	99.92	124,483	90	11,203
Ciampea	70.97	159,258	70.97	100.00	159,258	90	14,333
Ciawi	79.71	115,749	79.71	100.00	115,749	90	10,417
Cibungbulang	130.20	133,222	130.20	100.00	133,222	90	11,990
Cigudeg	158.89	65,424	13.29	8.37	5,473	90	493
Cijeruk	84.29	86,982	84.29	100.00	86,982	90	7,828
Ciomas	55.88	176,599	55.88	100.00	176,599	90	15,894
Cisarua	63.73	123,397	2.96	4.64	5,730	90	516
Dramaga	34.70	110,068	34.70	100.00	110,068	90	9,906
Leuwiliang	108.51	121,597	108.51	100.00	121,597	90	10,944
Megamendung	39.87	106,544	7.93	19.89	21,196	90	1,908
Nanggung	185.57	87,207	185.57	100.00	87,207	90	7,849
Rumpin	111	139,452	8.56	7.71	10,751	90	968
Total	**1,252.40**	**2,090,315**	**840.89**	**946.39**	**1,167,504**		**105,075**

Table 2
Comparison of Domestic Water Demand Calculation Result (using watershed and Subdistrict boundary)

Sub-District	Population	Population each district with watershed boundary	Domestic Water Demand (based on Subdistrict boundary)	Domestic Water Demand (based on watershed boundary)	Water demand difference
	person	person	m^3/day	m^3/day	m^3/day
Bogor Barat	236,302	4,443	21,267	400	20,867
Bogor Selatan	199,248	1,219	17,932	110	17,823
Bogor Tengah	104,682	3,526	9,421	317	9,104
Caringin	124,584	124,483	11,213	11,203	9
Ciampea	159,258	159,258	14,333	14,333	0
Ciawi	115,749	115,749	10,417	10,417	0
Cibungbulang	133,222	133,222	11,990	11,990	0
Cigudeg	65,424	5,473	5,888	493	5,396
Cijeruk	86,982	86,982	7,828	7,828	0
Ciomas	176,599	176,599	15,894	15,894	0
Cisarua	123,397	5,730	11,106	516	10,590
Dramaga	110,068	110,068	9,906	9,906	0
Leuwiliang	121,597	121,597	10,944	10,944	0
Megamendung	106,544	21,196	9,589	1,908	7,681
Nanggung	87,207	87,207	7,849	7,849	0
Rumpin	139,452	10,751	12,551	968	11,583
Total	**2,090,315**	**1,167,504**	**188,128**	**105075**	**83,053**

Conclusion

GIS application is used for overlay watershed boundary with Subdistrictity boundary to generate population data with watershed and river area boundary. For all district in Cisadane Upstream Watershed, the largest district in entire watershed are Cibungbulang, Leuwiliang and Nanggung. But the most dense population are Ciomas, Ciampea and Cibungbulang. The calculation using watershed boundary resulting significant difference from district boundary.

Implication

With spatial data population using watershed boundary, domestic water demand calculation result can be more accurate than using all district population data.

Limitation and Suggestion

For next result, GIS can be used to generate population distribution in entire watershed for each district, and population data can be projected to calculate water demand in the future.

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