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LAND AND WATER CARRYING CAPACITY ON INDUSTRY ALLOCATION IN KENDAL REGENCY

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ABSTRACT
The purpose of this study is to provide information and also clear and accurate pictures of the carrying capacity of land and water in the industrial designation in the Kendal Regency. The method of analysis used is system dynamics approach. The projection of calculation for the next 10 years (2021 - 2031) is a prediction of water demand which is known continues to increase. The availability of water in the Kendal Regency is still sufficient for the population's living and industrial needs during this period. The management of agriculture and plantations have taken several steps to maintain the function of land according to conservation aspects and to prevent degradation in order to keep the conservation area as a reservoir of natural water. The industrial estate area in Kendal Regency is 1,265,323 hectares which is consists of land for industry and trade, mixed gardens, fields, meadows, coastal sand, settlements, rice fields, fishponds and dryland agriculture.

KEYWORDS
Carrying Capacity, Land, Water, Industry

Introduction

The carrying capacity and land capacity of the environment as a consideration basis in the development and expansion of an area have been mandated since the enactment of Republic of Indonesia (RI) Law No. 4 of 1982 concerning Basic Provisions for Environmental Management which was later replaced by RI Law No. 23 of 1997 concerning Environmental Management. Meanwhile, RI Law No. 32 of 2009 has substituted Law No. 23 of 1997 which elaborates these mandates in some articles. It is including Article 12 which states that if the Environmental Protection and Management Plan (*Rencana Perlindungan dan Pengelolaan Lingkungan Hidup* / RPPLH) has not been prepared, then utilization of natural resources is carried out based on the carrying capacity and land capacity of the environment. In addition, Articles No. 15, 16 and 17 explain that the carrying capacity and land capacity of the environment is one of the study content that underlie the preparation or evaluation of regional / sub-national / national spatial plans (*Rencana Tata Ruang Wilayah* / RTRW), long-term and medium-term development plans (*Rencana Pembangungan Jangka Panjang* / RPJP and *Rencana Pembangunan Jangka Menengah* / RPJM) and policies, plans and / or programs that have potential to cause environmental impacts and / or risks, through a Strategic Environmental Assessment (*Kajian Lingkungan Hidup Strategis* / KLHS).

The increasing population causes the availability of land resources and capabilities will be increasingly limited due to the increasing number of living needs compared to the availability of existing land resources. In addition, the quality and condition of the land decrease due to human activities that do not pay attention to the sustainability aspects of the environmental function which worsens the quality of the environment [1]. The Kendal Industrial Zone (*Kawasan Industri Kendal* / KIK) development, which has 60 companies registered, and the Semarang-Batang toll road construction project are still under construction. This will certainly result decrease in environmental situation in some areas in Kendal Regency due to increasing use of natural resources from various industrial activities and existing waste products, including space for human life and other living things [2].

Water resources have a decreasing trend both in quality and availability in surface water and groundwater. This happens because the management of water resources does not pay attention to the carrying capacity and land capacity of the environment [3], [4]. As an illustration, big cities are currently experiencing a water crisis. Based on the water footprint, water availability cannot meet the needs of the population who live in a city, because of the tug of war water needs from various sectors [5]. In addition, poor water quality requires technology to process water into consumption. Management of water resources does require optimal efforts, therefore its availability and quality can always be maintained [6], [7]

The use of natural resources must be in harmony and balance with the functions of the environment. As a consequence, development policies, plans and / or programs must be imbued with the obligation to conserve the environment and achieve sustainable development goals which have 3 pillars, namely economic, social and ecological [3], [8]. As stated in Law No. 32 of 2009 concerning Environmental Protection and Management, carrying capacity and environmental capacity (DDDTL) of industrial areas can be used as a basis for consideration in the development of an area, utilization of natural resources, and determination in the formulation of policy making, plans, and / or programs in sustainable development.

Methodology

The scope of the environmental services study area around the industrial designation area of Kendal Regency is in the Kaliwungu sub-district covering an area of living space and land use area of 1,265 Ha. The collected data were obtained from secondary data, also from primary data includes data from observations and interviews. System Dynamics analysis begins with determining the objectives in the system [9]. Furthermore, determining the system requirements to achieve goals, formulating problems which are obtained from the results of studies, brainstorming, and expert discussions. Problems in the system are used as constraints in system effectiveness. The next stage is to identify the system by making input and output diagrams [6]. To make it easier to see the description of the relationship between variables, both input and output, it is described with a causal relationship (Causal Loop Diagram) in Fig 1. The causal loop function is also used to limit the system that will be studied [10]. Technical analysis is done by building a structure (Stock Flow Diagram) to be able to carry out simulations, where data grouping and data input are carried out in a model structure [11]. Thus it can be seen the behavior of the system that is formed. Validation needs to be done, therefore the model can be scientifically justified. System behavior can be seen from the factors / variables in the model, using quantitative important factors from the basic model and quantitative important factors that have been quantified [11]. Model evaluation is done by comparing the output of the scenario simulation and the expected output at the system identification stage. System Dynamics are an excellent analytical method for use in the short and long term, because it can be seen the behavior of changing conditions in the future, it can be seen that the relationship is abstract so that it is simplified by the relationship on the causal loop [12]. However, system dynamics require a lot of data in the form of time series so that it takes time and is limited by assumptions to limit the study. As many assumptions as possible are not too many to produce a good model [7].

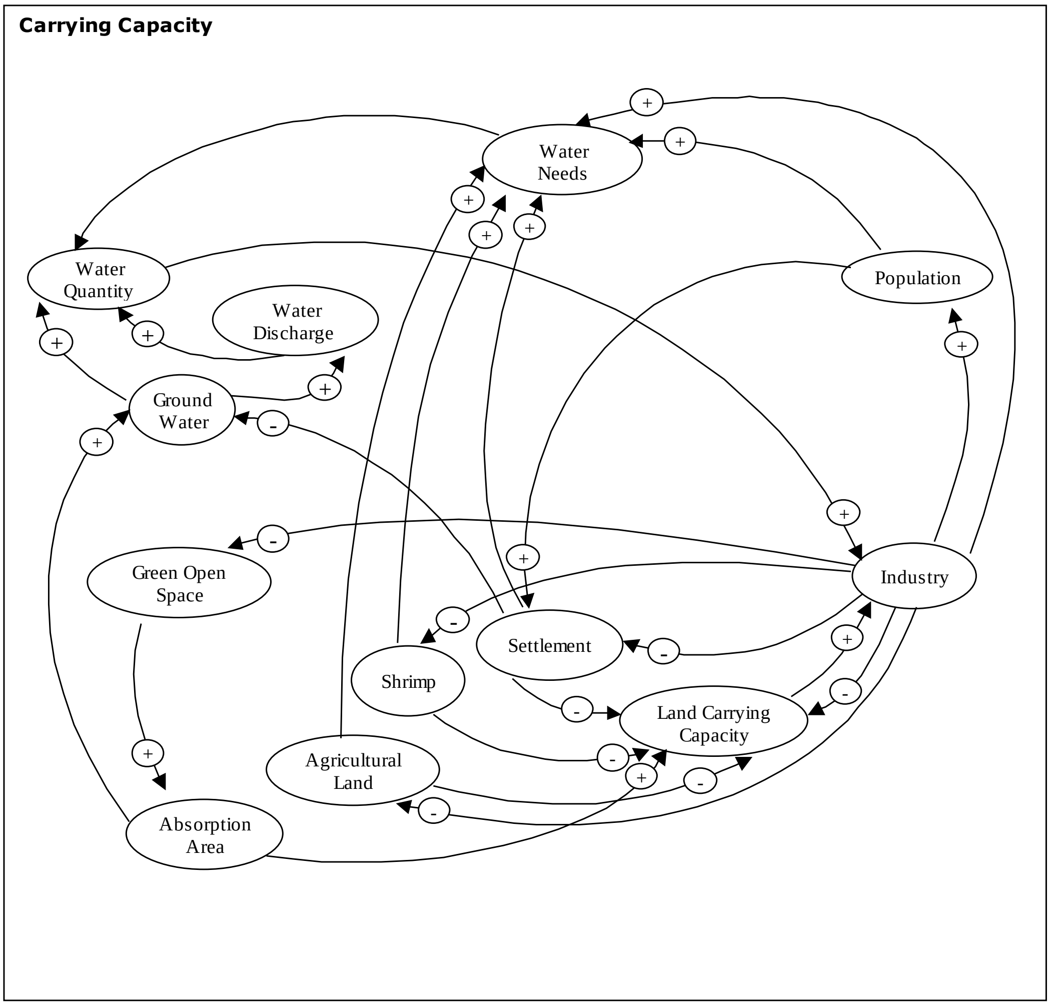

Fig 1. *Causal Loop Diagram* (CLD) Model of Land and Water Carrying Capacity in Kendal Regency

Result and Discussion

Water Availability in Kendal Regency

The carrying capacity of the environment is the ability of the environment to support human life and other living things. One way to determine the carrying capacity of the environment is the water supply and demand approach [3]. Water is a natural element that is indispensable for various forms of human activity. Water availability is a function of time, which is abundant / excessive in the rainy season and reduce in the dry season. The total amount of water around the world is constant. The total supply cannot be reduced or increased, but with efforts to develop and manage water resources, the distribution according to time and space can be adjusted according to their needs [7].

The environmental balance can be seen from the availability of water sources that are useful for meeting the needs, especially for the Kendal Regency Industrial Allocation Area. The river coverage includes the Blorong River, Kuto River, and Sungao Bodri. There are also other water sources, namely the Kedung Suren Reservoir and the Kendal Regency Spring. Water sources based on discharge in 2013-2017 are presented in Table 1.

Table 1. Water Sources in Kendal Regency 2013-2017 [13]–[18]

Water Sources	Season	2013	2014	2015	2016	2017	Unit
Blorong River*	Rainy season	498.7	498.7	498.7	497.6	498.7	m^3/s
	Dry season	99.7	61.2	61.2	101.7	99.7	m^3/s
	Average	299.2	279.95	279.95	299.65	299.2	m^3/s
Kuto River*	Rainy season	504.9	504.7	504.7	513.9	504.9	m^3/s
	Dry season	100.9	100.9	100.9	103.4	100.9	m^3/s
	Average	302.9	302.8	302.8	308.65	302.9	m^3/s
Bodri River*	Rainy season	215	315	315	376.6	215	m^3/s
	Dry season	43	98	98	76.9	43	m^3/s
	Average	129	206.5	206.5	226.75	129	m^3/s
Kedung Suren Reservoir	Volume	4817.71					m^3
Water Spring	Discharge Water	1.2545					m^3/s

Based on Fig. 2, it can be seen that the highest rainy season river discharge was in 2016 and decreased in 2017. The largest discharge is in the Kuto River with a discharge of 513.9 m^3/ / second and the lowest is in the Bodri River with a discharge of 215 m^3/ / second. Whereas in dry season the highest discharge is on the Kuto River at 103.4 m^3/ second and the lowest for the Bodri River at 43 m^3/ second. The amount of water availability is closely related to rainfall and land use in Kendal Regency. High rainfall and supported by abundant vegetation will result in high water availability [19]. The condition of water availability is in accordance with the current season. In the rainy season, it shows a fairly high availability compared to the dry season.

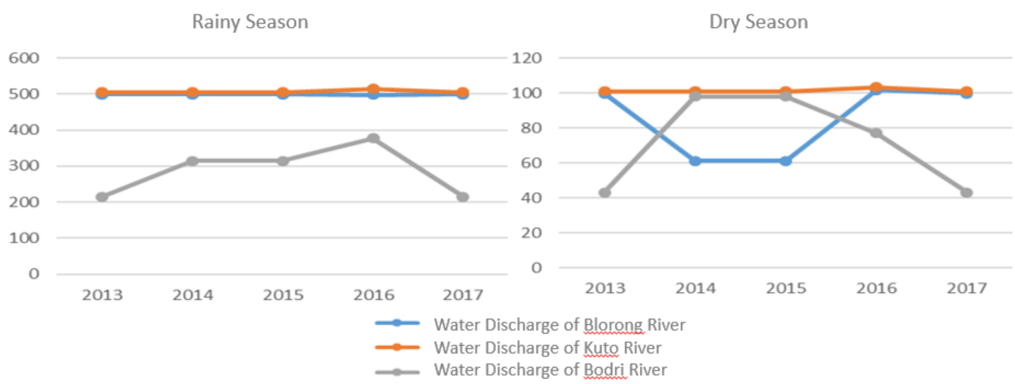

Fig 2. Water Discharge in Kendal Regency 2013-2017 [13]–[18]

The relationship between water supply and demand is presented in Fig. 2. Water availability as seen from springs: Blorong River, Bodri River and Kuto River. Water needs that are considered are industrial and domestic water needs. Domestic water needs are not only seen from the needs of the population but also agricultural needs, including rice fields, ponds and dry land agriculture.

The fluctuation of river discharge development is presented in Fig. 3. The fluctuation of river discharge development can be seen from 2013 to 2030. The largest river discharge is the Kuto River. The fluctuation of the Kuto River and Blorong River is not that significant when compared to the Bodri River. The discharge of Blorong River in 2013 is 9,306,316,800 m^3 / year and in 2030 it is estimated that it is 9,353,741,074 m^3 / year. The discharge of the Kuto river in 2013 was 9,421,401,600 m^3 / year and it is estimated that in 2030 it is 9,602,845,084 m^3 / year. The discharge of the Bodri river in 2013 was 4,012,416,000 m^3 / year and it is estimated that in 2030 it will be 8,546,222,419 m^3 / year. If we look at the fluctuations in the discharge of the Bodri river from year to year, there is a very significant fluctuation.

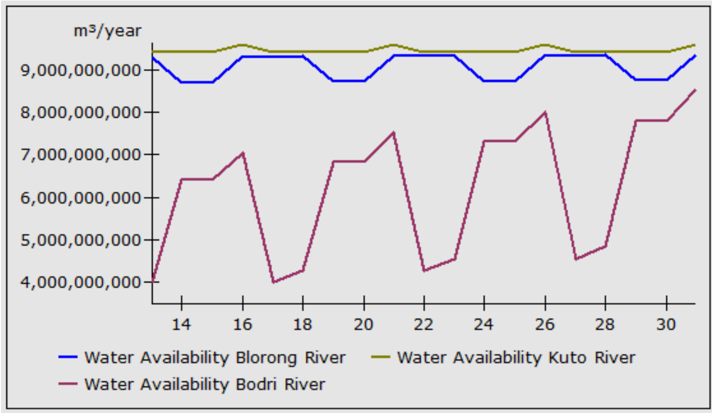

Fig 3. Fluctuated River Discharge

Water Need in Kendal Regency

The determining factor in calculating water demand is the population. Meanwhile, population growth has boosted demand for raw water for domestic, agricultural and industrial needs [4].

The highest population of Kendal Regency was in 2016, it was 961,989 people. Yet, the area for agricultural land has decreased every year from 2013-2017 because it has been converted to other land uses, the largest agricultural land in 2013 was 25,579 ha. Whereas pond land continued to increase every year in 2013 covering an area of 3,460 ha to 4,585 ha in 2017. This also affected the number of industries in Kendal Regency which continued to increase in this year, the number of industries in 2013 amounted to 15,054 industries that had increased up to 2017 to 16,876 industries. Kendal Regency water needs are presented in Table 2.

Table 2. Water Needs in Kendal Regency 2013-2017 [13]–[18]

Variabel	Water Needs		2013	2014	2015	2016	2017
Population	120	l/pop/day	955,949	950,463	952,966	961,989	957,004
Agricultural Land	1,157	l/s/ha	25,579	25,371	25,288	24,941	23,599
Shrimp	22497	m^3/ha/year	3,460	3,741	4,022	4,303	4,585
Industry	365000	m^3/Industry/year	15,054	15,493	15,946	16,411	16,876

Kendal Regency water demand based on simulation results until 2030 is presented in Fig. 4.

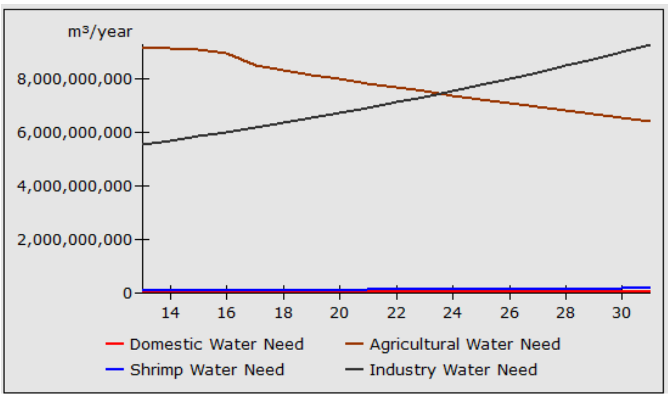

Fig 4. Water Needs in Kendal Regency

Based on the calculation of the projected population, the area of agricultural land, the area of pond land and the number of industries, the domestic water needs in Kendal Regency have increased every year in 2019, namely 42,311,272 m3 / year, the need for agricultural water is 8,160,785,812 m3 / year, the need for pond water amounting to 115,696,560 and industrial water needs 6,547,864,247 m3 / year. In 2031, domestic water needs are 47,884,351 m3 / year, agricultural water needs are 6,6424,873,356 m3 / year, pond water needs are 115,696,560 and industrial water needs are 6,547,864,247 m3 / year. Changes in land use from human activities are an indicator of population growth in an area [20]. The increase in population has a positive correlation with the level of population demand for water. The comparison of water demand and water availability is presented in Fig 5.

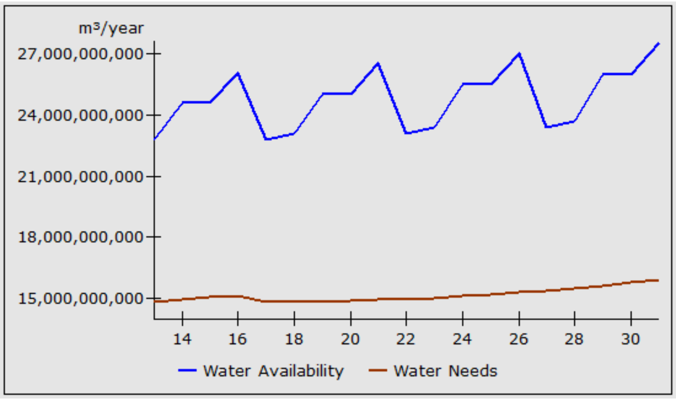

Fig 5. Water Needs and Availability

Based on the graph of water demand and availability of Kendal Regency in 2019, water demand is 14,866,657,891 m^3 / year with water availability of 25,488,537,717 m^3 / year. It is predicted that in 2031 there will be an increase in water demand by 15,914,098,670 m^3 / year with water availability of 27,543,587,009 m^3 / year. Based on the calculation of projections for the next 10 years (2021 - 2031), it is predictable that water demand will continue to increase. To ensure the availability of water in Kendal Regency remains sufficient for the needs of a decent living for local community and is able to maintain land functions according to conservation aspects and prevent degradation, there are steps to take in agricultural and plantation management. Therefore, the managegement will be able to maintain conservation areas as natural reservoirs [5], [7], [11].

Water Need in Industrial Allocated Zone

Industry sector is one of the bases service for a country's economy. Therefore, handling this sector demands an efficient effort to obtain optimal added value [4]. Based on the types of its products, industries can be in the form of processing, service, tourism, and others. Using water is always the necessity in industry sector. It is generally used for the production process, cooling, waste disposal, domestic purposes, and others [7].

The size of an industry is determined among others by the need for production per unit, water need per worker, and for value added production. The industrial water need is presented in Fig 6.

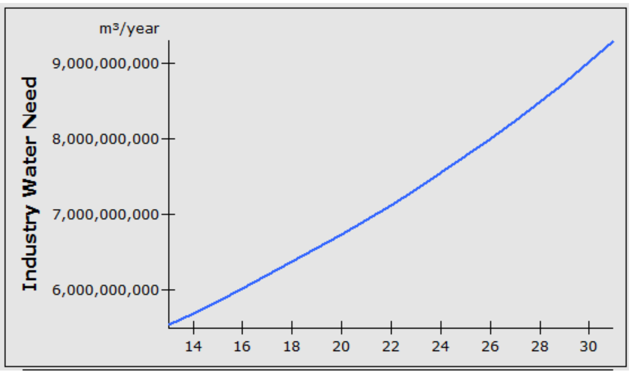

Fig 6. Water Needs of Industry

The need for industrial water has increased every year due to the increasing number of industries in Kendal Regency every year. In 2019 the need for industrial water is 6,547,864,247 m^3 / year, and in 2030, the demand for water will increase to 9,266,103,062 m^3 / year.

Land

The location of the Industrial Allocated Zone in Kendal Regency is exactly in Kaliwungu Regency with an area of 1,265.32 Ha. The map of existing land use in Kendal II Industrial Estate is presented in Fig. 7 and in full map is in Table 3.

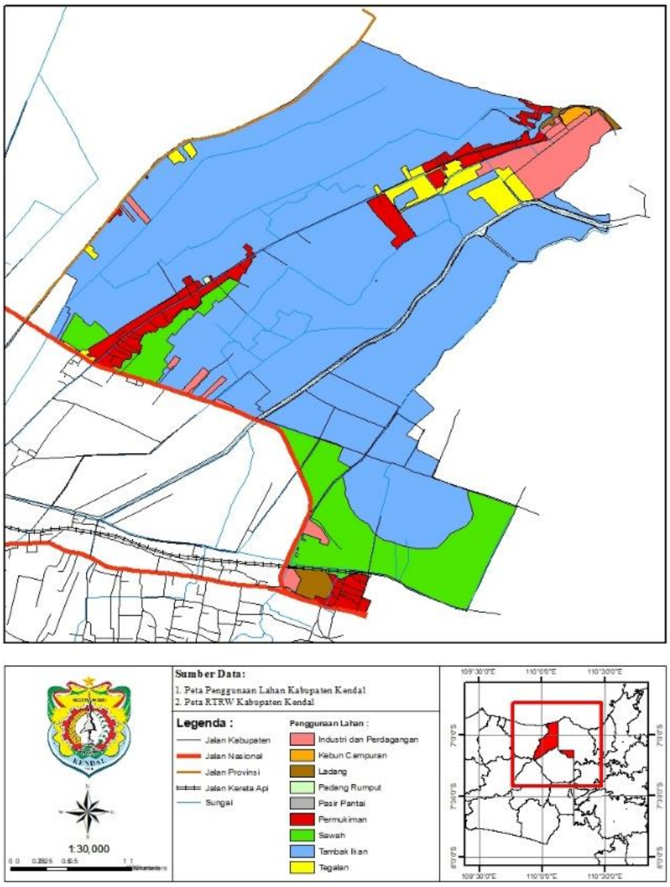

Fig 7. Land Use Map of Industrial Allocated Areas

Table 3. Area of Land Use for Industrial Allocated Areas

Landuse	Area (Ha)
Industry and Commerce	51.42
Mixed Farming	2.3
Agriculture Field	10.76
Grass Area	0.31
Sand Beach	0.1
Settlement	65.30
Paddy Field	148.52
Shrimp	954.58
Edge of rice fields	31.98
Grand Total	1,265.32

The number of industries is currently estimated reaching 60 industries in 2021. It is predicted as well that it will continue to grow on a *Business As Usual* (BAU) basis, and by 2031 the number of industries in this Industrial Allocated Zone of Kendal Regency will reach 366 industries. The prediction of the number of industries is presented in Fig. 8.

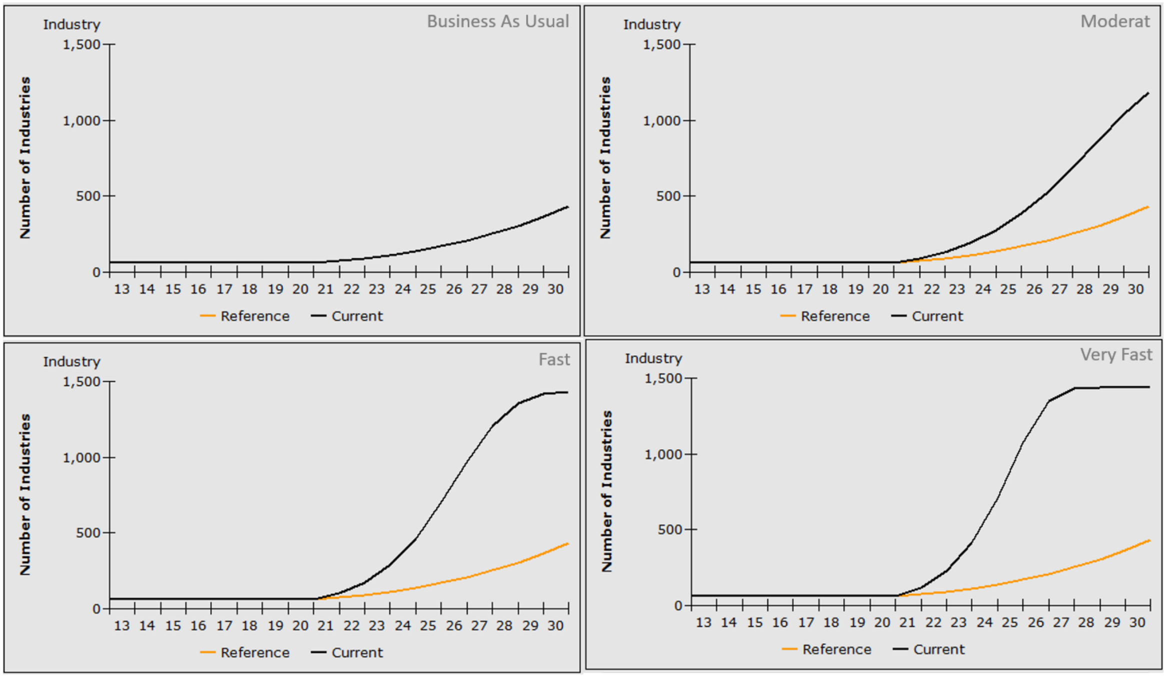

Fig. 8. Prediction of the Number of Industries in the Industrial Allocated Area of Kendal Regency

Simulation results based on BAU show that the number of industries in 2025 is 140 and in 2030 is 434. The model that has been built is then carried out a scenario to see the prediction of the number of industries that can be built. Based on the moderate scenario the number of industries in 2025 is 272 and in 2030 is 1185. Whereas the rapid scenario for the number of industries in 2025 is 464 and in 2030 is 1433, and the very fast scenario for the number of industries in 2025 is 711 and in 2030 is 1440.

Conclusion

Water needs in Kendal Regency come from industrial and domestic water needs. Domestic water need is not only seen from the need of the population, but also from agricultural needs, including rice fields, ponds and dry land agriculture. The availability of water in Kendal Regency is still sufficient for the living need of the population and industrial needs. In order to be able to maintain land functions according to conservation aspects and prevent degradation, some steps should be taken by agricultural and plantation management to maintain conservation areas as natural water reservoirs. The Industrial Allocated Area of 1,265.32 Ha consists of industry and trade, mixed gardens, fields, pasture, beach sand, settlements, rice fields, fish ponds and *tegalan* (edge of rice fields). Whereas the dominant land use is fish ponds covering an area of 954.58 hectares.

References

[1] M. Sukarja, “Pengaruh Alih Fungsi Lahan Pertanian Terhadap Ketahanan Pangan Kawasan Subang Jawa Barat,” Institut Pertaniasn Bogor, 2015.

[2] KIK, *Dokumen Analisis Mengenai Dampak Lingkungan Kawasan Industri Tahap I*. 2014.

[3] J. Zhou, Z. Erdal, P. Creanor, and F. Montalto, “Sustainability,” *Water Environ. Res.*, vol. 82, no. 10, pp. 1376–1395, 2010.

[4] M. Salazar-Ordonez, M. Rodrıguez-Entrena, and S. Sayadi, “Agricultural Sustainability from a Societal View: An Analysis of Southern Spanish Citizens,” *J. Agric. Environ. Ethics*, vol. 26, no. 1, pp. 473–490, 2013.

[5] I. Firmansyah and T. Sukwika, “Penilaian kondisi degradasi tanah di SPK Sawangan kota Depok,” *J. Tanah dan Sumberd. Lahan*, vol. 7, no. 1, pp. 45–57, 2020.

[6] G. Luo, C. Yin, X. Chen, W. Xu, and L. Lu, “Combining System Dynamic Model and CLUE-S Model to Improve Land Use Scenario Analyses at Regional Scale: A Case Study of Sangong Watershed in Xinjiang,

China," *Ecol. Complex.*, vol. 7, no. 1, pp. 198–207, 2010.
[7] A. Saysel, Y. Barlas, and O. Yenigun, "Environmental Sustainability in an Agricultural Development Project: a System Dynamics Approach," *Environ. Manage.*, vol. 64, no. 3, pp. 247–260, 2002.
[8] S. Sikdar, "Measuring Sustainability," *Clean Technol. Environ. Policy*, vol. 14, no. 1, pp. 153–154, 2012.
[9] D. Sterman, *Business Dynamic: System thinking and modelling for complex world.* USA: The Mc Graw-Hill Companies, 2000.
[10] Muhammadi, E. Aminullah, and B. Susilo, *Analisis Sistem Dinamis*. Jakarta: UMJ Press, 2001.
[11] I. Firmansyah, "Model Pengendalian Konversi Lahan Sawah di Dalam DAS Citarum," 2016.
[12] Widiatmaka, W. Ambarwulan, I. Firmansyah, K. Munibah, P. Santoso, and Sudarsono, "Land Suitability and Dynamic System Modelling To Define Priority Areas Of Soybean Plantation In Paddy Fields In Karawang, West Java.," *Agrivita*, vol. 36, no. 3, pp. 235–248, 2014.
[13] BPS, *Kabupaten Kendal Dalam Angka 2019*. 2019.
[14] BPS, *Kabupaten Kendal Dalam Angka 2016*. 2016.
[15] BPS, *Kabupaten Kendal Dalam Angka 2015*. 2015.
[16] BPS, *Kabupaten Kendal Dalam Angka 2018*. 2018.
[17] BPS, *Kabupaten Kendal Dalam Angka 2014*. 2014.
[18] BPPP, *Kajian Lingkungan Hidup Strategis Review RTRW Kabupaten Kendal*. 2017.
[19] Q. Shen, Q. Chen, B. Tang, S. Yeung, Y. Hu, and G. Cheung, "A System Dynamics Model for The Sustainable Land Use Planning and Development.," *Habitat Int.*, vol. 33, no. 1, pp. 15–25, 2009.
[20] P. Yadav, M. Kapoor, and K. Sarma, "Land Use Land Cover Mapping, Change Detection and Conflict Analysis of Nagzira-Navegaon Corridor, Central India using geospatial technology," *Int. J. Remote Sens. GIS*, vol. 1, no. 2, pp. 90–98, 2012.