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(RESEARCH ARTICLE)

Urban green space optimization in Sorong City of Southwest Papua Province based on environmental carrying capacity and environmental capacity

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Abstract

Immediate action is required to optimize the urban green open spaces in Sorong City to meet the obligation of increasing the baseline from 8.21% to 32.96%. The process will involve several stakeholders, including the Regional Government of Sorong City and Southwest Papua Province, Vertical Institutions, University of Papua, Development Partners, Indigenous Peoples, Media, and Private Parties. Upon evaluating the starting conditions in Sorong City, it is observed that the Environmental Quality Index (EQI) value stands at 58.96, indicating a sufficient category. This is mainly attributed to the detrimental impact of river water pollution (Water Quality Index, WQI) and the diminished coverage (Forest Cover Index, FCI) resulting from various commercial activities in metropolitan areas. Given the escalating climate change and the rise in hydrometeorological disasters, particularly heavy rainfall, erosion, and landslides, Sorong City must maximize the utilization of open green spaces (GOS). By improving the GOS, it was found that the Sorong Green Index (SGI) value was 94.77 in the outstanding category. In addition, utilizing the POAC approach for management analysis, it is imperative to promptly take necessary measures for various functions that are now inactive. The parties are expected to fulfill the task of job tagging and budget tagging to establish regional action plans.

Keywords: Green open space; Environmental Quality Index; Water Quality Index; Forest Cover Index; Sorong Green Index; POAC.

1. Introduction

Since becoming the capital of Southwest Papua Province in 2022, Sorong City has experienced notable transformations in infrastructural development and economic growth following its integration with West Papua Province. Population statistics from BPS West Papua reveal a population growth rate of 4.28% until 2022, resulting in a total population of 282,526 individuals. Similarly, the Gross Regional Domestic Product (GRDP) of Sorong City has experienced a growth of 5.29%, resulting in a total GRDP of IDR 15.46 trillion in 2022. This is one of the factors contributing to the decrease in both the quantity and quality of urban green open spaces in Sorong City [1,2,3].

Land usage not balanced with the availability and fulfillment of appropriate space results from unbalanced development. The poor usage of urban land as open space, both green and non-green, is one result of the high economic value of capital city land. This happens as the urban population grows and the need for housing and settlements grows. Aside from that, development that disregards river and coastal restrictions and climate change, which substantially impacts urban flooding situations, is exacerbated by urban drainage systems ignoring water management. Another trend in capital city areas is converting green open space to commercial and other structures. Furthermore, a lack of public understanding and participation in the value of green open spaces adds to the issues confronting metropolitan areas [4,5,6,7,8,9].

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Sorong City's green open spaces are currently in significantly worse condition than the guidelines set by the central government. Only 8.21% of the total mandated allocation of 30% has been met, with 20% going to the public sector and 10% to the private sector [10,11]. For the period 2000-2022, Sorong City experienced an average rate of deforestation of 0.02% and degradation of 1.96%, which had substantial negative consequences, particularly in the form of increased floods and landslides caused by climate change. On the 22nd and 23rd of August 2022, a tropical storm reached the northern shore of Sorong City, causing a significant occurrence. This incident killed three people, affected 9,000 people, demolished multiple residential buildings, and damaged hundreds of residences throughout the city. Steady rainfall of 132.5 mm for nearly 8 hours [12,13]. Flooding exacerbates landslides on steep slopes. Sorong (12.8%), Sorong Manoi (18.1%), and North Sorong (27.1%) had the highest number of villages and individuals affected by flooding among the areas analyzed [14,15].

Green open space is defined by Law No.26 of 2007 concerning spatial planning, Regional Regulation No. 12 of 2017 concerning the management of green open space, and Minister of Agrarian Affairs and Spatial Planning/Head of the National Land Agency Regulation No. 14 of 2022 concerning the provision and utilization of green open space. According to these regulations, green open space refers to elongated or clustered areas that are more accessible and allow for the growth of plants, both naturally occurring and intentionally planted. These areas are designed to consider ecological, water absorption, economic, socio-cultural, and aesthetic aspects. In addition, green open space enhances the atmosphere, soil, water quality, and the green-blue urban environment. It also contributes to the creativity and productivity of city dwellers [16,17].

Sorong City is currently preparing a Detailed Spatial Planning Plan, which serves as defense and security for small Pacific Ocean islands, independence, and economic growth, with sustainable use of natural resources and protected areas to improve the island's ecosystem. Small islands are environmentally friendly and are included in urban green open space supply. Aside from that, the revision of the Sorong City Regional Spatial Planning document for 2023-2042 is ongoing, and it is hoped that the management of Sorong City's urban green open space will be considered in discussions about protected areas. [18,19].

The objective of this study was to optimize the urban green open space of Sorong City to achieve the 30% target, taking into consideration environmental carrying capacity and environmental capacity. This will aid the City of Sorong in its efforts to forecast the escalating frequency and severity of hydrometeorological disasters and climate change. This is consistent with domestic and international initiatives aimed at mitigating greenhouse gas emissions, such as Indonesia's Folu Net Sink 2030 initiatives and the climate-resilient development outlined in the LTS LCCR 2050 for Indonesia [20,21].

2. Material and methods

2.1. Study area

Sorong City is located at geographic coordinates 131°51' East longitude and 0° 54' South latitude. The administrative divisions of Aimas District in Sorong Regency and Salawati District in Raja Ampat Regency delineate the southern region. On the eastern side, it shares a border with Sorong District in Sorong Regency, while the Dampier Strait determines the western boundary. Figure 1 shows that the urban green space consists of several components, such as mangrove ecosystems (4.64%), natural tourism parks (2.79%), village parks (0.92%), cemeteries (0.24%), urban forests (0.24%), green belts (0.11%), and district parks (0.05%). These elements constitute 8.21% of the total area designated as urban green space [22].

2.2. Method of data analysis

The environmental quality index (EQI) is used to assess the performance of environmental management programs and quantify their success. This index also contributes to policy formulation, program design, and public communication regarding environmental challenges. EQI can assist in determining the most significant programs and activities to improve environmental quality [23,24]. The formula used to calculate EQI can be seen as follows:

$$EQI = (WQIx30\%) + (AQIx30\%) + (FCI\ x40\%) \quad \ldots\ldots\ldots\ldots \quad 1$$

Which EQI = Environment Quality Index, WQI = Water Quality Index, and FCI = Forest Cover Index.

The Environmental Quality Index supplied by the Ministry of Environment and Forestry can be expressed in Table 1.

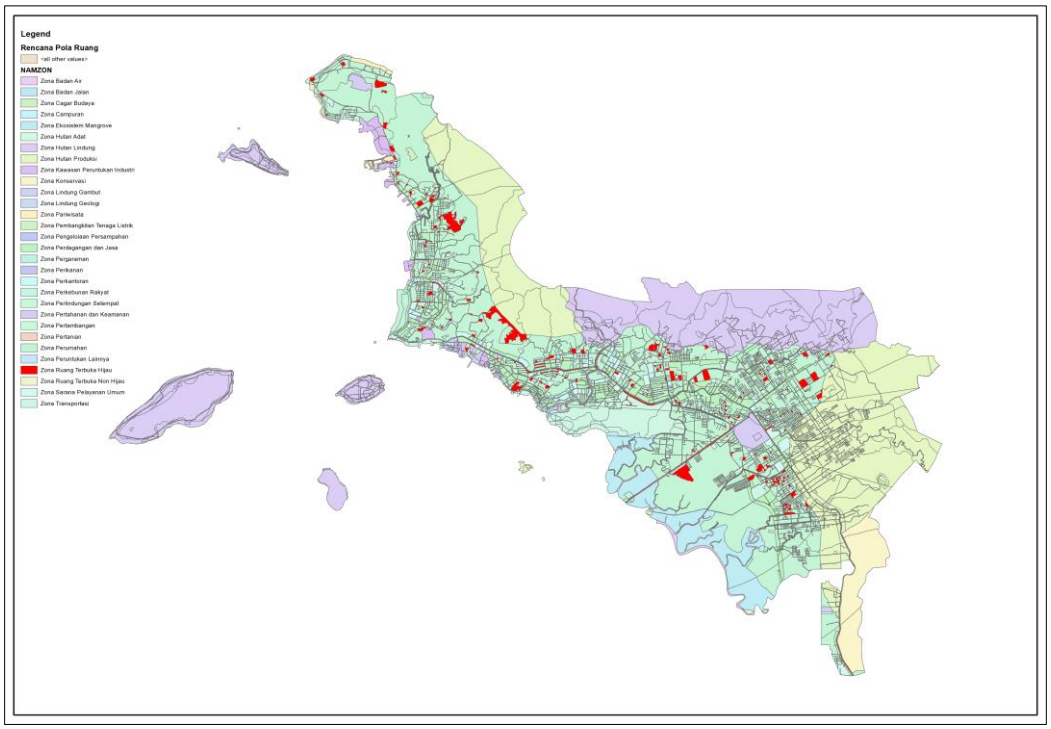

Figure 1 Sorong City's baseline urban green open space area

Table 1 Environmental quality index categories

Value	Category
90-100	Very Good
70-89	Good
50-69	Sufficient
25-49	Reduced
0-24	Poor

The EQI was created to collect information about Sorong City's environmental conditions. Environmental indicators include river water quality, air quality, and forest cover. According to Law No. 32 of 2009, the living environment is defined as space containing all objects, forces, situations, and living animals, including humans and their behavior, that influence the continuation of life and the welfare of humans and other living beings. In Indonesia, the environment is described as the space in which the Unitary State of the Republic of Indonesia exercises its sovereignty and juridical rights from an archipelagic perspective [25].

2.2.1. Water quality index (WQI)

The river water quality is assessed using various indicators, including Total Suspended Solids (TSS), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Phosphate, Fecal-Coli, and Total Coliform. These indicators account for 30% of river water quality measurements [26]. The formula utilized to calculate the WQI is as follows:

$$WQI = \frac{\sum sampel}{Total} x\ 100\ x\ weight \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 2$$

which WQI = water quality index, Σ sample = number of sampling points, Total = total number of sampling points, and weight = water contamination status with classified into four categories: satisfactory (70), light (50), moderate (30), and heavy (10).

The water quality index categories according to the Minister of Environment and Forestry Regulation N. 27 of 2021 concerning the Environmental Quality Index are presented in Table 2.

Table 2 Water quality index categories

Value	Category	Quality
90-100	Very Good	Water quality is safeguarded if there are no dangers or disturbances and the water level is close to its pure or natural state. If all quality standard measures have the same objective at all times, this index value can be determined.
70-89	Good	Water quality protection is ensured by assuming minimal hazard and disturbance and that conditions rarely depart from natural or desirable values.
50-69	Sufficient	Water quality protection is generally ensured, while occasional threats and disturbances can cause deviations from natural or desirable levels.
25-49	Reduced	Water quality is frequently endangered and damaged, with conditions deviating from natural and desirable values.
0-24	Poor	Water quality is frequently endangered and degraded, with conditions often straying from their natural and desired values.

2.2.2. Air Quality Index (AQI)

The indicators utilized for assessing AQI are categorized into NO_2 and SO_2, with a 30% weighting derived from the measurements of air quality parameters. The air quality index (AQI) is subject to many determinants, including natural elements, sector-specific policies that aid in air pollution control, and financial resources and support from external entities [27]. The equation utilized to compute the Air Quality Index (AQI) is stated as follows:

$$AQI = 100 - (\frac{50}{0.9} xIEU - 0.1) \quad \text{.....} \quad 3$$

$$NO_2\ Index = \frac{Average\ NO_2\ concentration}{EU\ Quality\ Standard} \quad \text{.....} \quad 4$$

$$SO_2\ Index = \frac{Average\ SO_2\ concentration}{EU\ Quality\ Standard} \quad \text{.....} \quad 5$$

which AQI = Air Quality Index, IEU= EU model air index, the other numbers= constant values, EU Quality Standar NO_2 = 40 and EU Quality Standar SO_2 = 20 .

The Air Pollution Standard Index categories, which have been revised by the Ministry of Environment and Forestry (2021), are served in Table 3.

Table 3 Air quality index categories

Value	Category	Quality
90-100	Very Good	The air quality level is excellent, posing no detrimental impact on humans, animals, and plants.
70-89	Good	The current air quality values remain within the permitted range for the well-being of humans, animals, and plants.
50-69	Sufficient	Air quality that is harmful to humans, animals, and plants.
25-49	Reduced	Air quality levels can increase health risks in several vulnerable populations.
0-24	Poor	Severely detrimental air quality conditions that pose a significant risk to public health and necessitate urgent medical intervention

2.2.3. Forest Cover Index

The forest cover indicator, which accounts for the area of both primary and secondary forests, carries a weight of 40%. This data is sourced from the Sorong City Central Statistics Agency for the year 2022. A primary forest is a forest that has remained untouched by human activities or disturbances. A secondary forest develops after undergoing significant disruptions, such as mining, farming, agriculture, transmigration, and other human activities [28]. The formula employed by FCI can be expressed as follows:

$$FCI = 100 - ((84{,}3 - (FCx100))x\frac{50}{54.3} \ldots\ldots\ldots\ldots \quad 6$$

which FCI = Forest Cover Index, FC = forest cover, and the other numbers = constant values.

Table 4 presents the modified FCI categories determined by the Ministry of Environment and Forestry (2021).

Table 4 Forest cover index categories

Value	Category	Quality
90-100	Very Good	The forest cover level is excellent, and the forest remains diligently preserved by local and indigenous communities.
70-89	Good	The current forest cover remains within the permitted range for the well-being and environment.
50-69	Sufficient	Forest cover that is harmful to the well-being and environment.
25-49	Reduced	Forest cover levels can increase environmental risks.
0-24	Poor	The forest cover conditions are severely damaging and constitute a severe risk to the public environment and affected communities.

2.2.4. Sorong Green Index (SGI)

The Sorong Green Index utilizes urban forests, a specific category of legally protected green open space, as a criterion for assessing the quality of optimal land cover. This calculation is predicated on Forestry Ministerial Regulation c, which states that 10% of the city area allocated to urban forest area is an adequate indicator of land cover quality. The IHM value obtained from the calculation with 10% verdant open space is 50, indicating the presence of sufficient conditions [29,30]. Additional categories are detailed in the subsequent table.

Table 5 Sorong Green Index value category

Category	Sorong Green Index
Very good	x > 90
Good	70 < x < 90
Sufficient	50 < x < 70
Insufficient	30 < x < 50
Extremely limited	x < 30

The subsequent equation is employed to compute the Sorong Green Index (SGI) :

$$SGI = 100 - ((35 - (GOSx100))x\frac{50}{19.5} \ldots\ldots\ldots\ldots \quad 7$$

$$GOS = \frac{GOS_1 + GOS_2 + \cdots GOS_n}{Total\ Area} \ldots\ldots\ldots\ldots \quad 8$$

which SGI = Sorong Green Index, GOS = Green Open Space, GOS1 = Green Open Space area-1, GOS2 = Green Open Space area-2, GOSn = Green Open Space area-n, Total Area = total area of Detailed Spatial Plan and the other numbers = constant values.

2.2.5. Management analysis

Management analysis is conducted Through implementing Planning, Organizing, Actuating, and Controlling (POAC) [31,32].

- Planning: evaluate the planning processes of the organization. Assess the clarity of the organization's objectives, the construction of strategies, and the creation of action plans. Analyze how the planning process corresponds with the mission and vision of the organization. Assess the organization's ability to proactively identify and strategize for forthcoming challenges and opportunities.
- Organizing: examine the organizational framework to ascertain its alignment with the intended accomplishments. Assess the allocation of duties and obligations to prove their efficacy. Evaluate how much the organization promotes collaboration and coordination between departments or teams.
- Actuating: assess the various leadership styles present in the organization. Evaluate leaders' ability to motivate and inspire employees. Assess the efficacy of communication channels and the capacity of the leadership team to exert guidance and influence.
- Controlling: conduct an assessment of the control mechanisms implemented by the organization, including feedback systems, performance metrics, and key performance indicators (KPIs). Evaluate the efficiency of feedback loops and monitoring to ensure that objectives are met. Determine how plan deviations are addressed and rectified.

3. Results and discussion

3.1. Water Quality Index (WQI)

The monitoring of river quality in urban areas encompasses a total of eight rivers, specifically the Kampung Salak River, Kampung Baru River, Remu River, Klagison River, Km 10 River, Km 12 River, Werimon River, and Klafma River. Table 6 presents the provisions of the 105 samples that were taken.

The water pollution monitoring measurements conducted in Sorong City indicate that the Water Quality Index (WQI) falls within the decreased category, with a precise value of 49.61. Consequently, the quality of water is frequently endangered and disrupted, since conditions frequently diverge from their natural and ideal levels as a result of alterations in urban land utilization and a deficiency of green open spaces to contain and control water contamination [33,34,35].

Table 6 Water pollution sampling in Sorong City

No	Category	Sample	Percent (P)	Weight (W)	Value (PxW)
1	Satisfactory	5	4.76	70	3.33
2	Light	94	89.52	50	44.76
3	Moderate	5	04.76	30	1.43
4	Heavy	1	0.95	10	0.09
Sum	Total	105		WQI (Equation 2)	49.61

3.2. Air Quality Index (AQI)

Traffic activity has a significant impact on air quality in Sorong City. Mobile sources contribute to urban air pollution, which is heavily influenced by fuel composition and engine combustion. Pollutants emitted by motor vehicles include CO, HC, SO_2, NO_2, and particulate matter. This is owing to an increase in the number of cars in Sorong City, both two-wheeled and four-wheeled, but it is still lower than the growth rate in other cities in Indonesia. As an illustration, the levels of NO_2 and SO_2 in Surabaya are four to five times higher than in Sorong [36].

Various locations in Sorong City were sampled for air quality, including two near urban petrol stations and two along the kilometers-long route. The presented findings are detailed in Table 7.

Table 7 Air quality index in Sorong City

Particulate	Average Concentration measurement (C. µg/m³)	EU Quality Standard (QS)	Index (C/QS)
SO_2	13.50	20	0.67
NO_2	9.98	40	0.25
Average Index Annual EU			0.46
AQI (Equation 3)			79.87

Monitoring air quality measurements by paying attention to NO_2 and SO_2 concentrations in Sorong City obtained a value of 79.87 in the good category. This can be shown that the number of vehicles in Sorong City in 2022 will only reach 15,116 with the following division: 83.27% motorbikes; 2.61% buses, trucks, and dump trucks; 9.54% minibus; and the remaining 4.58% from sedans, jeeps, pick-ups, and other four-wheeled cars. The number of vehicles is only 0.41% of large cities in Java such as Surabaya [37,38]. Hopefully, by increasing the status of the capital city of Southwest Papua Province, it will still be able to regulate its air quality index.

3.3. Forest Cover Index (FCI)

Forests have a crucial role in the ecology. Forests serve as a crucial water source, mitigate soil erosion, regulate the climate, and provide a habitat for diverse genetic resources. Forests are categorized into primary forests and secondary forests according to their classification. Primary forest refers to undisturbed forest that has not undergone any form of disruption. In contrast, a secondary forest is a forest that regenerates naturally through secondary succession following disturbances such as mining, plantations, and agriculture [39].

To compute the forest cover index, begin by summing the extent of primary forest and secondary forest, and thereafter divide this sum by the area of Sorong City. The Sorong City FCI may be found in Table 8.

The calculation of the forest area to the administrative area of Sorong City yields an FCI value of 50.28, which falls within the sufficient category. This situation demonstrates that the quality of land cover has exerted a significant level of hazard on flood conditions, erosion, and landslides at multiple locations within Sorong City [40,41].

Table 8 Forerst cover index in Sorong City

No	Type	Area (Ha)
1	Sorong City forest area (F)	41.502
2	Sorong City administration area (A)	110.500
3	Forest cover (F/A)	0.38
	FCI (Equation 6)	50.28

3.4. Environment Quality Index (EQI)

The EQI for Sorong City, obtained by summing the WQI, AQI, and FCI components, is presented in Table 9.

Table 9 Environmental quality index in Sorong City

Year	WQI	AQI	FCI	EQI (Equation1)	Category
2022	49.61	79.87	50.28	58.96	Sufficient

The data indicates that Sorong City is classified as sufficient regarding its EQI status, particularly in the AQI and FCI components. Hence, the Sorong City Government must acknowledge the imperative of constructing 30% green open space and rehabilitating deforested and degraded woods to reinstate and enhance environmental functionalities.

By improving and expanding the Environmental Quality Index (EQI), the ability of the environment to support life is automatically increased, leading to a corresponding rise in the Air Quality Index (AQI) and the Forest Cover Index (FCI). The environmental advancement in Sorong City requires this immediately [42,43].

3.5. Sorong Green Index (SGI)

The availability of urban forests, a sort of green open space with a legal umbrella, is regarded as a criterion for the quality of ideal land cover in developing the Sorong Green Index. The basis for this calculation is Forestry Ministerial Regulation No. P.71 of 2009, which states that a proportion of urban forest area of 10% of the city area is a sufficient measure of land cover quality. In the SGI calculation, with 10% green open space, the SGI value is 50, indicating that there are suitable circumstances, as shown in Table 5.

To calculate the SGI value, it is necessary to increase the green open space from 8.21% to 32.96% in each district. The SGI-specific allocation for each district may be seen in the table and figure below.

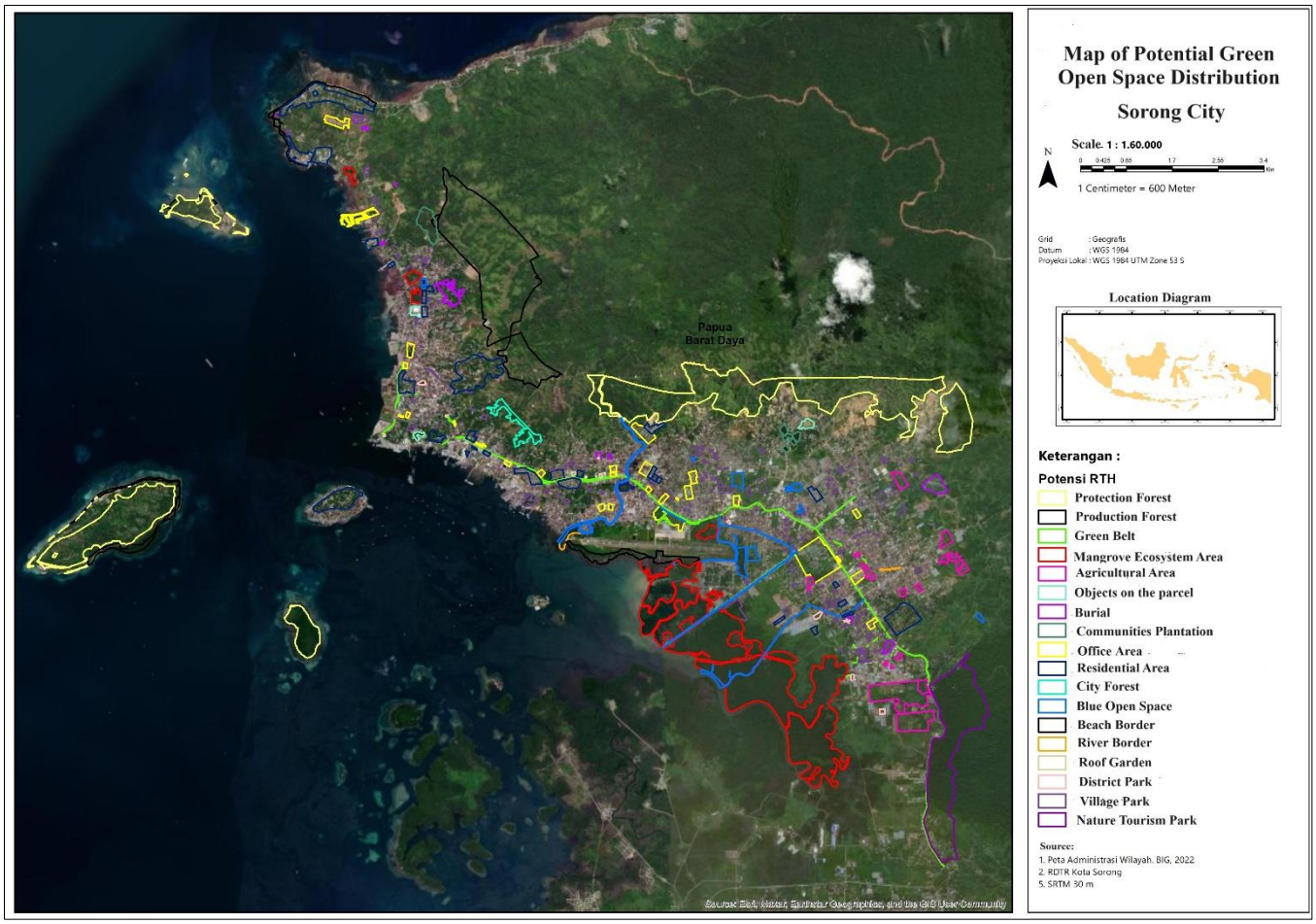

Figure 2 Potential green open space distribution in Sorong City

The calculation findings yielded a total SGI value of 94.77, which falls into the "very good" category for optimizing urban green open areas in Sorong City. Nevertheless, several districts, especially Sorong District and Sorong City District, continue to exhibit poor performance due to a significant increase in commercial property use and high land prices in these regions. Hence, it is imperative to develop a government policy in conjunction with the business sector to establish a shared dedication towards preserving urban carrying capacity and environmental capability [44,45].

Table 10 Sorong Green Index in Sorong City

District	District Area (Ha)	GOS Area (Ha)	% GOS	SGI
Klaurung	1.079	367.50	34.07	97.62
Maladum Mes	534	111.83	20.93	63.91
Malaimsimsa	540	203.58	37.70	106.93
Sorong	346	53.49	15.46	49.90
West Sorong	793	426.07	53.74	148.05
Sorong Islands	399	268.50	67.27	182.75
Sorong City	357	39.80	11.14	38.82
Sorong Manoi	669	149.74	22.37	67.61
East Sorong	1.233	484.13	39.28	110.97
North Sorong	1.191	249.13	20.92	63.90
Grand Total	7.141	2.354	32.96	94.77

3.6. Management Analysis

According to the findings of a study on enhancing the management of urban green open spaces in Sorong City, the execution of the management strategies has not been fully achieved optimally. The implementation of management analysis, which includes the processes of Planning, Organizing, Actuating, and Controlling (POAC), faces several barriers in the field. The analysis of POAC management is shown in Table 11 below.

Tabel 11 Maangement analysis of POAC

No	Management function	Variables/Dimensions	Result	Conclusion	Improvement
1	Planning	Guidenlines for planning GOS in Sorong City	Detail Spatial Plan for Sorong City	Revision	Integration with GOS optimization
			Regional Spasial Plan for Sorong City	Revision	Integration with GOS optimization
			Green Open Space Masterplan	Planning	Prompt recognition
			Green Open Space Regional Action Plan	Panning	Prompt recognition
			Participation of the parties	The level of private sector involvement is insufficient.	Private Public Partnership (PPP)
2	Organizing	Structural Organization Configuration	Sorong City Spasial Planning	Optimization of GOS (8.21%)	The optimization of GOS with the local institution (University of Papua) has been upgraded to 32.96%
			Responsibilities and Delegations	The shortage of personnel in the Sorong City	Task and authority delegation via job

				government's OPD responsible for managing GOS has resulted in an overlap of tasks and authorities.	labeling and budgeting
3	Actuating	Location Target	The target location for GOS optimization in ten districts is 2,354 ha, with an administrative area of 7,141 ha based on the Sorong City Detailed Spatial Plan document. As a result, the overall GOS is 32.96%, in conformity with a minimum of 30% urban responsibilities	Not yet realized	Prompt recognition
		The Role of OPD in the GOS Management	Public Works and Public Housing Office, Environmental and Forestry Agency, and Regional Development Planning Agency	Not yet realized	Prompt recognition
4	Controlling	Monitoring	The monitoring of green open space utilization in Sorong City is carried out by a small number of persons	Not yet realized	Prompt recognition
		Evaluation	The evaluation efforts in Sorong City focused on the usage of GOS	Not yet realized	Prompt recognition

An examination of management using the POAC technique reveals that certain activities are currently in progress, while most require urgent implementation. This necessitates the active participation of all parties involved, as they assign work and provide budgets to ensure the completion of key tasks and functions [46,47,48].

4. Conclusion

Sorong City ranks 58.96 out of 100 on the Environmental Quality Index (EQI), putting it in the sufficient category. This is because the Air Quality Index (AQI) and Forest Cover Index (FCI) values are likewise low quality, with various river basins polluted and the administrative area's forest acreage declining owing to conversion to commercial sectors.

Enhancing the utilization of green open spaces is crucial for elevating the Environmental Quality Index (EQI) from 8.21% to 32.96% across ten districts in Sorong City. The expertise of scholars from the University of Papua would facilitate this endeavor. The rise in GOS has improved the Sorong Green Index for various sub-districts and the entire city of Sorong.

Management analysis utilizing the POAC technique reveals that numerous ongoing actions have not been executed. Hence, it is imperative for the parties involved to collaboratively establish and employ GOS as a proactive measure to mitigate the impact of climate change and disasters on Sorong City.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

There is no conflict of interest.

Statement of ethical approval

Ethical clearance was approved by the Ethics Committee of Southwest Papua Spasial Planning referring to Minister of Agrarian Affairs and Spatial Planning/Head of the National Land Agency Regulation No. 14 of 2022 on July 2022, concerning the Provision and Utilization of Green Open Space.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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