

WATERFRONT CITY MANAGEMENT TO REALIZE LOW CARBON LANDSCAPE IN PEKANBARU CITY, INDONESIA

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Abstract

Poor regional spatial planning makes the lack of water catchment functions and green open spaces result in environmental problems, particularly in Pekanbaru City, Indonesia. The solution is to utilise the potential of the Siak River and its historical heritage through waterfront city (WFC) management. Structuring a WFC based on a low-carbon concept can solve environmental problems by significantly reducing carbon emissions. This study aims to inventory, map, and evaluate the condition of the existing landscape, analyse public perceptions, and develop recommendations for a WFC with a low-carbon landscape concept. The methods used are historic urban landscape analysis, spatial analysis with land evaluation, community perception, and the preparation of recommendations. The results showed that the management of historical and cultural heritage is still poor. Based on the evaluation of land suitability, the WFC area has the potential to develop tourism, settlement, conservation, and pond areas with varying degrees of suitability according to the function of the area and several limiting factors. Through public perception, the level of enthusiasm of respondents is very high for applying the low-carbon landscape concept. Recommendations are made with the 15-Minute City Strategy through zoning and management programmes, namely tourism, mixed-use, conservation, and cultural preservation.

Keywords: Landscape Management; Low carbon; Pekanbaru City; Urban landscape; Waterfront city

Introduction

The rapid rate of population growth that is not balanced by proper urban spatial planning impacts the high rate of land-use change, resulting in various environmental problems. This can be seen in the area of Pekanbaru City, Indonesia, which has not been arranged optimally with the concentration of development as a residential area and trade centre due to the increase in population. According to data from the Central Bureau of Statistics in Pekanbaru City, the population growth rate for 2021 in Pekanbaru City is 1.53% [1]. This population growth increases the number of slum settlements in the Siak River riparian, which affects the amount of waste. However, a waste management system that is still not optimal causes a decrease in environmental quality, such as flooding and pollution of water and soil, to encourage greenhouse gas (GHG) effects [2, 3]. The lack of green open space in urban areas as air and water filters also supports the GHG effect. One of the impacts of GHG effects is climate

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change, which has become a global issue related to energy, economy, environment, and technology on the national research agenda [4].

These problems can be solved by applying the concept of a low-carbon city. A low-carbon city is a sustainable urbanisation approach centred on reducing the city's anthropogenic carbon footprint by minimising the use of energy sourced from fossil fuels. This concept combines the features of a low-carbon society and economy while supporting partnerships between government, the private sector, and civil society [5]. In addition, Pekanbaru City has an impressive historic landscape with the development of Malay culture. The historical heritage of the Malay Sultanate of Siak Sri Indrapura is directly connected to the Siak Watershed as the beginning of the growth of Pekanbaru City. This potential can be maximised as a waterfront city (WFC) area. Waterfront areas can be among many other mandatory elements of sustainable urban development and can contribute to the urban environment if appropriately managed [6]. Currently, the Pekanbaru City government is constructing a WFC as a tourism area along the Siak River. The WFC area is expected to be built with a low-carbon landscape. The WFC development can create residential areas on the banks of the river with landscape functions and economic and social utility functions to encourage economic development and city image to achieve strategic goals of sustainable urban development [7]. Therefore, this study aims to inventory, map, and evaluate the condition of the existing WFC landscape, analyse public perceptions of low-carbon landscapes, and compile recommendations for waterfront cities with low-carbon landscape concepts with a historic urban landscape (HUL) approach.

Experimental part

Methods

The research was conducted in the WFC of Pekanbaru City, Indonesia, which is included in the administrative area of six sub-districts by Pekanbaru City, namely Rumbai Pesisir, Rumbai, Tenayan Raya, Lima Puluh, Senapelan, and Payung Sekaki Districts (Fig. 1). The research stages consist of data collection, landscape characteristics identification, land suitability evaluation, community perceptions, and the preparation of recommendations.

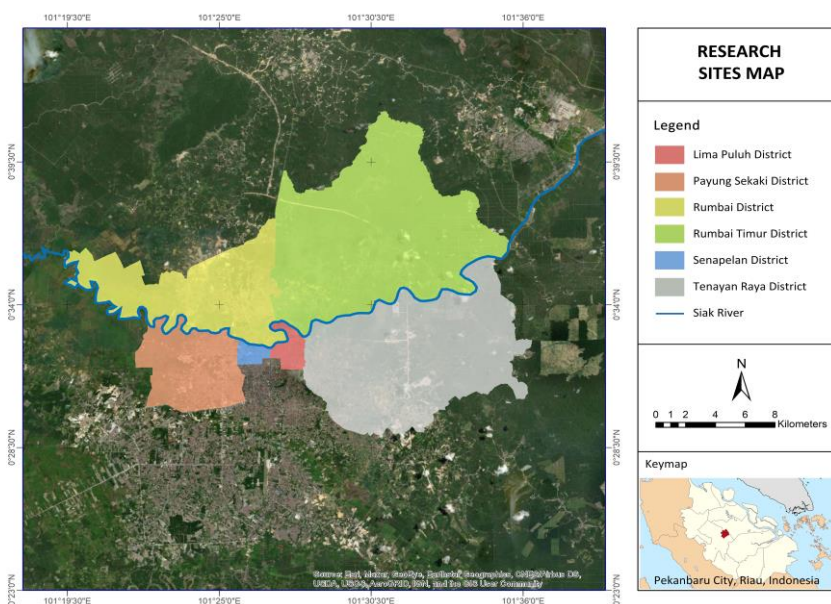


Fig. 1. Research Sites Map (Source: Esri USGS and the GIS User Community)

Data collection

Data collection is divided into several ways, namely, developing Geographical Information System (GIS) data, field surveys, questionnaires, interviews, and literature studies. GIS is used to collect data spatially based on satellite image data without having to make direct contact with the object under study [8, 9, 10]. In addition, a field survey was conducted to determine the characteristics in more detail from the spatial data. Questionnaires were distributed to determine public perceptions of the low-carbon landscape concept in the WFC of Pekanbaru City. The recorded respondents were 180 people ($n = 180$) on average in six sub-districts where the study was located. Interviews were also conducted to obtain in-depth information from government agencies and the public.

Identification of existing landscape characteristics

Identification of the existing landscape using GIS analysis and the HUL Quick Scan Method. The HUL method is a practical tool for generating ideas for the future of heritage preservation in urban landscapes and encouraging everyone to participate in sustainable historical heritage [11]. The method consists of an analysis of the historical environment, challenges and opportunities, determination of a vision, principles of development, and a proposal for a future perspective. This method is a model of historical heritage preservation and sustainable development.

Land suitability evaluation

Land suitability is evaluated on biophysical aspects to obtain the best land use, including land use for tourism, residential, mangrove conservation, and fishponds. The determination of land suitability is carried out using a GIS spatial analysis approach with the help of ArcGIS software version 10.6. This evaluation is intended to determine the classification of each land designation into four assessments, namely S1, S2, S3, and N [12] (Table 1).

Table 1. Land suitability criteria

Class	Land suitability	Description
S1	<i>Highly Suitable</i>	The land does not have severe limitations for applying the given treatment.
S2	<i>Moderately Suitable</i>	The land has a severe enough constraint to maintain the level of treatment that must be established.
S3	<i>Marginally Suitable</i>	The land has a very severe barrier, but it is still possible to overcome/improve.
N	<i>Not Suitable</i>	The land is completely unusable because it has a permanent barrier.

Low carbon society perception

Perception data were collected based on a questionnaire sent to 180 respondents concerning the Low Carbon Cities Framework (LCCF) parameters [13], covering the environment, transportation, urban infrastructure, and buildings. There are several criteria for low-carbon cities to reduce carbon emissions through policies, processes, and technology development. The respondent's perception data collected was calculated using a Likert scale. Then, the Pearson correlation test and the degree of importance analysis were conducted to determine the relationship between the two variables and the respondent's priorities. Pearson correlation analysis was assisted by IBM SPSS Statistics software to determine the level of strength of the significantly related variables (Table 2). Meanwhile, the degree of importance analysis was carried out using Microsoft Excel software to calculate the score for each perception statement.

Table 2. Correlation strength value

Pearson correlation value	Correlation strength level
0.00 – 0.19	Very low
0.20 – 0.39	Low
0.40 – 0.59	Moderate
0.60 – 0.79	High
0.80 – 1.00	Very high

Recommendations

The data that has been analysed is then synthesised based on the potential and constraints of various aspects. Thus, recommendations can be made to apply the concept of a low-carbon landscape with the HUL quick scan method approach to the WFC landscape in Pekanbaru City. Recommendations are made in the form of a WFC management and development strategy. The management strategy is formulated by applying the concept of a low-carbon city. Meanwhile, the development strategy aims to produce zoning maps and management programmes.

Results and discussion

Pekanbaru City is the capital city of Riau Province, geographically located in the middle of Sumatra Island. Biophysically, Pekanbaru City is located in a tropical climate area with a topography ranging from 5 to 50 metres above sea level. The majority of the research area has an elevation level between 0-2% or is relatively flat, passing by the Siak River. The Siak River in Pekanbaru City acts as a sea and industrial transportation route with a length of 300 kilometres, a depth of 29 metres, and a width of 100–400 meters. The WFC area has undergone various developments, so it is dominated by pavement in several border areas of the Siak River. There are several areas of undeveloped land located in the middle and downstream.

Existing landscape character

The WFC area of Pekanbaru City is an area that is undergoing rapid development for urban activities. Some areas with potential that are not optimised can be developed towards the WFC concept. There are several lands uses in this area, namely business, industrial, historical, cultural, and religious tourism. This research focuses more on optimising the attractiveness of the historical and cultural heritage of the Siak Sri Indrapura Sultanate in Pekanbaru City.

The Pekanbaru City started as a small village located on the border of the Siak River. This village was founded around the 14th century and named Kampung Senapelan (now Senapelan District). The formation of Pekanbaru City to date has undoubtedly experienced various challenges and obstacles, from the Senapelan Mysticism period to the post-independence period. From this, history produces urban heritage, both tangible and intangible. There are 16 historical urban heritage sites based on a field survey (Figs. 2 and 3).

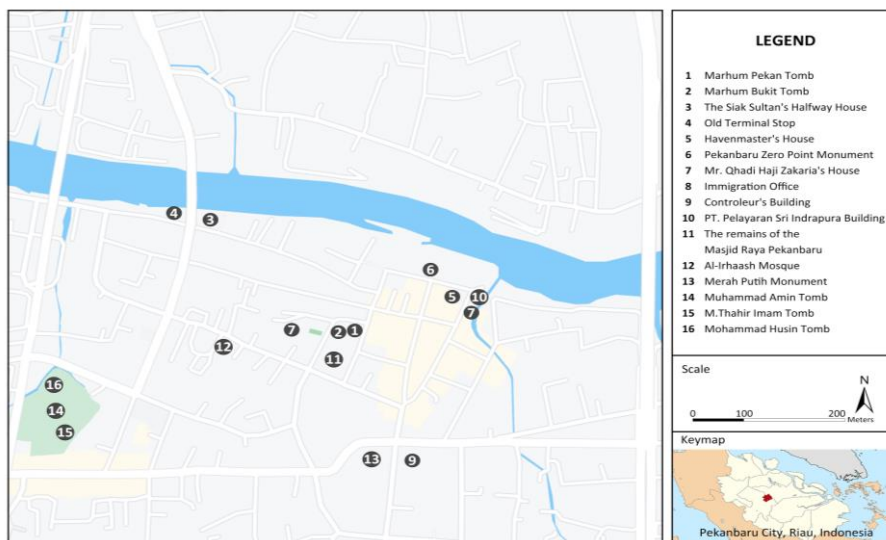


Fig. 2. Historical Heritage Map (Source: Google Map)

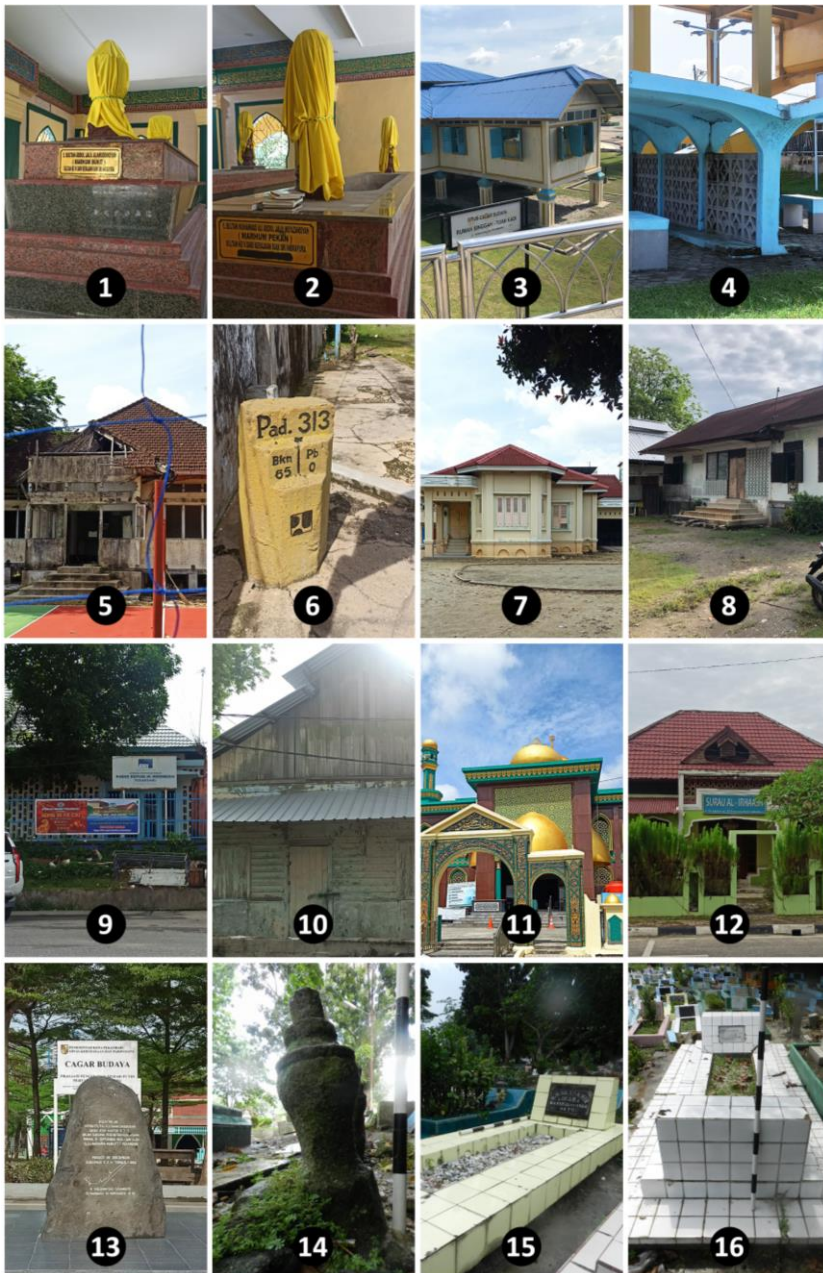


Fig. 3. Collection of urban heritage

These urban heritages are directly connected to the Siak Sri Indrapura Sultanate and colonialism. The level of urban heritage management consists of various conditions (Table 3). Based on observations, there are several challenges: the government's lack of attention to historical heritage, historical data that is still minimal, environmental problems, limited facilities and access, and some buildings that are not registered as cultural heritage. Therefore, it is necessary to take advantage of opportunities optimised with good management. Some opportunities that can be optimised are heritage sites that are close and interconnected,

administrative areas that are included in the development of historical and cultural tourism destinations, the existence of the Siak River, and the existence of supporting communities.

Table 3. Condition of historical heritage

Picture Number	Historical Heritage	Condition	Explanation
1.	Marhum Pekan Tomb	Highly maintained	Tomb of Sultan Siak V
2.	Marhum Bukit Tomb	Highly maintained	Tomb of Sultan Siak V
3.	The Siak Sultan's Halfway House	Highly maintained	Stopover for the Sultan of Siak
4.	Old Terminal Stop	Poorly maintained	The first entrance to Pekanbaru City
5.	Havenmaster's House	Poorly maintained	The place of the Dutch official who guards the port
6.	Pekanbaru Zero Point Monument	Poorly maintained	Pekanbaru City benchmark point
7.	Mr. Qhadi Haji Zakaria's House	Maintained	Palace perch of Sultan Siak XII
8.	Immigration office	Poorly maintained	Government office during the colonial period
9.	Controleur's Building	Maintained	Government office during the colonial period
10.	PT. Pelayaran Sri Indrapura Building	Poorly maintained	Port office
11.	The remains of the Masjid Raya Pekanbaru	Highly maintained	Pekanbaru City's first place of worship
12.	Al-Irhaash Mosque	Maintained	Places of worship and headquarters of fighters during the colonial era
13.	Merah Putih Monument	Highly Maintained	Memorial monument for the first flag-raising event
14.	Muhammad Amin Tomb	Poorly maintained	Tomb of independence pioneer
15.	M.Thahir Imam Tomb	Poorly maintained	Tomb of religious leaders and Districhoofd Pekanbaru
16.	Mohammad Husin Tomb	Poorly maintained	Tomb of independence pioneer

Land suitability evaluation results

Based on the evaluation of the land as a tourism area, the results obtained are moderately suitable for an area of 311.96ha (85%) and marginally suitable for an area of 54.68ha (15%) (Fig. 4). The limiting factor for tourism development is flood susceptibility. Furthermore, the analysis of land suitability as a residential area shows that 240.39ha (65.58%) are highly suitable, 77.66ha (21.18%) are moderately suitable, 7.33ha (1.99%) are marginally suitable, and 41.26ha (11.25%) are not suitable. The limiting factors are the distance from the river and flood susceptibility. The results of the evaluation of the land as a conservation area show that the area of 17.59ha (4.79%) is highly suitable, 16,86ha (4.59%) is moderately suitable, 0.86ha (0.23%) is marginally suitable, and 331.33ha (90.39%) is not suitable. The limiting factor is the distance to the river, which is more than 300 metres, which is the ideal limit for the characteristics of mangrove forests. In addition, there is a function for ponds as water bodies measuring 1m² to 2ha that are permanent or seasonal and are formed naturally or manufactured for fishery production [14]. At the same time, the evaluation of the land as a fishpond area is highly suitable, covering an area of 99.11ha (27.03%), moderately suitable for 37.22ha (10.15%), according to a marginal area of 219.40ha (59.84%), and not suitable for 10.91ha (2.98%). The dominant limiting factors are the slope of the land and the distance to the river.

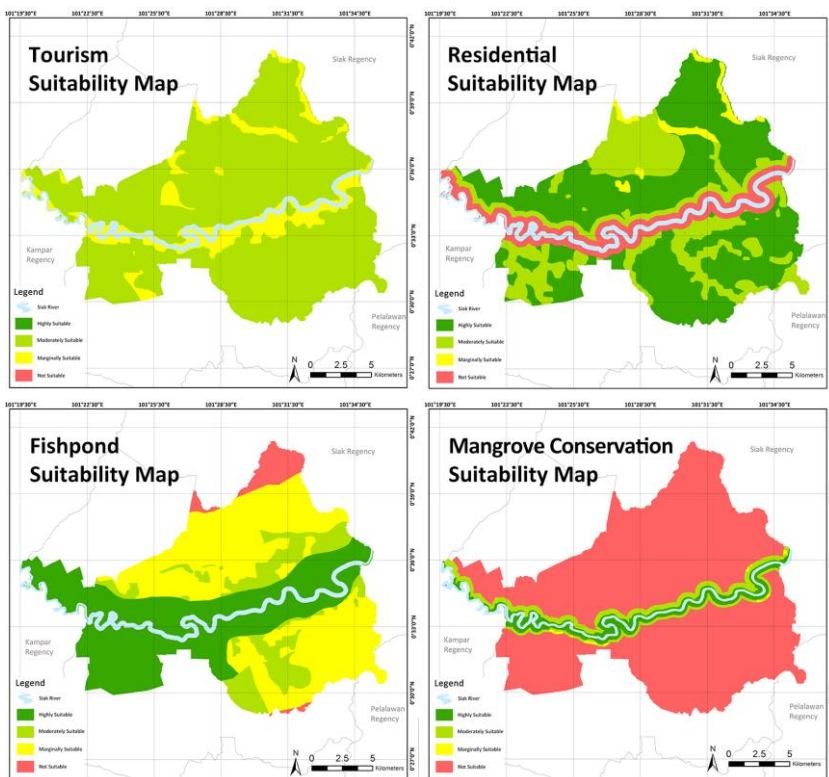


Fig. 4. Land suitability evaluation map

Low carbon society perception

The characteristics of respondents in the data recorded in this study are domicile, age, gender, last education, length of stay, occupation, and monthly income. The domicile of the respondents is evenly divided into six research administration areas. Most of the respondents are female, with a percentage of 59.44%. Respondents consisted of three age categories: 17–29 years (80.56%), 30–44 years (16.67%), and 45–60 years (2.78%). The education level of the respondents varied, dominated by senior high school (SMA) (47.78%) and undergraduate graduates (38.89%). The length of stay of respondents is dominated by people who lived less than 20 years in Pekanbaru City, with a percentage reaching 73.89%. Respondents who participated in filling out the questionnaire consisted of various backgrounds in the field of work, including education (5.00%), public service (5.56%), health (21.67%), trade (6.11%), agriculture (0.56%), fisheries (0.56%), students (42.78%), freelancers (6.11%), transportation (3.89%), and unemployed (7.78%). Most of the respondents earn less than 500,000 IDR, with the percentage reaching 38.89%. While the smallest percentage are respondents with a monthly income of 5,000,000 to 7,000,000 IDR (2.22%).

The results of the analysis of the urban environment parameters show a relationship between the factors of gender, education, occupation, and monthly income in several public perceptions (Table 4). First, there is a significant relationship between gender and the perception that the Siak River is clean and free of waste. Respondents dominated by women felt that the Siak River was clean and free of garbage. In the education variable, there is a significant relationship between the respondent's education level and the perception that the amount of green open space in Pekanbaru City is sufficient to reduce the effect of greenhouse gases. This means that the higher the education level of the respondents, the more people feel

that the amount of green open space in Pekanbaru City is still not enough to overcome the adverse effects of greenhouse gases. Meanwhile, from the income variable, it was found that the higher the respondent's income, the more the community thought that the management of the Siak Riverbank area had not been running well.

Table 4. The results of Pearson correlation analysis on several variables

Perception	Variable	Value	Strength Level
Siak River is clean and free from garbage	Gender	0.08	Very low
I feel that green open space in Pekanbaru City is sufficient in reducing the effects of greenhouse gases	Education	-0.26	Low
The management of the Siak River bank area has been going well	Income	-0.30	Low
There has been a movement or an appeal to switch to public transportation	Education	-0.24	Low
Pekanbaru city is pedestrian friendly	Job	-0.14	Very low
I am comfortable using public transportation in Pekanbaru City	Income	-0.30	Low
Waste management in Pekanbaru City is good	Education	-0.22	Low
I feel that the garbage that is sorted by the community is then mixed by the cleaners at the final disposal site	Education	-0.01	Very low
There is already a waste recycling program in Pekanbaru City	Education	-0.25	Low
Office, commercial, entertainment, education and residential buildings should apply the low-carbon concept	Education	0.03	Low
Low carbon buildings have a big impact on reducing carbon emissions	Education	0.07	Low
I hope the government will issue a policy that every office, commercial, entertainment, education, and residential building must contribute to reducing carbon emissions	Job	-0.10	Low

In the transportation parameter, there is a significant negative correlation between the education variable and the perception that there has been a movement or an appeal to switch to public transportation. This means that the higher the respondent's education level, the more they feel that the movement or appeal to switch to public transportation is still lacking. In addition, there is an indication that there is a connection between the type of community work and the discomfort of pedestrians in Pekanbaru City. The lack of pedestrian path facilities can be used to indicate whether a city is feasible to live in. This is also supported by the perception statement that the higher the respondent's income, the less comfortable they are using public transportation in Pekanbaru City.

Furthermore, there is a significant negative correlation with a low level of power on the education variable on the statement that waste management in Pekanbaru City is good. The higher the education level of the community, the more they agree that waste management is still far from good. This is also supported by several perception statements that have a significant relationship. The community sorts the waste and then mixes it with the cleaners at the final disposal site, and there is no waste recycling programme in Pekanbaru City.

In the education variable, there is a positive correlation between the two perception statements that office buildings, commercial, entertainment, education, and settlements should apply the low-carbon concept, and low-carbon buildings have a significant impact on reducing carbon emissions. This means that the higher the education level, the more respondents think low-carbon city zoning is needed. This is inversely proportional to the job variable. There is a negative correlation to the statement that the government's contribution to the policy of each building must contribute to reducing carbon emissions.

The results of the analysis of the degree of community interest show that most people strongly agree that the area on the banks of the Siak River has tourism potential through the development of a WFC, and the reforestation in the WFC area can help reduce carbon emissions. However, the lowest index is found in the perception statement that Pekanbaru City is free from traffic jams. The community strongly agrees that public transportation is a solution to reducing the carbon footprint. Meanwhile, the community doubts that the handling of

flooding and garbage problems is good. To overcome these problems, most people strongly agree that all elements of society should apply the low-carbon landscape concept to policymakers.

The readiness of low-carbon cities must also be supported by urban infrastructure, which includes the provision of infrastructure, waste management, water, and energy. In providing infrastructure, the community strongly agrees that planning is needed to consider environmental sustainability to minimise the greenhouse effect's risk. This is done to reduce the impact of urban development on the environment. Human activities in daily life also contribute to the carbon emissions produced, namely energy and water. Efficiency is needed in the use of electronic devices and water, which has become a basic human need [15]. Based on the perception index of the energy management sub-parameters, the public strongly agrees that it is necessary to choose energy-efficient electronic devices in their daily lives and turn off electronic devices when they are not used. In addition, the community also strongly agrees that it is necessary to conserve water and not dispose of domestic household waste in the river.

Waterfront city management with a low-carbon landscape concept

The WFC development in Pekanbaru City is intended for tourism by utilising the Siak River as the main attraction. This attraction arises from the advantages of the WFC's economic, social, and cultural potential [16], so that it can become a centre of economic growth. To understand and realise these values, it is necessary to design an analytical framework that links the opportunities provided by WFCs with creative and sustainable urban development [17] (Fig. 5.).

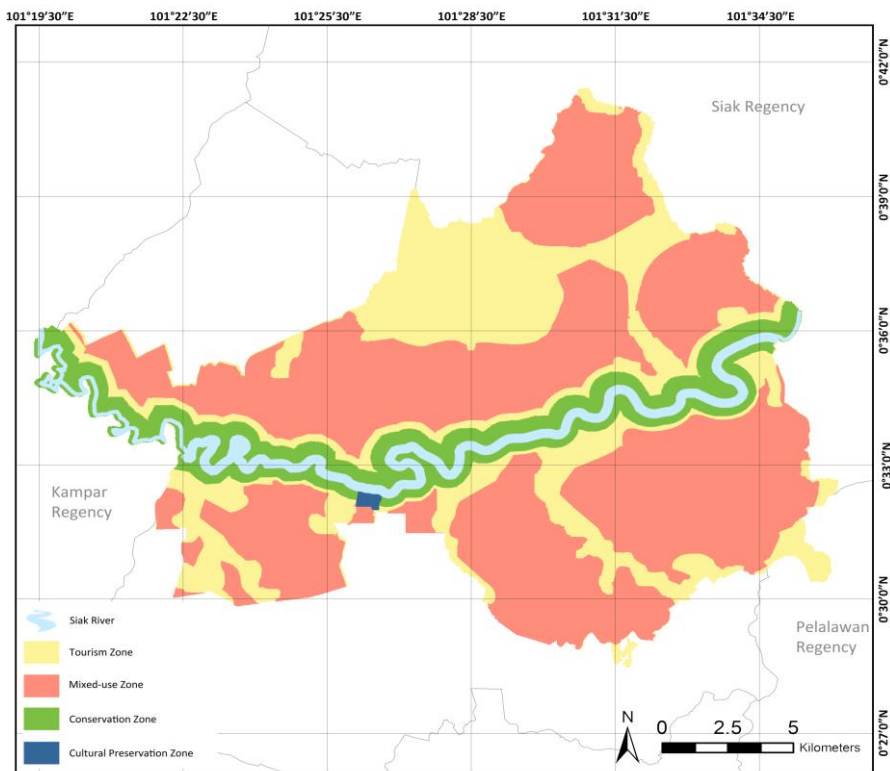


Fig. 5. Recommendation zone

The main idea of a WFC is to create a unique landscape that is open to all who want to live in it, work and play in beautiful spaces, and inspire with architecture that connects the city

with the river. In addition, the environment must be protected, and the identity of Pekanbaru City as the centre of Malay culture must be preserved in order to protect the heritage for future generations. Identity is needed for a city to form its sensitivity to a place [18].

To achieve a low-carbon economy, the best strategy is to apply the idea of "*15 Minute Cities*". Through this strategy, the WFC's development can be based on the application of the principles [19–21], namely encouraging development by prioritising each function, reducing the amount of energy consumption and mobility of private vehicles, planning mixed-use area development by promoting transportation efficiency and being friendly to pedestrians, providing pedestrian infrastructure that is comfortable, safe, shady, and comprehensive, and increasing the number of green open spaces. The principles of low-carbon development must be supported by implementing zoning and management programs. The zoning can be seen in Fig. 5 and the management programme in Table 5.

Table 5. Waterfront city low carbon management program

Zone	Area	Management Program
Tourism	51.14 ha (14.18%)	<ul style="list-style-type: none"> a. Planning for the construction of tourism buildings with low carbon landscape principles [22]. b. The use of tourism activity materials that are easily recycled. c. Arrangement of vegetation by building green corridors for pedestrians. d. Facilitate access to public transportation in tourism areas. e. Applying regulations, every tourist attraction must-have free tap water treatment. f. Increase the percentage of tree cover of the total tourism land area.
Mixed-use	289.37 ha (80.20%)	<ul style="list-style-type: none"> a. Encourage innovative building designs that combine rooftop gardens and vertical gardens. b. Increase the percentage of tree cover from the total land area with a requirement for a minimum allocation. c. Making regulations that are friendly to plastic bags, especially in shopping centers. d. Availability and affordability of a cheap and efficient public transportation system e. Establish an integrated waste management plan. f. Optimizing energy consumption [23], especially in buildings and urban roads.
Conservation	19.99 ha (5.54%)	<ul style="list-style-type: none"> a. The improvement of the mangrove forest utilization program is not only for environmental conservation, but also as an ecotourism destination with supporting pathways and facilities. b. Making regulations in every sub-district must have a mangrove forest. c. Naturalization of residential land that is still on the river border, making soil retaining facilities and adding vegetation through the yard [24, 25]. d. Increase urban biodiversity and the creation of new habitats.
Cultural Preservation	0.29 ha (0.08%)	<ul style="list-style-type: none"> a. Making historical tourism path programs to connect historical and cultural heritage. b. Provision of electric vehicles as public transportation. c. Revitalization of cultural heritage buildings that have been damaged and not appropriately managed. d. The submission of Pekanbaru City as a heritage city is an effort to preserve the assets of the Siak Sri Indrapura Sultanate.

Conclusions

The WFC of Pekanbaru City is experiencing rapid development for urban activities. There are activities in the form of business, industry, settlements, and tourism, especially history and culture. The greatest potential of Pekanbaru City as part of the less optimised Malay cultural civilization is seen in the management of historical and cultural urban heritage in Senapelan District. Based on the evaluation of land suitability, the WFC area has the potential to develop tourism, residential, conservation, and fishpond areas with varying degrees of suitability according to the function of the area. In addition, it is necessary to adjust and resolve several limiting factors in the existing landscape of each function of each area in an effort to improve the quality of human life and the environment. Through public perception, the level of enthusiasm of respondents is very high for the application of the low-carbon landscape concept

in Pekanbaru City. Several variables have a significant relationship to the statement of perception based on Pearson correlation analysis and the index of the degree of public interest. The proposed recommendation is the *15 Minute City Strategy*. With the concept of a decentralised city, Pekanbaru City is divided into four zonings, namely tourism zone, mixed zone, conservation zone, and cultural preservation zone, supported by the management programme of each zoning.

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