Estimation of Marine Carbon Sink Capacity and Analysis of Influencing Factors in Guangdong Province

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Abstract. China is a firm practitioner of the goal of "carbon peak" and "carbon neutrality", and the ocean, as the largest active carbon pool on the earth, plays a vital role in China's "dual-carbon" strategy. As an important part of the Guangdong-Hong Kong-Macao Greater Bay Area, Guangdong Province has a vast sea area, so it is of great economic and social significance to study its Marine carbon sink activities. This paper selects relevant data from 2012 to 2022 to estimate the marine carbon sink data of Guangdong Province according to China's "Marine Carbon sink Value Accounting Method", and explores the influencing factors of Marine carbon sink in Guangdong Province. The results show that in recent 11 years, the Marine carbon sink capacity of Guangdong Province has been continuously improved, showing a trend of increasing year by year. The production of Marine shellfish and the employees of Marine related industries have a significant impact on the Marine carbon sink of Guangdong Province, and the gross Marine product is positively correlated with the Marine carbon sink.

Keywords: Marine carbon sink; Guangdong; Carbon sink estimation; Double-log linear regression model

1 Introduction

Under the "dual carbon" target, Marine carbon sink as an important part of the earth's carbon sink has been gradually attracted attention. As a major maritime province, Guangdong has a sea area of nearly 420,000 square kilometers. According to statistics, in 2022, the gross Marine product of Guangdong Province has reached 1.99 trillion yuan, accounting for 16% of the provincial gross Marine product and 22.1% of the national gross Marine product, ranking first in the country for 27 consecutive years[1]. In December last year, the Guangdong Provincial Development and Reform Commission proposed to support the Shenzhen Emission Rights Exchange to carry out Marine carbon sink trading pilot plan. In April, Xi Jinping went to Guangdong Province for investigation and research, and conducted research in enterprises, ports and rural areas in Zhanjiang, Maoming and Guangzhou, etc., and proposed to cultivate sea, herd fish and build sea pastures and "blue granaries" in Marine construction. It can be seen that the Marine carbon sink development space of Guangdong Province is huge potential.

The calculation of ocean carbon sink capacity is one of the key foundations for its development. There are probably methods for calculating ocean carbon sink capacity, such as carbonate system models, isotope tracing methods, submersible observation methods, and satellite remote sensing technology. Considering the availability of data, this article adopts the

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"Marine Carbon Sink Accounting Method" published by the Ministry of Natural Resources of China as the accounting basis. This industry standard adopts conventional and mature survey methods, greatly ensuring the operability of the data acquisition process and the comparability of regional data. Due to the fact that this method was only released in September 2022, the estimation of relevant data is still in its early stages in China. Therefore, this article attempts to conduct marine carbon sink accounting in Guangdong Province, which is an important marine province and core component area of the Greater Bay Area. This has important pioneering significance in related fields. Combining the characteristics of the data and conducting regression analysis on the influencing factors of marine carbon sink capacity based on its estimation can help understand the inherent relationship between marine carbon sink capacity and economic activities, and provide important theoretical basis for promoting the development of the marine economy in Guangdong Province and even the whole country.

2 Materials and Methods

2.1 Method for estimating marine carbon sink

In the earliest period, scholars fortunat Joos and Michele Bruno published the long-term changes of land and marine carbon sinks (1988), which mentioned an inversion method called Double deconvolution to investigate the long-term variability of anthropogenic carbon uptake by land and ocean[2]. In the research on the economic value estimation of marine carbon sinks (2019), Fangming Liu proposed that the value of marine carbon sinks can be estimated by using the "total economic value method", including the classified value index system and the classified accounting method[3]. Therefore, the estimation of marine carbon sinks can start from many aspects, and the research angles and methods are diverse. This study is based on the formula of "marine carbon sink value accounting method" for estimating the marine carbon sink.According to the formula, the Marine carbon sink, net carbon productivity, deposition rate, area of mangrove, salt marsh, seaweed, deposition rate, mean carbon ratio, phytoplankton, macroalgae, shellfish, corresponding wet weight and dry weight conversion coefficient (data comes from State Oceanic Administration, Ministry of Natural Resources, Institute of Oceanography, and some references [4][5][6]), Excel estimated Guangdong Marine carbon sink in 2012-2022. The symbols of each indicator variable are as follows in Table 1:

Table 1. Symbolic representation.

index variable	symbol	index variable	symbol
Sediments weight	ρ	Conversion coefficient between wet and dry weight in class i. macroalgae	K_i^{ma}
Deposit of the organic carbon content	S	Biomass of class i. macroalgae (wet weight)	P_i^{ma}
Deposition rate of the sediment	R	Carbon content ratio at dry mass in class i. macroalgae	CF_i^{ma}
area	A	Conversion coefficient between wet weight and dry weight of shellfish class j.	K_j^{sh1}
Annual net primary productivity	P	Biomass of class j. shellfish (wet weight)	P_j^{sh1}
Average carbon ratio	CF	The proportion of shellfish dry mass in the dry weight state of class j.	R_j^{sh1}

Area of the *i*th station	A_i	Carbon ratio at stem mass of shellfish j.	CF^{sh1}_j
Net primary productivity in the *i*th year	P_i	The proportion of dry mass of soft tissue in the dry weight state of shellfish in class j.	R^{sh2}_j
The *i*th average carbon content ratio	CF_i	Carbon content ratio at dry mass of shell software in class j.	CF^{sh2}_j

Using the above indicator variables and carbon sink expression symbols, the calculation formula is shown in Table 2 formula(1)- (5):

Table 2. Formula of carbon sink capacity for sediments, plants and shellfish.

Carbon sink capacity		Formula expression	
deposit sediment	mangrove salt marsh Seagrass bed macroscopic algae shellfish	$C'_1 = \rho \times S \times R \times A$	(1)
plant	mangrove salina Seagrass bed	$C'2 = \sum(A_i \times P_i \times CF_i)$	(2)
	macroscopic algae	$C'_3 = \sum(K^{ma}{}_i \times P^{ma}{}_i \times CF^{ma}{}_i)$	(3)
shellfish	conch	$C'_4 = \sum(K^{sh1}{}_j \times P^{sh1}{}_j \times R^{sh1}{}_j \times CF^{sh1}{}_j)$	(4)
	soft tissue	$C'_5 = \sum(K^{sh1}{}_j \times P^{sh1}{}_j \times R^{sh2}{}_j \times CF^{sh2}{}_j)$	(5)

The carbon summary capacity of each system is summarized in Table 3 formula(6)-(12):

Table 3. Formula representation for the total carbon sink capacity of all ecosystems and oceans.

Carbon sink capacity of each ecosystem		
mangrove	$C_1 = C'_1 + C'_2$	(6)
salina	$C_2 = C'_1 + C'_2$	(7)
Seagrass bed	$C_3 = C'_1 + C'_2$	(8)
macroscopic algae	$C_4 = C'_1 + \sum(C'_4 + C'_5)$	(9)
shellfish	$C_5 = C'_1 + \sum(C'_4 + C'_5)$	(10)
phytoplankton	$C_6 = A \times P \times CF$	(11)
Marine carbon aggregation capacity	$C_{Ocean} = C_1 + C_2 + C_3 + C_4 + C_5 + C_6$	(12)

Due to different soil depth and different mangrove community, salt marsh of carbon content is different, this paper takes 0 to 10cm soil depth statistics of different mangrove carbon content, take salt marsh 8 to 10cm soil depth statistics of different types of salt marsh carbon ratio, set the primary productivity range of about 500 to 1,000 g of carbon per square meter[7].

2.2 Empirical analysis method of influencing factors

Marine carbon sinks are affected by many complex aspects, such as nature, society, economy, etc. Domestic and foreign scholars have studied the influencing factors of marine carbon sinks from different perspectives[8][9][10]. This study explores the influencing factors of marine carbon sink in Guangdong Province from the following five aspects. They are respectively the gross marine product (X1), mariculture area (X2), employees in marine related industries (X3), marine algae production (X4), and marine shellfish production (X5). These data is comes from National Bureau of Statistics.

Based on the problem that there may be a nonlinear relationship between the independent variable and the dependent variable, the double-log linear regression model can replace the nonlinear relationship in the model with a linear relationship, which can reflect the sensitivity of the dependent variable to the change of the independent variable. Therefore, this study selects the data of relevant factors from 2012 to 2022 as the sample, fills the missing data with the mean method, and takes the calculated "marine carbon sink" as the dependent variable y to build the following double-log linear regression model(13).

$$\ln Y = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \varepsilon \tag{13}$$

In the above formula, ε means random disturbance term, $\beta 1, \beta 2, \beta 3, \beta 4, \beta 5$ refers to the impact of each variable on the marine carbon sink, i.e. "elasticity", which means the percentage of change in dependent variable caused by a percentage change in independent variable.

3 Results & Discussion

3.1 The results of estimation

Combined with the calculation data of mangrove, salt marsh, seagrass beds, phytoplankton, macroalgae and shellfish, the total carbon sink of mangrove in 2020 is about 6,045 tons per year, the carbon sink is about 6,913 tons per year, the total carbon sink of seagrass beds is about 3,922 tons, phytoplankton is about 68 tons per year, macroalgae is about 5,250 tons, and 3,650 tons per year. Therefore, the Marine carbon sink value in 2020 is about 25,851 tons.

According to the change law of Marine carbon sequestration capacity, the data of Marine carbon sequestration from 2012 to 2022 is obtained, as shown in the figure below:

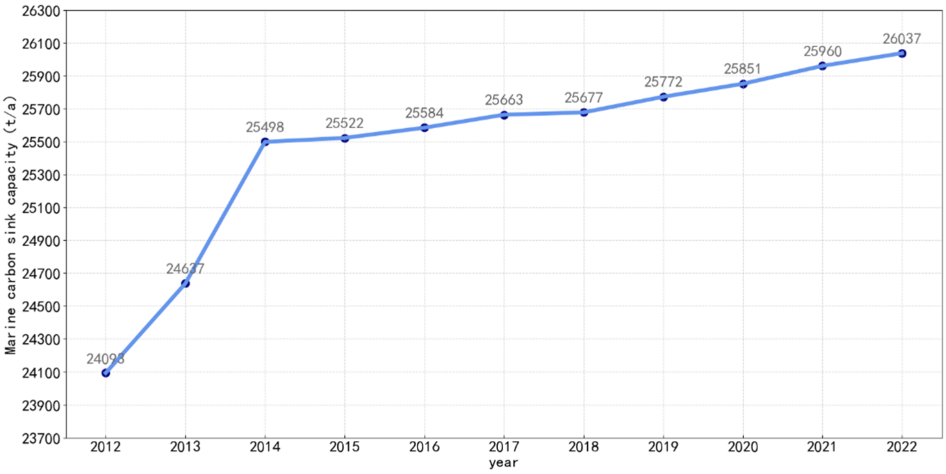

Fig 1. 2012-2022 Marine carbon sink capacity of Guangdong Province.

Fig 1 shows that from 2012 to 2022, the Marine carbon sink capacity of Guangdong province has been continuously improving, showing a trend of increasing year by year, showing the potential of the Marine carbon sink capacity of Guangdong province. In the future, Guangdong will deeply explore the economic value of Marine carbon sink.

3.2 Analysis results of influencing factors

By using spss26.0 software to explore the original data, the estimation and test results of the output model are as follows.

Table 4. Model summary.

Variable	B	Std.Error	t	Sig.	
(Constant)	18.800	2.295	8.192	0.001	
LNX1	0.105	0.025	4.285	0.013	
LNX2	0.099	0.100	2.497	0.067	
LNX3	0.164	0.160	2.197	0.093	
LNX4	-0.218	0.149	-1.465	0.217	
LNX5	0.363	0.263	2.246	0.088	
R Square	0.889		Durbin-Watson	2.267	
Adjusted R Square	0.750		Std.Error of the Estimate	0.01182	
ANOVA	Sum of Squares	df	Mse	F	Sig.
Regression	0.004	5	0.001	6.396	.048[b]
Residual	0.001	4	0.000		
Total	0.005	9			

According to Table 4, the regression equation of the sample is formula(14):

$$\ln Y = 18.800 + 0.105\ln X_1 + 0.099\ln X_2 + 0.164X_3 - 0.218X_4 + 0.363X_5 \tag{14}$$

From the perspective of the relative effect of regression, the determination coefficient (R^2) is 0.889, and the regression equation is highly significant. Therefore, lnX1, lnX2, lnX3, lnX4 and lnX5 have strong explanatory ability for lnY. From the absolute effect of regression, the estimated value of regression standard error ($\hat{\sigma}$) is 0.01182. Its value is small enough to indicate that the regression effect is good.

According to Table 4, the value of F is 6.396, the value of P is 0.048. It shows that the regression equation is highly significant, that is, the independent variable after taking logarithm has a highly significant linear effect on the dependent variable as a whole.

Table 5. The test results of the model.

		LNX1	LNX2	LNX3	LNX4	LNX5
Collinearity Statistics	Tolerance	0.451	0.525	0.268	0.122	0.170
	VIF	2.219	1.905	3.738	8.199	5.888
Heteroscedasticity Statistics	rs	-0.2	0	-0.273	-0.564	-0.539
	t	-0.57735	0	-0.80265	-1.9318	-1.80994

Multicollinearity test: Since the P values of $\ln X_2$, $\ln X_3$, $\ln X_4$ and $\ln X_5$ are greater than 0.05, indicating that there may be multicollinearity betwe en explanatory variables. Therefore, the multicollinearity is tested by calculating VIF. Table 5 shows that the maximum VIF is 8.199, which is smaller than 10, and the average VIF is 4.3898, which is greater than 1, so there is no multicollinearity.

Autocorrelation test: According to the DW value in Table 4 and formula(15), the value of $\hat{\rho}$ is -0.1335. Because its absolute value is close to 0, it can be seen that there is no autocorrelation between error terms, and the residuals are independent of each other.

$$\hat{\rho} \approx 1 - \frac{1}{2}\mathrm{DW} \tag{15}$$

Heteroscedasticity test: Table 5 shows the test results of heteroscedasticity. The rank correlation coefficient was calculated by spss26.0, and the sample rank correlation coefficient was tested by t test. The test statistic is formula(16).

$$t = \sqrt{n - 2r_s} / \sqrt{1 - r_s^2} \tag{16}$$

According to Table 5, the absolute value of t is less than or equal to $2.306(t_{0.025}(8))$, considered as the absolute value of residual and independent variable is not significantly correlated.

Based on the above model test and estimation results, it can be considered that formula(14) is a relatively good regression model. It has the following significance.

Initially, the elasticity of marine carbon sink to marine gross domestic product is 0.105, indicating that marine gross domestic product is the key factor affecting marine carbon sink in Guangdong Province. Through the model analysis, it is found that there is a causal relationship between the marine gross domestic product and the marine carbon sink. When the marine gross domestic product increases by 1%, the marine carbon sink will increase by 0.105%, This shows that the marine carbon sink has a positive impact on the marine gross domestic product to a certain extent, and has a significant role in promoting the development of marine economy in Guangdong Province.

Second, the elasticity of marine carbon sink to marine shellfish production is 0.363, indicating that marine shellfish production has a significant impact on marine carbon sink in Guangdong Province. Through the model analysis, it is found that there is a causal relationship between marine gross domestic product and marine carbon sink, that is, when the marine shellfish production changes by 1%, the marine carbon sink will increase by 0.363%.

In addition, the elasticity of marine carbon sink to mariculture area is 0.099, and the elasticity of marine carbon sink to employees in marine related industries is 0.164. Although its impact is not as large as that of marine shellfish production, it also plays an important role in marine carbon sink. Increasing mariculture area is also conducive to the increase of marine carbon sink.

4 Conclusions

The measurement of Marine carbon sink capacity is the basis of marketization of Marine carbon sink and the premise of sustainable and orderly development of Marine carbon sink. Therefore, reasonable and effective estimation of ocean carbon sink capacity is of great practical significance. This paper attempts to calculate the Marine carbon sink of Guangdong Province, an economically important province in China, and finds that the current Marine carbon sink capacity of Guangdong will reach 26,037 tons in 2022, and the trend is increasing year by year, which will have an important impact on the emission reduction potential of China. At the same time, through the analysis of the influencing factors of the Marine carbon sink capacity, it is found that the elasticity of the total Marine product, mariculture area, Marine industry related employees and Marine shellfish production on the carbon sink capacity is positive, indicating that the increase in the number of these influencing factors will improve the Marine carbon sink capacity, and the expansion of Marine production has the most significant effect on the increase of Marine carbon sink capacity. For the purpose of coordinating the development of the ocean economy and carbon sinks, to establish a National Ocean Economy and Carbon Sink Development Plan, to encourage sustainable aquaculture with implementing promoting policies, to regulate fishing practices and to increase investment in research and development of ocean-based renewable energy sources are some policy recommendations that the government can consider. Taking everything into considered, strengthening the coordinated development of Marine economy and Marine carbon sink is another important way to achieve China's "double carbon" goal.

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