Forestry Modeling Based on Carbon Sequestration

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Abstract. The main problem is to develop a carbon sequestration model to determine the carbon sequestration capacity of forests and their products and then, based on this, to determine a forest management plan that is most effective in sequestration of CO2. After that, a decision model for understanding forest utilization is developed. Finally, we select Chinese forestry as the representative and present the results of a study on selective felling of temperate coniferous and mixed broad-leaved forests to promote carbon sequestration in a reasonable time interval.

Keywords: Carbon sequestration model; Principal component analysis; Metamodel; Transition strategy.

1. Problem restatement

It is now widely accepted that the increasing concentration of greenhouse gases, especially carbon dioxide, in the atmosphere is the most important driving force of global warming.

As the main body of the earth's land natural ecosystem, the forest is the main component of the earth microbial environment. Although the world forest area accounted for only twenty-seven percent of earth's land territory, the ground plant carbon storage with about eighty percent of the world's plant carbon stock on the ground, forest soil carbon library is around forty percent of the world's stock of land carbon deposits lie. Since the annual carbon exchange between forest light transmittance and respiration function and the earth's atmospheric environment is as high as 90% of the annual carbon exchange in the earth's terrestrial natural ecosystem, it is of great significance in the process of regulating the world weather and maintaining the world carbon balance.

2. Model establishment and solution

2.1 Carbon Sequestration Model

Climate change poses a great threat to life. To mitigate the effects of climate change, we need to take drastic action to reduce the number of greenhouse gases in the atmosphere. We need to work to increase the amount of CARBON dioxide trapped in the atmosphere by biosphere or mechanical means. The process is called carbon sequestration. The biosphere sequesters carbon dioxide from plants (especially large plants like trees), soil, and water environments. Forests are therefore an integral part of any climate change mitigation effort. The combination of sequestration in some forest products with sequestration due to the regeneration of young forests can allow more sequestration over time compared to the sequestration benefits of not cutting down forests at all. At the global level, forest management strategies, including appropriate logging, can contribute to carbon sequestration. Overfishing, however, can limit carbon sequestration. Forest managers must balance the value of harvesting the forest products they produce with the value of allowing the forest to continue to grow and sequester carbon. They must make forest management decisions based on the multiple ways forests are evaluated. Given the other ways in which forests are valued, the best forest management plan for carbon sequestration is not necessarily the best for society. Develop a decision model that allows forest managers to understand the best use of the forest.

Biomass abundance index =(0.5x forest floor area + 0.3 x water floor area +0.15x grassland floor area +0.05 others)

Vegetation cover index =(0.5x woodland area +0.3x grassland area +0.2x farmland area)/ regional area Water network density index = river width/watershed area + lake storage volume/watershed area + water resources amount/watershed area

Land degradation index =(0.05x mildly corroded GFA +0.25x moderately corroded GFA +0.7x severely corroded GFA)

Pollution load index =(0.4xSO2 emissions +0.2x solid waste CO emissions +0.4xCOD emissions)/ regional precipitation.

Considering the absorption of carbon dioxide by forests, with the maximum absorption as the goal, the methods can be directed not cutting down. It lets the forest grow directly or uses wood processing to sequester carbon dioxide.

In this paper, standardized data processing is carried out for the data in Annex I, abnormal processing is carried out, and part of the data is selected to draw a boxplot to reflect the characteristics of the distribution of original data to realize the comparison of the distribution characteristics of each group of data. It is drawn the boxplot as follows:

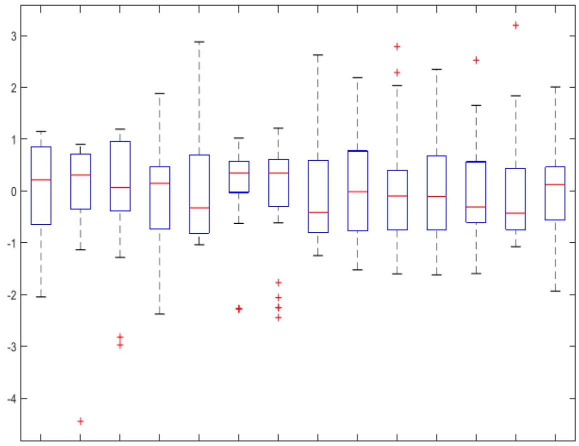

Figure 1. boxplot

2.2 A Decision Model To Measure The Use Of Forests

2.2.1 Principal component analysis

Car models are imported and solved the data in 123 countries. The results are shown in the following table.

Table 1 Common factor variance

	The initial	extract
ATSc1	1.000	0.938
nBondsD	1.000	0.844
SCH-4	1.000	0.354
VC-5	1.000	0.942
nwHBa	1.000	0.708
nsCH3	1.000	0.786

Table 2 Component matrix

	1	2
ATSc1	0.968	0.040
nBondsD	0.917	0.064
SCH-4	0.072	0.591

VC-5	0.968	0.071
nwHBa	0.123	0.832
nsCH3	0.864	0.200

The six indicators mentioned above are represented by six letters A, B, C, D, E, and F. The following table is the correlation matrix of each indicator.

Table 3 Correlation matrix

	A	B	C	D	E	F
A	1.000	0.903	0.046	0.902	0.168	0.782
B	0.903	1.000	0.032	0.862	0.166	0.628
C	0.046	0.032	1.000	0.039	0.080	0.065
D	0.902	0.862	0.039	1.000	0.057	0.842
E	0.168	0.166	0.080	0.057	1.000	0.082
F	0.782	0.628	0.065	0.842	0.082	1.000

2.2.2 Multiple regression analysis

Regression equation: $y = 0.024 - 0.024x_1 - 2.394x_2 + 0.075x_3 + 0.024x_4$, where x_1, x_2, x_3 are initial buffer peak value, average rate of playback stage and E2E RTT respectively.

Joint significance test: Original hypothesis: H_0, β_0, β_1, β_2, β_3 and are all 0. Alternative hypothesis: H_1, β_0, β_1, β_2, β_3 and at least one of them is not 0.

Table 4 Multiple regression analysis

Impact risk	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
A	0.024	0.020	1.17	0.241	0.063	0.016	
B	2.394	0.079	30.11	0.000	2.550	2.238	* * *
C	0.075	0.027	2.74	0.006	0.021	0.128	* * *
D	0.024	0.001	28.63	0.000	0.022	0.025	* *
E	3.526	0.048	-	0.000	3.594	2.856	*
F 0.185 0.046 3.64 0.000 0.052 0.005							

Mean dependent var	0.000	SD dependent var	0.010
R-squared	0.088	Number of obs	10000.000
F-test	319.561	Prob > F	0.000
Akaike crit. (AIC)	64653.206	Bayesian crit. (BIC)	64624.364

SSR=0.087, SSE=0.911, SST=0.998, R-squared = 0.0875, Adj R-squared =0.0872.Prob > F= 0.0000<0.05, so the original hypothesis is rejected and the coefficients are not all 0.

Since our model is an interpretive regression model, R2 is not required very much, so we aim to focus on the significance of the model as a whole.

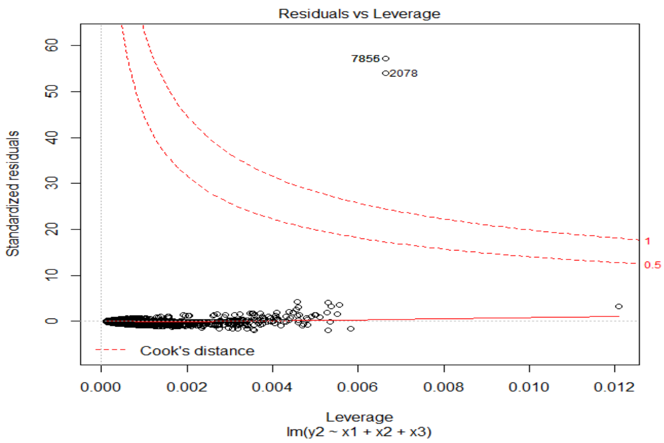

Figure 2. model

2.3 Economic value comparison

A common meta-regression model is based on least-squares multiple linear regression:

$$\ln y_{ij} = \alpha + \beta^{e} X^{t} + \beta^{c} X^{c} + \beta^{c} X^{e} + \beta^{s} X^{s} + u_{ij}$$

Where Y is the service price of the forest ecosystem (yuan hm2). α is the constant term, and X is the independent variable matrix, where X stands for ecosystem service category. X stands for research site characteristics (i.e., vegetation division and forest area). X stands for the surrounding environment (i.e., forest abundance and rail width), and X stands for social and economic conditions (i.e., population and GDP per capita).β is the correlation coefficient matrix, and U is the random error term.

2.3.2 Results of meta-regression model

By comparing the results of various return methods, it was found that the panel data regression model had the best overall fitting efficiency, so we selected the random effect model in the panel data regression method to establish the meta-regression equation.

Ecosystem service categories, plant regionalization, forestland area, forest abundance, railway length, population size, and average GDP explain about 48 percent of the variation in land values. In the return conclusion, the return coefficient of the dummy variable (ecosystem service category, plant area) reflects the deviation direction and deviation degree of a particular variable compared with the control group. The return coefficient during continuous variables (forest coverage, forest abundance, etc.) represents the elastic relationship, the ratio of the change rate between the dependent and independent variables. Specific analysis of the returned conclusions includes:

(1) Ecosystem services category: diversity conservation, fruit production, maintaining water cultivation, soil and water conservation. Carbon sequestration, the release of oxygen woodland leisure, and air purification recovery coefficient are significantly higher than 0 ($P < 0.01$). It is indicated that the rest of the requirements on the invariable situation, the above seven the economic value of ecosystem services category (nutrient accumulation) and control group have different, and thus with the nutrient accumulation of product price lowest value. By comparing the regression coefficients, it was found that the ecosystem service value of Marine biodiversity conservation and water source cultivation was obviously higher than that of other species, while the ecosystem service value of forest tourism was low.

(2) Plant division method: other regression coefficients are divided into six plants significantly less than zero in addition to the cool coniferous forest zone. It is shown that in any case, premise condition unchanged the plant classification of forest ecosystem services value (subtropical evergreen broad-leaved forest) and control group have different, so which economic value per unit area of subtropical evergreen broad-leaved forest zone to the maximum. The regression coefficient value is not significantly positive in the cold temperate coniferous forest region, probably because the sample

size is too small (only six value observation values). The comparison of standardized return coefficients shows that the economic value per unit area in the tropical desert and alpine plant zone is lower than any other type.

(3) Forest area: the regression coefficient of forest area was significantly less than 0($P<0.01$), which indicated that the marginal effect of forest ecosystem service value decreased with the increase of land area. With other conditions unchanged, the total value increases with the increase of forestland area, but the price per unit area decreases. For every 10 percent increase in forestland area, the total price per unit area will decrease by about 1.7 percent.

(4) Forest abundance: The regression coefficient of forest abundance was significantly lower than 0($P<0.05$), indicating that under any conditions unchanged, the expansion of forest area around the study area or in other areas would lead to a decrease in unit area value of the study area, which may also be related to the substitution effect of ecosystem service supply. For every 10% increase in the area value of other forests within 50 km, the unit area value of the study area decreased by 0.6%.

(5) Railway length: the standardized regression coefficient of total railway length is significantly lower than 0($P<0.1$), indicating that the railway construction will have a significant negative impact on the price of ecosystem services per unit area in the studied region under the condition that other requirements remain unchanged. In other words, a 10% increase in the total length of lines within a 50km area will reduce the service price per unit area by about 0.6%.

(6) Population: Although the regression coefficient of the total population is negative, it is not significantly different from zero. The continuous increase of population will lead to the decline of ecosystem function, resulting in a decrease of the benefit per unit area of forest land.

(7) PER capita GDP: The regression coefficient of per capita GDP was significantly less than 0($P<0.05$), indicating that the higher the per capita GDP level of perfect-level cities in the study region, the lower the price of per unit area of forest, but the development of the economy can lead to a significant decline in ecosystem function. For every 10% increase in the PER capita CDP value, the unit area value decreased by 2.7%.

Results: Based on the conclusion of the meta-regression model, the economic value of each ecosystem service category was water conservation > ecological diversity maintenance > carbon fixation and oxygen release > soil and water conservation > air quality purification > forest and fruit production > forest recreation > nutrient accumulation.

2.4 Environment status in New Zealand

Man-made activities in New Zealand are driving greenhouse gas emissions.

(1) In 2017, New Zealand's carbon dioxide emissions per capita totaled 7.7 tons, ranking 17th out of 32 member countries of the Organization for Economic Cooperation and Development.

(2) Road transport was the largest source of CO_2 emissions in New Zealand in 2018 (43%), with emissions from road transport increasing by 22% between 2009 and 2018. The spread of more fuel-efficient vehicles, particularly light trucks and sport-utility vehicles, means transport emissions continue to rise despite improvements in engine technology.

(3) In 2018, methane emissions accounted for 43 percent of New Zealand's greenhouse gas emissions, of which 86 percent came from livestock, while agricultural emissions accounted for 48 percent.

(4) The increase in the size and population of New Zealand's economy contributed to the increase in CARBON dioxide emissions, which was partially offset by the increase in fuel efficiency and the availability of green fuels.

Climate change and environmental change in New Zealand.

(1) Since 1909, the mean temperature in New Zealand has increased by 1.13±0.27℃, with an average increase of 0.10℃ per decade. From 1989 to 2018, the average increase was 0.31℃ every decade.

(2) Changes in rainfall began to appear, especially in extreme rainfall. In early 2020, Auckland experienced its most extended dry spell lasting 47 days, well above the average of 10 days per year between 1960 and 2019.

(3) Climate change affects the natural environment.Sea level in New Zealand has risen by an average of 1.81±0.05 mm per year since records began in the 1880s, and the average rate of rising from 1961 to 2018 was twice the average rate since records began.

(4) The observed data from 30 sites in New Zealand show that the annual mean temperature of 28 sites increased from 1972 to 2019. From 1972 to 2019, the average winter temperature and maximum winter temperature of all stations increased, and the frost days of 40% of stations decreased. From 1972 to 2019, the number of warm weather days (maximum temperature over 25℃) increased at nearly 2/3 of stations. Almost half of the stations showed an increasing trend in annual rainfall, and most of them also showed an increasing rainfall intensity from 1960 to 2019. Short-term drought intensity increased at 14 sites from 1972 to 2019, 11 located on the North Island. From 1997 to 2019, six sites recorded days of extreme fire danger that were most likely on the rise.

2.4.2 Regional planning model

Based on the model establishment of the first three questions, we put forward our regional planning model aiming at the current ecological environment of New Zealand.

For forming regional plans, the core management idea is to formulate specific management objectives, policies, and methods around "problems." The definition of land in the zoning is not strictly according to the nature of land as in the traditional zoning, but only according to the characteristics and importance of natural and artificial geographical environment of different areas in the urban planning, as well as the environmental protection level to ensure their healthy development. Therefore, the "natural area" concept management system covering the whole city area is established in the regional plan, and the "natural area law" is used to supervise and manage development activities that have an opportunity to affect resources and ecology."Natural area" consists of six categories, each of which has different resource and environmental characteristics. In contrast, the problems of these categories are relatively similar (Table 1).In this way, the "problem" rather than the "area" of the traditional zoning is taken as the basis of operation and regulation, which will promote the urban resources and environmental problems to get as much attention as possible to formulate more targeted and reasonable environmental control measures for the regional planning.

There are five types of land development activities covered by the NDRC: Vegetation Alteration, Earthworks, Impermeab1e Surfaces, and Estab1ishment Of vegetation), grazing, and Forestry (Stock Graz-ing and Forestry). All the aforementioned behaviors may significantly impact social resources and the ecological environment, especially the cumulative impact on individual behavior and the comprehensive impact of various social behaviors. Therefore, it is necessary to control it reasonably. District planning is also actively exploring the link between management and action impact, making decisions about how to implement and what management controls to apply. The basis of concern and monitoring is not the action per second but the specific degree of influence and harm that the action may cause.

Accordingly, the urban area plan divides development activities into six levels."Permissive activities" have correspondingly little impact on the environment and can only be carried out with little impact. "Prohibited Activities" do great harm to the natural environment and are prohibited under all circumstances. In addition, other criminal behaviors can be divided into controlled activities and Limited Discretionary behaviors from light to serious according to the seriousness of possible social harm Activities, discretionary Activities, or non-complying Activities. All four levels of development in the area need to be vetted and approved by the regional council before they can be implemented. For each case, the regional planning department has provided detailed behavioral and environmental evaluation standards, such as impervious surface under the surrounding water, natural landscape, flood, and other aspects of the environmental impact on more than ten criteria. The evaluation criteria are apparent. For applicants of a particular behavior, the comparison criteria can be used to predict whether the application is approved or not so that the scope of behavior can be adjusted accordingly. For the applicant, the legal essence of regional norms can be correctly mastered so that the evaluation scale can be unified in the examination so that the result of discretion is more fair and just, and the scope of power of discretion is limited. Taking the regional norm of "common natural zoning" as an example, this paper deconstructs the types of behaviors restricted by the regional norm, the levels of behaviors involved, and the corresponding evaluation criteria.

(1) Even if the international community meets all current emission reduction commitments and targets, global warming is expected to remain 3 ° C above pre-industrial levels by the end of the 21st century.

(2) Under current policies, the Government estimates that New Zealand's greenhouse gas emissions will decline in the coming decades at a rate that will not meet the 2030 targets set out in the Paris Agreement.

(3) New Zealand's climate will undergo profound changes, with temperatures expected to rise across the country, drought and wildfire risks increasing in many places, and extreme precipitation becoming common. Extreme events, rare for contemporary generations, may become the new normal.

(4) Even without more co_2 emissions, there will be no return to an undisturbed climate or even to the climate it used to be.

3. Result

Based on these optimal rotations, it has been shown that they can improve the carbon sequestration capacity of forests as part of good forest management. However, the impact of forest management on carbon sequestration has not been quantified. Therefore, the carbon content in various organs was measured for 323 species, 247 shrubs, and 233 herbs in 7 temperate coniferous and broadleaved mixed forests during selective cutting recovery times of 100, 55, 45, 36, 25, 14, and 6 years to explore dynamic changes in carbon storage. The results showed that the distribution pattern of biomass carbon in different organs was tree trunk > root > branch > leaf. More carbon accumulates in different organs and soils with a longer recovery time. When recovery time exceeds 50 years, ecosystem carbon storage is greater than 100 years of old-growth forest, suggesting that reasonable selective felling intervals can increase forest carbon sequestration. The mean chest height diameter (DBH) was positively correlated with forest carbon storage. When the mean DBH of the stand was more than 15, the carbon storage of selective felling exceeded that of primary forest. Therefore, forest mean DBH can be used as an indicator for combining sustainable forest management and forest carbon sequestration. In addition, the classical coefficients of 0.45 and 0.50 used to estimate carbon sequestration value are underestimated at 2.65% and an overestimate of 8%. China has implemented six major national ecological restoration projects in recent decades, which have significantly increased carbon sequestration, equivalent to 50-70% of the annual sink of all major terrestrial ecosystems. However, China is still under considerable pressure to reduce carbon emissions, which will increase its forest stocks by four.5 x 109m3 by 2030, compared to 2005 levels. Sustainable management practices can be used to enhance forest C storage. Selective logging refers to the regular and repeated harvesting of trees in specific areas and is a keylogging method for the sustainable management of natural forests in China. Estimate appropriate selective cutting intensities and intervals to promote forest growth and regeneration and enhance its carbon sequestration.

In terms of vegetation, there were significant differences in carbon storage of trees, shrubs, and herbaceous plants at all sites. Trees stored the most C, followed by shrubs and herbaceous plants ($P<0.05$). With the extension of recovery time, the order of C storage in trees was 55>100>45>36>25>14>6 years. C stocks in trees were more significant than in primary forests when recovery time exceeded 50 years. C was stored in different tree organs in descending order: trunk > branch> branch > leaf.

Table 5 Mean C storage in various types of vegetation according to restoration age

Restoration duration (year)	Tree C storage (kg C m^{-2})	Tree Ratio (%)	Shrub C storage (kg C m^{-2})	Shrub Ratio (%)	Herb C storage (kg C m^{-2})	Herb Ratio (%)	Total C storage (kg C m^{-2})
100	8.91 ± 2.47^{b}	99.34	0.02 ± 0.02^{ab}	0.20	0.04 ± 0.01^{bc}	0.46	8.97 ± 2.47^{b}
55	12.66 ± 2.05^{a}	99.34	0.03 ± 0.01^{ab}	0.25	0.05 ± 0.01^{abc}	0.40	12.74 ± 2.06^{a}
45	8.84 ± 0.67^{b}	99.50	0.01 ± 0.01^{ab}	0.14	0.03 ± 0.01^{cd}	0.36	8.89 ± 0.68^{b}
36	8.49 ± 1.96^{b}	99.57	0.01 ± 0.00^{b}	0.01	0.04 ± 0.01^{cd}	0.42	8.53 ± 1.95^{b}
25	7.51 ± 1.25^{bc}	99.16	0.05 ± 0.03^{a}	0.67	0.01 ± 0.00^{d}	0.17	7.58 ± 1.24^{bc}
14	6.47 ± 0.52^{bc}	98.37	0.04 ± 0.04^{ab}	0.60	0.07 ± 0.02^{ab}	1.04	6.58 ± 0.48^{bc}
6	5.33 ± 0.77^{c}	97.78	0.05 ± 0.05^{ab}	0.90	0.07 ± 0.02^{a}	1.32	5.45 ± 0.80^{c}

Means followed by the same letter do not differ significantly at $P < 0.05$

There was no significant difference in carbon storage between forests at different restoration times for soil. However, there are significant differences in carbon stocks at all measured sites for ecosystems. Ecosystem C storage is similar to vegetation C and significantly positively correlates with recovery time. Soil and trees store most of pool C in soil.

Selective logging may affect microenvironmental characteristics, stand growth, biomass allocation, and forest carbon storage. In this study, vegetation carbon storage increased gradually with the extension of restoration time and was higher than that of the original forest with a restoration time greater than 50 years. After selective felling, C storage of forest vegetation decreased significantly.1) Due to the direct reduction of tree density and biomass. However, light availability and individual tree nutrition are improved, and competition between trees is reduced to the extent that smaller trees grow faster, leading to rapid increases in productivity and biological growth rates.

Meanwhile, high-density forests' C balance and natural regeneration can be increased. Carefully developed selective felling strategies can promote the growth of surplus wood, regeneration of woody plants, and the development of stand structure. Therefore, the fixed amount of C in the stand will be higher than that in the non-selectively felled forest. In conclusion, selective harvesting within recovery intervals of more than 50 years can enhance carbon sequestration and bring economic benefits to the temperate forests studied here. It should be noted that these intervals may vary between different forest types, such as tropical or subtropical forests

References

[1] Dugan Alexa J., Lichstein, Jeremy W.Messalanta Juha M., Bic Steven, Hollinger David Y

[2] Forest ecosystem services: a review [J].Chinese journal of ecology, 2017,29(3): 391-397.

[3] Forestry;Chinese Academy of Forestry.Evaluation of REDD+ cost and carbon sink [J].

[4] Effects of different land use patterns on soil carbon sink [J].Liu zhi-qiang ecological processes,2020,9 (1):

[5] of forestry;Forest carbon sequestration and water saving: a review [J].Ecological And Environmental Protection, 2020:

[6] Ecological Research -- Ecological Economics;Zhang X D, Zhang X D, Zhang X D, et al. Study on the measurement and economic value of wetland carbon sink based on ecological economics [J].

[7] A study on forest resources evaluation based on GIS [J].International review of forestry,2019,21 (1):

[8] Morgan Edwards.Cadman Tim McKidan.Forest ecosystem management based on GIS [J].Environmental science & technology, 2018,34(10): 577-581.]