Table 2: Statistics of the selected 10 impoverished counties for road network extraction performance comparison.

Year	Avg. popu	Avg. GDP	Avg. Area	Avg. #Images
2017	0.4218	0.8930	2079	8045
2021	0.4463	1.288	2079	8045

A Additional Information on Experiments

A.1 Validation Dataset Statistics

To assess the performance of our proposed framework for road network extraction, we randomly select 10 impoverished counties from those declared out of poverty in recent years in the file "List of 832 National Poverty-Stricken Counties" [The National Rural Revitalization Administration, 2014], whose statistics are shown in Table 2. The unit for the average population is "million people", the unit for average GDP is "million Chinese Yuan (CNY)", and the unit for average area is km^2.

The selected impoverished counties' names are "Shufu County", "Xixiang County", "Guanghe County", "Danfeng County", "Jiangzi County", "Honghe County", "Libo County", "Linquan County", "Jingyu County", and "Lingqiu County".

A.2 Evaluation Metrics

Graph sampling [Biagioni and Eriksson, 2012; Aguilar and Buchin, 2021] is a commonly used method for comparing two graphs, which simultaneously evaluates the geography and topology of graphs. In our evaluation process, the core idea is to first compute a set of point samples separately on the ground truth road network G and the proposed road network H. The point samples are determined by a fixed sampling interval on the road edge, which we set as 0.01. Then, the selected point samples on G and H are matched one-to-one globally according to a maximum matching distance, which we set as 0.1 by experiment trials.

The precision, recall, and F1-score showing the accuracy of the road networks are computed as follows,

$$precision = \frac{\#matched\ samples}{\#samples\ on\ H}, \tag{11}$$

$$recall = \frac{\#matched\ samples}{\#samples\ on\ G}, \tag{12}$$

$$F1 - score = \frac{2 * precision * recall}{precision + recall}. \tag{13}$$

Then, the road intersection recovery rate (RI) is used for further evaluation. RI reflects the recovery percentage of road intersections in the ground truth road network, and we select the intersection of over three road segments. Besides, Mean Absolute Percentage Error over road length (MRL) and road density (MRD) are adopted for evaluation. MRL and MRD measure the difference between the road length and road density from extracted road network H and ground truth G, respectively. The metrics are calculated as

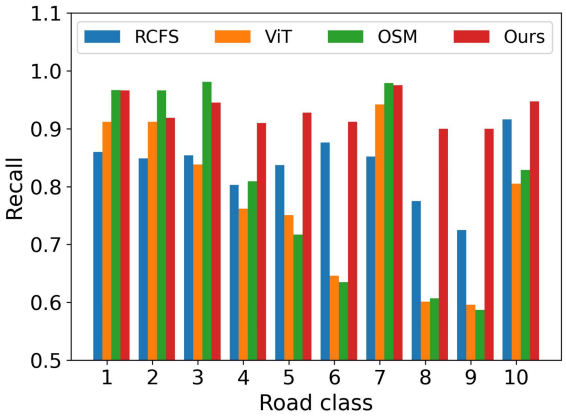


Figure 10: The results of recovering different classes of roads in 2017.

$$MRL = \frac{1}{N}\sum_{i}^{N}\frac{|RoadLength(G_i) - RoadLength(H_i)|}{RoadLength(G_i)}, \tag{14}$$

$$MRD = \frac{1}{N}\sum_{i}^{N}\frac{|RoadDensity(G_i) - RoadDensity(H_i)|}{RoadDensity(G_i)}, \tag{15}$$

$$RI@k = \frac{1}{N}\sum_{i}^{N}\frac{\#Matched\ intersections@k}{\#Intersections@k\ on\ G_i}, \tag{16}$$

where N denotes the number of selected counties for evaluation, and $RI@k$ denotes the road intersection recovery rate over k road segments($k = 3$).

A.3 Road Classification

There are following 10 classes of roads used in the experiments. They are classified based on their width and speed restriction. From the highest to the lowest level, which is the same order used in the experiments, the exact road class names are "Highway", "National Road","Provincial Road", "County Road", "Township Road", "Village Internal Roads", "Major Road", "Minor Road", "Ordinary Road", and "Pathway".

We also show in Figure 10 the recognition results of the above mentioned roads in 2017. We can see that our proposed framework performs well on reconstructing the low-class roads that are important and usually missing in the public dataset.

B Dataset Description and Additional Socioeconomic Analysis

B.1 Dataset Characteristics

We leverage the satellite image to generate a road network dataset targeting impoverished areas to support SDGs. And 382 impoverished counties are selected from those declared

	Regions	#County	#Prov	#Image	Area	Popu	GDP	SSE	Balance	RL	RD	RPC
2017	Western	214	12	33105	2210	355.8	7.513	2.920	6.363	1878	0.95	6.61
	Central	132	6	31079	1999	572.0	11.75	4.783	11.50	2537	1.43	5.74
	Eastern	30	2	20518	1171	362.0	7.447	2.710	8.922	2444	2.68	7.66
	Northeastern	6	2	81775	3720	283.3	6.601	2.681	5.713	3265	1.08	12.5
	All combined	382	22	32180	2079	428.7	8.930	3.543	8.328	2172	1.26	6.48
2021	Western	214	12	33105	2210	370.1	10.75	3.576	9.776	2340	1.17	8.06
	Central	132	6	31079	1999	597.2	17.31	6.242	19.04	3236	1.85	7.05
	Eastern	30	2	20518	1171	360.0	9.887	2.696	15.64	2842	3.17	9.05
	Northeastern	6	2	81775	3720	275.0	6.546	1.322	9.695	3484	1.19	13.8
	All combined	382	22	32180	2079	446.3	12.88	4.393	13.44	2707	1.56	7.88

Table 3: Dataset statistics of the selected impoverished counties in different economic regions in 2017 and 2021.

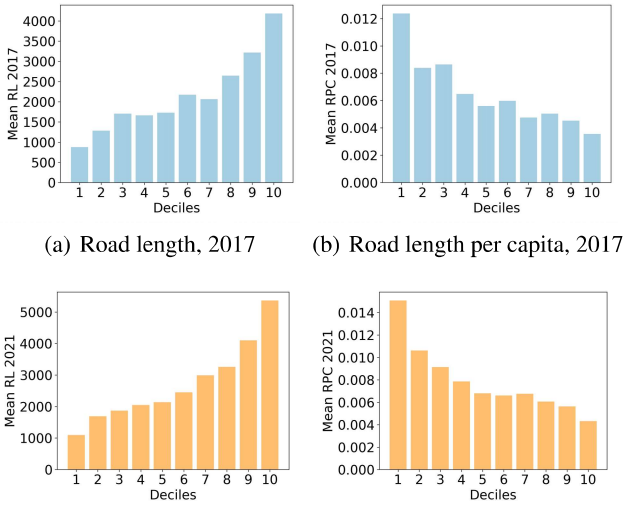
out of poverty in recent years in the file "List of 832 National Poverty-Stricken Counties" [The National Rural Revitalization Administration, 2014] in China. The 382 impoverished counties are assigned to China's four major economic regions, which are determined by the China State Council according to the socioeconomic development of different regions. Those four regions are the western, central, eastern, and northeastern economic regions.

We select the Gross Domestic Product (GDP), added value of the secondary sector of the economy (SSE), and resident saving balance (Balance) as the indicators reflecting the regional socioeconomic development. These indicators are collected from the "China County and City Statistical Yearbook[2]" published by China Statistics Press in 2017 and 2021. The detailed socioeconomic status of the selected counties in different economic regions are presented in Table 3. Altogether, we show the number of counties (#County), number of provinces (#Prov), average number of images (#Image), average area (km^2), average population (popu, thousand people), average GDP (billion CNY), average added value of the secondary sector of the economy (SSE, billion CNY), average resident saving balance (Balance, billion CNY), average road length (RL, km), average road density (RD, km/km^2), and average road length per capita (RPC, m). Most of the counties reside in the western and central economic regions, because China's economic development is higher in eastern provinces than other regions and most counties declaring out of poverty are located in the western and central regions. From the perspective of the road networks, the western region still has the least road length and road density, and the eastern region almost has twice the road density, which shows the road accessibility inequality among different economic regions.

B.2 Road Network Features with County Size

In this section, we compare the road network length and per capita road length in our generated dataset across counties with different population size. Specifically, we group the counties into 10 deciles (that means decile 10 represents the counties with the top 10% population and decile 1 includes the counties with the least 10% population) and compute the mean road length (RL) and road length per capita (RPC).

[2]http://www.stats.gov.cn/zs/tjwh/tjkw/tjzl/202302/t20230215_1908004.html



(a) Road length, 2017 (b) Road length per capita, 2017

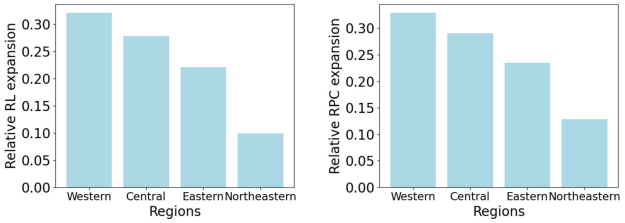
(c) Road length, 2021 (d) Road length per capita, 2021

Figure 11: The comparison of road network length and per capita road length in counties from different population groups.

The results in different deciles in 2017 and 2021 respectively are presented in Figure 11. The results show that counties with more population have more road length, but the expansion of road network is slower than the growth of population, which is consistent with the findings in US metropolitan areas [Levinson, 2012].

B.3 Inequality of Road Network Expansion

The economic development of the four economic regions in China is different, with the eastern region being the most developed and the western region the least developed. Therefore, the difference in road network variation in those regions can help understand the improvement of the local economy. We present mean values of the relative road length (RL) growth and relative road length per capita (RPC) growth from 2017 to 2021 in impoverished counties from four economic regions in Figure 12. We can see that the road length growth in the western region is the highest, which might be due to the efforts of road construction to alleviate poverty and boost the economy in the western region. Next, impoverished counties in the central region experience the second fastest expansion in road infrastructure.



(a) Road length. (b) Road length per capita.

Figure 12: The expansion of roads in impoverished counties from different groups.

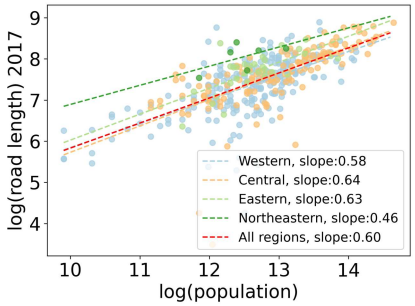


Figure 13: The scaling law between population and road length in different economic regions in 2017.

B.4 Scaling Law of Road Network in Year 2017

The scaling law analysis between the log(population) and log(road length) in 2017 is shown in Figure 13. The slopes of the western and central regions in 2017 demonstrate the uneven development of the road network spatially.

B.5 Correlation Analysis in Year 2017

The correlation analysis of road network length and population, GDP, SSE, and balance in our generated datatset in 2017 is shown in Figure 14. We can see the population, GDP, and balance show higher R^2 than SSE.

B.6 Division of Control and Treatment Groups in Causal Analysis of Road Network

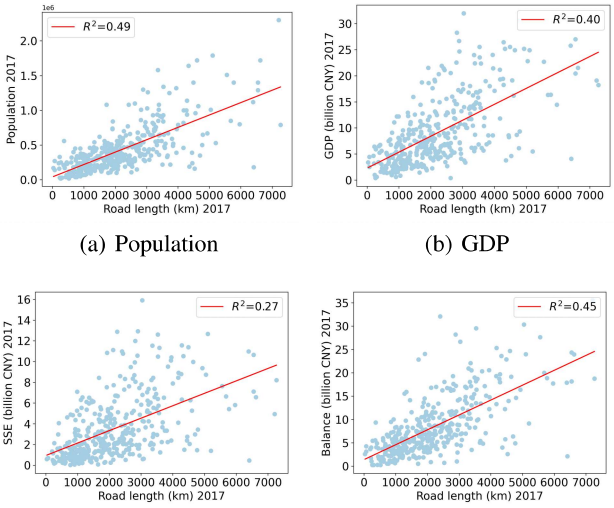
We divide the counties into control and treatment groups according to the metrics: absolute road length variation (ARL), relative road length variation (RRL), and relative per capita road length variation (RRPC). The calculation formulas are as follow:

$$ARL = RL_{t_2} - RL_{t_1}, \tag{17}$$

$$RRL = (RL_{t_2} - RL_{t_1})/RL_{t_2}, \tag{18}$$

$$RRPC = \frac{(RL_{t_2}/P_{t_2} - RL_{t_1}/P_{t_1})}{(R_{t_2}/P_{t_2})}, \tag{19}$$

where RL_{t_2} and RL_{t_1} are the road length in year t_2 and t_1, and P represents the county's population.



(a) Population (b) GDP

(c) SSE (d) Balance

Figure 14: Correlation between the road length and socioeconomic indicators, i.e., population, GDP, SSE, and Balance in impoverished counties in 2017.