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Distribution Patterns and Influencing Factors of Soil Organic Carbon in Mountainous Areas of Southwest China

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ABSTRACT

Soil organic carbon (SOC) is critical for the global carbon cycle, soil fertility, and climate change mitigation. The mountainous areas of Southwest China—covering parts of Sichuan, Yunnan, Guizhou, and Tibet—boast complex topography and diverse ecosystems but remain understudied for SOC dynamics. This study explores SOC distribution patterns and key influencing factors via literature review, field sampling, and statistical analysis. Results show SOC content varies spatially, with higher levels in high-altitude regions, forests, and topsoil. Key drivers include climate (temperature/precipitation), vegetation, topography (altitude/slope), soil properties (pH/bulk density), and human activities. Findings support sustainable land management for SOC conservation in the region.

KEYWORDS

Soil organic carbon; Distribution patterns; Influencing factors; Southwest China mountains

1 Introduction

Soil is a massive storehouse for carbon. In fact, the top one meter of the world's soil holds about 1,500 billion tons of organic carbon. This is more carbon than what is found in all the plants on Earth and in the air combined. This stored soil carbon plays a critical role in regulating our climate [1]. When soil is disturbed and organic matter decomposes, it releases carbon dioxide into the atmosphere, which makes global warming worse. On the other hand, when soils are managed well, they can pull carbon out of the air and safely store it, which helps fight climate change.

Our study looks at the mountainous region in Southwest China. This is a vast area, covering over two and a half million square kilometers. The landscape rises from low valleys, less than 100 meters high, to towering peaks over 8,000 meters high. Because of these extreme height differences, the area has many different local climates, from warm and humid in the lowlands to cold and harsh in the high mountains. These conditions support a variety of ecosystems, including dense forests, open grasslands, and high-altitude meadows.

Even though this region is very important for storing carbon, past research on its soil carbon has been limited. Most studies have only looked at small, specific locations. We lack a clear, big-picture understanding of how carbon is stored across the entire region. At the same time, human activities like cutting down forests for farming are changing the land quickly. This makes it urgent to conduct a thorough study [2].

The main goals of our research are to create a map showing where the soil carbon is located, to understand how the environment controls its storage, to measure the effects of human activity, and finally, to use this information to help protect this vital natural resource.

2 Study Area and Methods

2.1 Study Area

This research focused on a large area in the southwestern part of China. The land in this region is very rugged and uneven, featuring famous mountain ranges and high plateaus. Because the area is so vast and the elevation changes dramatically, the local climate and plant life vary a great deal from one place to another[2].

The amount of rain that falls each year ranges from 600 to 2000 millimeters. The weather in this area changes a lot with the landscape. In the high mountains, it can be very cold, with an average temperature as low as -2°C. But down in the low valleys, it's much warmer, averaging around 25°C.Because of these different climates, you find different types of plants at different heights. Down low (below 1, 000 meters): You'll see green forests that don't lose their leaves and plenty of farmland.In the middle (1,000 to 2,500 meters): The forests are mostly made up of cone-bearing trees like pines, or a mix of different trees. Up high (above 2,500 meters): It's too cold for trees. Instead, you find wide, open grassy fields. The soil also changes from place to place. It can be different colors, feel different, and have different levels of acidity.

2.2 Data Collection and Analysis

To learn about the soil carbon in this area, we got our information in two ways. First, we read 128 different science papers about the region, all published between 2000 and 2022. Second, we did our own fieldwork from 2018 to 2022, collecting 384 soil samples from six different locations. For every sample we collected, we did standard lab tests to measure its organic carbon, how dense it was, and its acidity. We also used official weather data to get the average temperature and rainfall for each spot where we took a sample. Once we had all this information, we used statistical software to carefully look for patterns and find our answers [3].

We used different methods to understand our data. One method helped us compare the average soil carbon in different landscapes, like forests versus grasslands. Another method helped us see how soil carbon was connected to things like temperature and rainfall. A more advanced technique showed us which factors were the most important in deciding how much carbon was in the soil.Finally, we used special software to turn all our data into a simple, color-coded map. This made it easy to see the patterns across the whole region.This map shows how soil carbon is spread across the whole region, which made the patterns we found easy to see and understand.

3 Results

3.1 SOC Distribution Patterns

3.1.1 Regional & Altitude Gradients

On average, we found 24.6 grams of carbon in every kilogram of soil, measured from the top meter down. But the amount changed a lot from place to place—some soils had only 3.2 grams, while others had as much as 89.7 grams per kilogram [4].

Where the soil is located makes a big difference. Soils that are very rich in carbon (more than 35 grams per kilogram) are mostly in the high, rugged mountains, like the edges of the Tibetan Plateau. On the other hand, soils with low carbon (less than 15 grams) are usually found in the flat, low-lying farmlands of the Sichuan Basin.

We saw a very clear pattern with height: the higher you go, the more carbon the soil has. This link is very strong. In areas below 1,000 meters, the soil carbon is quite low. At middle heights, the amount nearly doubles. And in the highest places, above 2,500 meters, the soil holds the most carbon.

This difference is biggest in the very top layer of soil. In the mountains, the surface soil holds more than three times the carbon of the soil in the lowlands. This shows that the ground in high places is a especially important carbon store.

3.1.2 Soil Depth

As you dig deeper, the amount of carbon in the soil always gets lower. This happens everywhere, whether it's a forest, a grassland, or a farm.

The very top layer of the soil (the first 20 centimeters) has by far the most carbon. On average, it holds 35.7 grams per kilogram. That's almost twice as much as the layer of dirt right beneath it. And when you look even deeper, the difference gets much bigger. The topsoil has nearly three times more carbon than soil from 40-60 cm down, and almost five times more than soil from 60-100 cm down.

But this decrease doesn't happen in the same way everywhere. In natural places like forests and grasslands, the carbon level drops very quickly just below the surface. Most of the carbon is packed into the top layer.

On farmland, the change is less dramatic. The top layer still has the most carbon, but the difference between it and the deeper layers isn't as huge as it is in nature. This shows us that farming can change how carbon is stored deep in the soil.

3.2 Influencing Factors

3.2.1 Climate

The local climate really affects how much carbon gets stored in the soil. The biggest factor is temperature.

We found a clear link: colder places usually have more carbon in their soil. For every 1 degree Celsius drop in temperature, the soil carbon goes up by about 3.8 grams per kilogram. This is because cold weather slows down the tiny life in the soil that normally breaks down dead leaves and plants. When this process is slow, the carbon from the dead plants builds up in the soil.

Rainfall is also important, but in a different way. In places that get up to 1,500 mm of rain per year, more rain means more plants can grow, which puts more carbon into the soil. But in very wet areas that get more than 1,500 mm of rain, this link fades. Too much rain can actually wash the carbon and nutrients away from the topsoil, which cancels out the benefit of having lots of plants.

3.2.2 Vegetation & Topography

The kinds of plants that grow in an area make a big difference in how much carbon the soil can hold. In our study, we found that some landscapes store much more carbon than others.

The best at storing carbon were the cold, grassy fields high in the mountains. They held the most carbon by far. Evergreen forests were next, followed by mixed forests and then leafy forests. Areas with mostly bushes held less, and farmland held the least of all [5].

The shape of the land is also very important. We already know that higher places have more carbon because it's colder. But the steepness of a hill matters too. Steeper hills tend to have less carbon because wind and rain easily wash the valuable topsoil away.

Even the direction a hill faces makes a difference. Hillsides facing north are shadier and cooler, so they hold more moisture and end up with more carbon. Sunnier, south-facing slopes are warmer and drier, which leaves them with less carbon in the soil.

3.2.3 Soil Properties & Human Activities

The soil's own makeup plays a big role in how much carbon it can keep.

First, how acidic the soil is really matters. We found that more acidic soils usually hold a lot more carbon than less acidic ones.

Also, how compacted the soil is makes a difference. Hard, tightly packed soil has less space for air and organic stuff, so it holds less carbon.

On the other hand, soil with a lot of clay is good at holding carbon. Clay particles are tiny and sticky. They act like a shield, forming tiny clumps that protect the carbon from being eaten by microbes. This basically locks the carbon safely into the soil.

What we do has a huge effect on the carbon in the soil, both good and bad.When forests are cleared for farmland, the soil loses a lot of its carbon very quickly. Our study found that in just ten years, this can cause the top layer of soil to lose about two-thirds of its carbon.The good news is that we can also help bring this carbon back. By planting trees on old farmland—which is called reforestation—we can slowly help the soil build up its carbon again.Similarly, changing farming methods can make a big difference. Switching from conventional ploughing, which breaks up the soil and exposes carbon to decomposition, to no-till farming, which disturbs the soil much less, was found to increase soil carbon by 23%. This shows that our land management choices directly control the health of the soil and its role as a carbon sink.

4 Discussion & Conclusion

The mountains in Southwest China hold a significant amount of soil carbon. On average, there are 24.6 grams of carbon in every kilogram of soil here. This is more than what is found in the soils of China's Qinling Mountains and Taihang Mountains. However, it is less than the amount stored in the cold boreal mountains of Siberia.

The amount of carbon in the soil is mainly controlled by a few key factors. The most important one is altitude, as it affects both the temperature and the type of plants that grow. The local average temperature is also crucial, with cooler areas storing more carbon. Furthermore, the kind of vegetation, like forests or grasslands, and the soil's acidity level play big roles.

Looking ahead, climate change poses a serious risk to this carbon. If temperatures continue to rise, the soil in high mountain areas could lose a large portion of its stored carbon over the next 50 years. More frequent heavy rains could also wash away the valuable topsoil.

To protect this important carbon storage, we suggest several actions. First, it is vital to protect existing high-altitude meadows and forests. Second, we should plant trees on former forest land and encourage farming methods that do not involve ploughing the soil. Third, it is best to reduce farming on steep hillsides where soil erosion is a major problem.

In conclusion, this study offers scientific evidence to help manage the land in a sustainable way and prepare for the challenges of climate change in this region.

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