Evaluation of SOC under different vegetation stand types and forest site status in South China

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Abstract:
Forest soils and the nutrients within it are impacted by spatial activities. The concentration of soil organic carbon (SOC) was evaluated in different forest management location sites in relation to the environmental condition and management status of each forest site. Three distinct forest soils were collected in three locations (0-25 and 25-50cm profiles) of different forest management regimes in Guangdong Province, China. SOC concentrations, as well as physical and chemical soil properties were measured in the laboratory in relation to industrial, urban and protected forest locations. SOC concentration was highest at the Deqing forest site (30.24±1.35 and 26.65± 2.49) as a state regulated management system than in the industrial and urban sites. SOC was significantly highest in the Deqing site (48 g/kg). Duncan's test of SOC density revealed a critical statistical difference between Deqing and the other sites. Soil metal concentrations at the Dongguan industrial site showed significant differences in high amount of copper, lead and cadmium (15.1±2.67, 42.30±4.91 and 35.09±5.89). SOM concentration evaluated as sequestration parameter at the Deqing site (47g/kg) was statistically different from the others. Pearson's correlation and multiple comparison analysis on chemical and physical properties indicated critical differences (0.01 level) between the Deqing site (SOC, SOM, TotN, AvK) and the Guangzhou site (SOM, TotN, Avk and AvP) compared to the Dongguan site. The Deqing and Guangzhou forest sites showed attributes of better forest management systems. We strongly recommend an active effluent discharge policy, a Nutrient sensitive zones policy, a land Use policy, a Compulsory industrial implementation best management practices policy; and an Implementation and mitigation option policy.

Keywords: Land and land use; Climate change; Urban and Industrial pollution; SOC Concentration; Forest Management Regimes; Forest stand types; Environmental knowledge, South China.

1. Introduction

Terrestrial ecosystems and pool of organic carbon interact strongly with atmospheric composition. Anthropogenic and industrial activities must be considered in evaluating the effects of climate change on soil environment and forest ecosystems, since paleoecological evidence supports the significant effect of climate change on terrestrial ecosystems. (Schlesinger) [1] reported that SOC storage is controlled by the balance of C inputs from plant production and outputs through decomposition however the study sites may be influenced by climate, temperature, soil texture, and mostly significantly greenhouse gas emissions into the atmosphere, all of which are bound to play important role in the stabilization and concentration of SOC. Industrial and urban activities no doubt exhibit various impacts on natural ecosystems. China's large population is a key socio-economic indicator and is accompanied by trends of positive economic development, local environmental protection, and technological change. The innovation and advancement of environmental knowledge has developed as a response to industrial growth increases emission of greenhouse gases in the atmosphere. Generally, environmental management should be integral part of industrial development (Kralj.D et al., [2]. Land use, land-use change and forestry have been critical areas of interest in managing carbon-dioxide (CO_2) emission into the atmosphere in China while forest management practices has been documented by Kamaruzaman Jusoff and Dato' Hj. Dahlan Hj. Taha [3].

SOC, climate, and soil texture change are associated with depth and various studies by Spain et al., and Burke et al., [4-5] conducted on a regional basis that identified SOC has higher concentrations on top and surface level ranging from 20 to 30 cm. Of specific interest, we referenced the pollution category as industrial and atmospheric pollutants, effluent discharges, urbanization, and its influences on SOC concentration in forest management systems. This paper explores a multidisciplinary concept for specific opportunities of understanding how industrial and urban pollution may affect SOC concentration within spatial forest management regimes in Guangdong Province, China. This investigation is valuable: 1) To acquire a preliminary understanding of the influence of pollution on terrestrial ecosystems; 2) To establish a hypothetical relationship between site pollution and the sensitivity of SOC concentration in soils and forest health; 3). To assess industrial, urban and associated anthropogenic activities, such as emission of greenhouse gases may have adverse impact on terrestrial ecosystems. We hereby explore what might be the impact of pollution on SOC concentration; do environmental interactions influence SOC and its properties among forests? How is SOC concentration effected by different forest management regimes? The aim of this paper is to provide preliminary answers to these research questions, based on soil evaluation dataset acquired in the Guangdong Province, in Southern China. The main hypothesis of this study is that land use, land use change and forestry management systems are major primary controls of the total amount of SOC, and SOC level are influenced by environmental pollution. Plant potentials to sequester atmospheric carbon dioxide (CO_2) therefore depend on the forest management schemes. The relative controls of all kinds of environmental pollution (industrial and urban emission) do play significant terrestrial roles in the allocation and concentration of SOC, especially in a regional setting. As energy, transportation, industrial and socio-economic development have increased, so too have carbon emissions and other kinds of environmental pollution. We identified three forest management regimes within industrial, protected and urban spatial location in Guangdong Province with different forest stand types and management regimes. The specific objectives of this study are to (1) examine the site pollution status that may slow the concentration of carbon sequestration in terrestrial ecosystems (2) evaluate the relationship and distribution of SOC among the different forest management regimes, and (3) evaluate forest soil physical and chemical properties in relationship to SOC concentration at the sites.

In line with the provisions of clean development mechanisms (CDM) and its implementation, the Chinese government and its policy makers have shown greater interest in environmental sustainability and in the resolution of environmental problems. Generally, many mitigating measures are required with regard to carbon sequestration and reduction of greenhouse gas emissions through public policy options. As a result of the uncertainty and need to verify interacting forces of industrial and urban activities on terrestrial ecosystems within a regional setting this study is of paramount importance.

2. Materials and methods

2.1. Study area

This study was conducted in Guangdong province in Southern China and focused on three forest sites with different management regimes. Guangdong province is a highly industrial development region, coupled with large population. The Deqing site is located at 112°01' E, 23°26' N, has few or no neither industrial nor urban activities. The Dongguan site is located at 22° 57' N, 113° 47' E and associated with a conglomerate of industries, frequent human interaction, and urban activities, while the Guangzhou site is located at 113°21'E, -23°09'N within the center of a large urban area with its attendant frequent human interaction. The forest site and stand type locations were classified as nature reserves, public forest, and secondary forest respectively. The study sites were selected from different spatial locations of the region that will provide us specific evaluation of SOC concentration. Fig.1 shows the geographic location of the sites in Guangdong Province, China. The sites were located in Deqing Sanchading Nature Reserve, Dongguan Dalingshan Forest Park, and Guangzhou Changguangshan Nature Reserve.

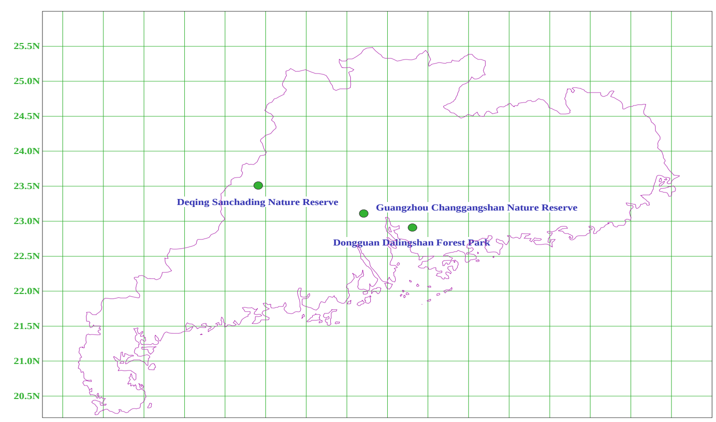

Fig.1 Map showing the study sites in Deqing Sanchading Nature Reserve, Dongguan Dalingshan Forest Park, Guangzhou Changguangshan Nature Reserve

2.2 Sampling design

The sample forest soils were selected on plantation nature reserved, and mixed forest as major forest stand types and management regimes. The sites at Deqing Sanchading Nature Reserve, Dongguan Dalingshan forest park, and Guangzhou Changguangshan Nature Reserve were selected to evaluate forest condition and evaluation of SOC concentration. Several models and study approaches were consulted as sources of literature and background; enumerated as Weinstein et al.[6], studied tree models and environmental stress, hydrologic as a component of community forest growth models and physiological based to vegetation dynamics Luxmoore R.J [7], Organic matter decomposition models, Jenkinson et al., [8], Molina et al., [9] and Clay et al., [10], Forest ecosystem models, Bossel et al., Liu et al., [11], Urban et al., [12] and Community vegetation demographic models.

2.3. Forest management regimes and vegetation stand types

The forest sites history are summarized as; 1) Deqing Sanchading Nature Reserve - reserve for forest ecosystems and wild life nature reserve, of about 1,100 kinds of plant under state protection, sub – tropical evergreen broad leaved forest and mixed conifers 2) Dongguan Dalingshan Forest Park - a history of dense forest areas, monsoon evergreen broad-leaved vegetation with frequent interference as a result of population and industrial growth to destruction of original forest. Current vegetation status is mostly artificial pin, eucalyptus and bamboos 3) Guangzhou Changgangshan Nature Reserve - a protected University arboretum with forest stands like *Schima superba,* Eucalyptus plantation, *Pinus elliottii*, *Cyclobalanopsis* and other mixed forest.

Table 1 Location and site status

Site	Location	Mgt Regime	Site Status
Deqing	112°01′E, 23°26′N	Nature reserve	Reserve
DG	22°57′N, 113° 47′E	Public forest Park	Industrial
GZ	113°21′E, 23°09′N	Secondary forest	Urban

Deqing: Deqing site, DG: Dongguan site, GZ: Guangzhou site, Mgt-Management

2.4. Field soil sampling and laboratory analyses

At each forest site, a plot measuring 20 x 20 m was marked off, and then subdivided into ten 5 x 5 m (0.025) quadrants, five of which were randomly selected for sampling. Surface (mineral) soil level was categorized under soil below O horizon and deep soil was adopted for sampling at depth of 0 – 25 cm (surface level) and 25 – 50 cm (deep level) using a standard 2-cm diameter stainless steel sampling probe. A total of 10 cores were used as a composite for each quadrant. Two 5 x 5 cm cores (strata) designated for surface and inner depth were taken per plot (forest site) sample to determine bulk density. Soil samples at both depth samples were separately finely mixed, air dried grounded and sieved. Organic matter concentration of each site was determined by loss on ignition (450° for 4 h). We considered the entire organic soil using a 15 x 15 (225 cm^2) template for each quadrant and collected soil samples for laboratory chemical analysis. Laboratory methods applied in chemical and physical parameters of forest soil sites includes SOM determination by [13], SOC concentrations and SOC density by Nelson and sommers [14], Total and Available Nitrogen by Pella E [15], Total and Available Phosphorous by Olson and Sommer [16], Natural moisture content by Gardner [17], and pH values by Mclean E.O [18].

2.5. Statistical analysis

This study involved spatial (field scale) selection and distributions of terrestrial parameters and were structured to assess the scaling and quantification of variability. Data accumulated from the sites were analyzed using different software packages. Descriptive statistics parameters were calculated with Microsoft Excel and STASTICA software 6.0 versions (Statistica Inc) [19] and SPSS software (SPSS Inc) [20]. SOC concentrations were described and compared among the environmental variables (industrial pollution, urban influence and protected areas), that is to say, all data obtained across the samples measured (determined soil chemical and physical factors in respect to forest management regimes), were subjected to a test of significance as analysis of variance (ANOVA). The Kruskal-Wallis median test was used at 5% probability level to evaluate and determine the difference between SOC variations of forest sites and location as shown at least significant difference (LSD). Soil Organic Carbon, including bulk density and organic carbon variations among forest soil sites were evaluated. A multivariate analysis was performed with SPSS software to evaluate the SOC concentration and Pearson correlation analysis (critical values 0.01 level) of SOC to determine the effect of chemical and physical soil properties by forest location and status. Further environmental considerations were on spatial variation by source of soil pollution at site. pH and heavy metal concentrations, as an influencing attribute, were assessed to give insight on SOC sequestration potential.

3. Results and discussions

3.1. Implication for SOC concentration by site pollution status

Based on the various forest soil and site activity status, it is widely accepted that economic activities and the environment are interrelated and virtually inseparable. Factors to examine when considering vegetation and soil interactions include cloudiness, precipitation, temperature, humidity and atmospheric deposits of pollutants were documented by Virginia et al., [21]. SOC concentration evaluated at the Deqing site had 30.24±1.35 (0-25cm) and 26.65±2.49 (25-50cm), as shown in table 2, and by site status, it has sources of pollution (classified as highly protected with no or little interference, i.e., disturbance and other forms of pollutants). This is to say, that the impact of pollutants in turn are constrains to nutrient status, chemical and physical soil properties, as well as forest management history as shown in table 1

Table 2 SOC concentration evaluation in Deqing forest reserved site

Depth	SOC(g/kg)	SOC(g/kg) Sdv	SOC(g/kg) Min.	SOC(g/kg) Max.
0-25 cm	30.24±1.35	11.71	12.59	56.97
25-50 cm	26.65±2.49	21.53	4.22	105.62

Comparatively, the Dongguan site is located in a concentrated industrial zone that is a major source of environmental pollutants as indicated in table 3, 12.68±0.89 (0-25cm) and 10.7±0.7 (25–50cm) of the site SOC concentration. These results indicated that urban and industrial forest location sites (Dongguan and Guangzhou) were comparably and significantly different.

These are attributes and evidence of the characteristics of greenhouse gas emissions that are associated with industrial activities, human, and urban disturbances. The Guangzhou forest site in table 4 is associated with urban characteristics, human interaction and disturbance that showed 11.69±0.71 (0–25cm) and 11.69±0.71 (25-50 cm) results.

Table 3 SOC concentration evaluation in Dongguan industrial forest site

Depth	SOC(g/kg)	SOC(g/kg) Sdv	SOC(g/kg) Min	SOC(g/kg) Max
0-25 cm	12.68±0.89	7.72	4.68	42.72
25-50 cm	10.7±0.7	6.08	2.85	28.93

Table 4 SOC concentration evaluation in Guangzhou urban forest site

Depth	SOC(g/kg)	SOC(g/kg) Sdv	SOC(g/kg) Min	SOC(g/kg) Max
0-25 cm	11.69±0.71	6.11	4.50	28.51
25-50 cm	10.28±0.84	7.30	2.33	29.36

3.2 Comparative analysis of SOC concentration by forest soil sites

We conducted a comparative analysis of soil organic carbon concentration for the three forest sites in reference to site status, shown in fig.2 while no great significant difference occurs in the protected forest site (p = 00.0000) on SOC concentration, (Deqing site 29 g/kg), The Guangzhou site (11.0 g/kg) and the Dongguan site (11.02 g/kg), respectively show a marked impact.

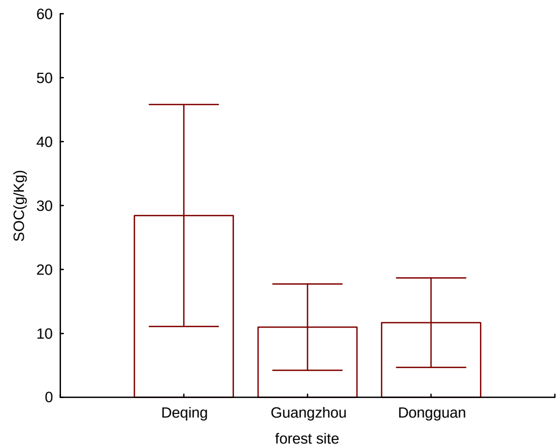

Fig.2 Comparative evaluation of SOC concentration among the forest sites

Pollution by industrial activities produces contamination from heavy metals and affects decomposition of soil organic matter (SOM), thereby exerts major problems in the concentration of soil organic carbon and soil properties. A wide range of investigations have been conducted on the effect of heavy metals in polluted soils, Such studies include Ladd et al., [22]; Sampson et al., [23], and Tiessen et al., [24] and over the fate of heavy metals in polluted soils by Hughes et al., [25] and Harter and Naidu [26]. Our investigation in South China is in conformity with those earlier studies. The effect of pollution and other forms of forest soil environment disturbances has an attribute to negative impact on terrestrial ecosystems, as shown in table 5, where the Dongguan (10.99±0.55) and Guangzhou (11.69±0.57) sites showed critical significance using Duncan's critical statistical assessment.

Table 5 Duncan's critical evaluation of SOC among the forest site status

Sites	SOC(g/kg) Sde	SOC(g/kg) Sdv	SOC(g/kg) Min	SOC(g/kg) Max
Deqing	28.44±1.42	17.37	4.22	105.62
Guangzhou	10.99±0.55**	6.75	2.33	29.36
Dongguan	11.69±0.57**	7.00	2.85	42.72

** Highly significant difference among the forest sites with reference to location

3.3 Soil pH and heavy metal concentration status

Generally, greenhouse gas mitigation has become a critical issue in global environmental sustenance, and forestry management is one significant model. Generally, in reference to pH and heavy metal accumulation measured among the forest sites, as depicted in table 6, the Dongguan site showed a classical result and was the highest (15.1±2.67) in copper. The emission of carbon dioxide and other established pollution sources from industrial and urban activities are potential sources that impact soil health and terrestrial ecosystems. Associated and critical soil environmental factors, acidic and heavy metal concentrations at the sites in table 6 confirmed that industrial heavy metals, fertilizer application and urban emissions were in active play in the region. The Dongguan site showed high levels of zinc (42.30±4.91) and the highest amount of lead (35.09±5.89), a clear evidence of industrial/effluent discharges.

The Guangzhou was highest in zinc (44.17±4.03), evidence of urban disturbance, while the Deqing site was highest in zinc (58.20±3.31), and high in lead (30.61±0.46), evidence of fertilizer application and of the effect of forest conversions.

Table 6 pH and heavy metals evaluated across soil samples in the forest sites

Site	pH	Cu /mg kg^{-1}	Zn mg/kg^{-1}	Cd mg/kg^{-1}	Pb mg/kg^{-1}
Guangzhou	4.26±0.20	11.48±2.51	44.17±4.03	31.01±5.89	0.68±0.09
Dongguan	4.73±0.13	15.1±2.67	42.30±4.91	0.03±0.00	35.09±5.89
Deqing	4.53±0.03	6.07±0.77	58.20±3.31	0.10±0.02	30.61±0.46

3.4. Assessment of SOM for forest potential in carbon sequestration

The measurement of SOM at 0–50cm depth as shown in fig.3, indicated 47 g/kg at highest concentrations at the Deqing site and a statistical difference (p = 00.0000). The evaluation of SOM at surface level indicated a parameter for soil carbon sequestration potential by forest stand, as well as soil. Industrial and urban pollutants have left much to be reconciled by scientists as a result of the metallophyte and toxins that are incorporated into the SOM pool, not only in terrestrial ecosystems, but also with regard to general impact on global functioning of soil–plant systems, as reported by Baath [27].

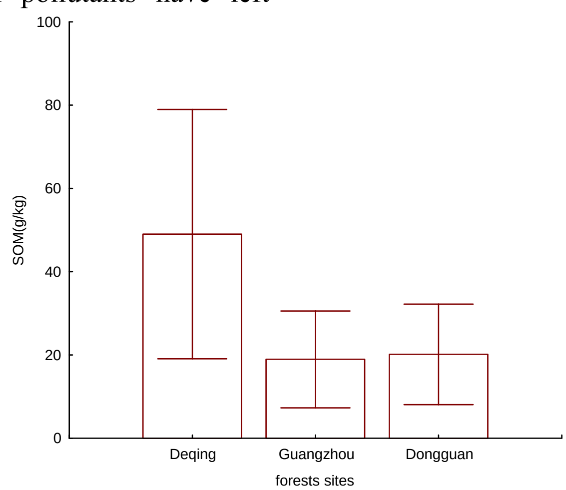

Fig.3 SOM evaluation as a sequestration parameter

3.5 Soil chemical and physical factors analyses among sites

The result of soil pH level tests gave information on the soil acidic composition of the region. Disposals of industrial and urban products especially by effluent discharges, results in soil pollution and increases in heavy metals that correspondingly affects soil biota in its diversity, abundance, soil properties, and activity, which has been supported by Brooker [28]; Mhatre et al [29]; and Raskin et al., [30]. Soil chemical and physical properties were statistically evaluated using Pearson's correlation among the sites. Physical soil properties in table 7 and 8 showed that electrical conductivity in the Deqing and Guangzhou sites (0-25cm) were strongly correlated. NMC and BD at the Dongguan site (25-50cm) were also strongly correlated as shown in Table 9.

Table 7 Pearson correlation analysis of SOC against physical properties

Deqing	NMC		BD		pH		EC	
	0-25	25-50	0-25	25-50	0-25	25-50	0-25	25-50
0-25	0.056	-0.20	-0.03	0.27	0.02	-0.01	-0.40*	0.60**
25-50	-0.478*	0.03	0.25	-0.39	-0.02	-0.06	0.10	0.22

Table 8 Pearson correlation analysis of SOC against physical properties

Guangzhou	NMC		BD		pH		EC	
	0-25	25-50	0-25	25-50	0-25	25-50	0-25	25-50
0-25	-0.14	-0.09	-0.23	-0.04	-0.37	-0.37	-0.40*	0.60**
25-50	-0.03	0.02	-0.09	-0.01	-0.42*	-0.39	0.10	0.22

Table 9 Pearson correlation analysis of SOC against physical properties

Dongguan	NMC		BD		pH		EC	
	0-25	25-50	0-25	25-50	0-25	25-50	0-25	25-50
0-25	-0.09	0.19	-0.32	-0.05	0.10	-0.05	-0.11	0.07
25-50	-0.08	0.56**	-0.24	-0.52**	0.20	0.12	0.46*	0.02

** Correlation (2-tailed) is critical significant at 0.01 level, * Correlation (2-tailed) significant at 0.05 level
NMC – natural moisture content, BD- Bulk Density, pH – acidic level, EC – Electrical conductivity, SOC-Soil Organic Carbon, SOM- Soil Organic Matter

Our results were further supported by the fact that decreased litter decomposition near sources of pollutants emission was evident, as shown in table 10 on the statistical differences and multiple comparisons of evaluated parameters in the forest soils of Deqing, Dongguan and Guangzhou forest regimes. Various categorized pollution influences forestry and SOC concentration that can be interactive in their impacts. Delcourt and Delcourt [31] reported that these varieties take place in temporal and spatial scales with wide range of effects upon the forest ecosystem.

3.6. Policy option in environmental pollution and terrestrial ecosystem management

Pollution management focuses on the interface and interaction between science, technology, and policy on the environment. The industrial and high technological era has brought about such anthropogenic activities as fossil fuel combustion, deforestation, greenhouse gas emissions, and effluent discharges, which require policy action to effectively manage environmental pollution. Our findings further revealed that both physical and chemical soil factors were influenced; this is further noted in the multiple comparisons shown in table 11, the Deqing site shows significant differences in both SOC concentration and SOM from Guangzhou and Dongguan sites (0-50cm).

Table 10 Multiple comparisons of major physical factors among the three sites

Site	NMC	BD	pH	EC	SOM
Deqing 0-25	230.703±7.512 bc	1.41±0.03 bc	4.65±0.05 **a**	98.55±11.4107 **a**	30.238±2.356 **a**
Deqing 25-50	248.103±9.137 ab	1.38±0.02 bc	4.82±0.06 **a**	67.16±9.122 **b** 8	26.651±4.338 **a**
Guangzhou 0-25	272.191±11.010 **a**	1.24±0.03 **a**	4.91±0.04 **a**	67.45±6.1597 **b**	11.694±1.240 **b**
Guangzhou 25-50	264.549±12.561 **a**	1.33±0.04 **b**	4.99±0.05 **a**	58.98±5.4025 **bc**	10.284±1.481 **b**
Dongguan 0-25	218.758±8.996 bc	1.44±0.02 **c**	4.81±0.11 **a**	34.73±7.455 4 **c**	12.678±1.566 **b**
Dongguan 25-50	215.604±11.364 **c**	1.43±0.02 **c**	6.25±1.28 **a**	39.66±11.3779 **c**	10.699±1.234 **b**

Means with the same letters in a column are not significantly different (P>0.05)

Table 11 Multiple comparisons of major chemical factors among the three sites

Site	SOM g/kg	SOC g/kg	AvN mg/kg	TotN g/kg
Deqing 0-25	52.130±4.0622 **a**	30.238±2.356 **a**	109.951±10.408 **a**	2.020±0.217 **a**
Deqing 25-50	45.946±7.4785 **a**	26.651±4.338 **a**	59.844±10.602 **bc**	1.423±0.189 **b**
Guangzhou 0-25	20.161±2.1373 **b**	11.694±1.240 **b**	62.349±7.032 **b**	0.936±0.069 **bc**
Guangzhou 25-50	17.729±2.5533 **b**	10.284±1.481 **b**	37.349±6.522 **cd**	0.793±0.141 **c**
Dongguan 0-25	21.857±2.7001 **b**	12.678±1.566 **b**	27.035±6.628 **d**	1.099±0.260 **bc**
Dongguan 25-50	18.445±2.1268 **b**	10.699±1.234 **b**	24.263±5.930 **d**	0.995±0.209 **bc**

Means with the same letters in a column are not significantly different (P>0.05)

The above analysis supports the hypothesis that the Deqing site (protected) was higher in SOC concentration and C sink potential compared to all the other sites. Lal. R [32] has documented evidence that soil can be a source (CO_2, CH_4 and N_2O) or sink (CO_2 and CH_4) of gases depending on land use and management. Industrial production of goods and services, agricultural practices, conversion of natural sites to agricultural ecosystems, land use, and urban activities are a few major human activities that must be regulated. Long term solutions can be achieved through regulatory policies, such as sourcing alternative options to fossil fuels and the decarbonizing of fuel as a strategic policy. Both the Guangzhou (a university arboretum) and the Deqing sites showed attributes of better soil/fertility management because the sites had an adequate forestry management scheme. The important practices evident in those sites can lead to C sequestration and potential reduction of atmospheric carbon dioxide, however plants and vegetation species can be useful in site remediation and improving site polluted status (Hamidov A. et al., [33]. Industrial and environmental policy action becomes a strong tool which has been identified in this investigation that Dongguan forest site has been affected significantly by the intensive industrial and urban activities. These actions directly contribute to the decline of soil/environmental quality and soil degradation that leads to depletion of soil C pool. Policies that must be put in place include those that manage effluent discharge, urban forestry and the appropriate use of technology

4. Conclusions

This study reveals that specific pollution source and locations of certain activities are influential factors in the management of SOC in three forest management sites in Guangdong province, China; we strongly recommend that certain compulsory and active policies must be put in place. Such include an effluent discharge policy, a nutrient sensitive zones policy, a water and air quality policies, an agricultural and land use pollution policy, a compulsory industrial implementation best management practices policy, and an implementation and mitigation option policy and waste management policy. Finally, there should be a down to top (local to national) implementation of administrative and Environmental Protection Authority (EPA) policies and enforcement of laws to checkmate prevent environmental degradation.

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