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# Assessment of Soil Organic Carbon Stock in Five Forest Types of Northern Kashmir and Himalaya

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**ABSTRACT: Soil organic carbon (SOC) stock assessment in Northern temperate forests of Kashmir Himalaya is important to evaluate their contribution to national and global carbon stock. In this study, soil physic-chemical properties were measured to estimate SOC stock at three soil depths (0-10, 10-20 and 20-30 cms) under five forest types: *Pinus wallichiana* (PW), *Abies pindrow* (AP), *Cedrus deodara* (CD), *Picea simithiana* (PS) and *Betula utilis* (BU) in temperate forest of northern Kashmir Himalaya, India. Mean SOC stock values ranged from 46.21±1.84 Mgha$^{-1}$ to 67.09± 1.23 Mgha$^{-1}$ in PS and BU forest types respectively at 0-30 cm depth, respectively. Among the forest types, significantly greater SOC stock at three depths (0-10, 10-20 and 20-30 cms) was observed in BU forest type (23.65, 22.25 and 21.19 Mgha$^{-1}$, respectively) and the lowest was observed in PS (17.22, 15.46 and 13.53 Mgha$^{-1}$, respectively) forest type. Present study indicates that variability of C stock is influenced by species composition and altitude and BU forest type is more significant for carbon sequestration. Further, results of this study provides a baseline data for monitoring SOC stocks and also emphasizes the role of Gulmarg forests in climate change.**

**Key words:** Soil organic carbon; Kashmir Himalaya; Climate change; Bulk density; Temperate forest

## I. INTRODUCTION

Forests play vital role in the dynamics of regional and global Carbon (C) cycles [1] as they hold large proportion of the terrestrial C stock in biomass and soil organic matter (SOM) and helps to stabilize rising concentrations of atmospheric carbon dioxide ($CO_2$) [2]. About two-thirds of earths terrestrial C is retained in standing forests, under storey vegetation, forest debris and in forest soils [3]. Long-term fate of active C in forest ecosystems rely on whether it is retained in living biomass or soils. World soils hold significant pool of active C that plays vital role in the global C cycle [4]. It has been reported that, global forest carbon pool is 3.8 times the size of biotic pools and 3 times the amount of atmospheric C pool [5]. Moreover, residence time of vegetation C is less than that of soil C. Therefore, even a minute change in soil C pool could have a major impact on global atmospheric concentration [6]. Hence, it is pertinent to understand the variation in forest SOC and furthermore, soil carbon sequestration is considered to be viable option for reducing the increasing concentration of atmospheric $CO_2$ [7]. Soil C stock is greatly influenced by the type of forest, litter quality and litter production by vegetation, soil properties, and climate [8, 9].

Out of the total world forest C stock, temperate forest ecosystems accounts for a significant share of the SOC contributing 14 % to world forest carbon stock [10,11]. Himalayan temperate forests represent nearly 19% of India's geographical area and holds 33% of SOC pool of the country [12]. Northern temperate forests are reported to accumulate SOC stock double as that in aboveground vegetation biomass [13]. Several studies have revealed that monitoring of SOC stock variation using standard methodologies need to be accounted periodically at regional and national levels in drawing relation with $CO_2$ balance and climate [14, 15]. In context of huge data gaps for this region, it is important to study the dynamics of SOC stock which will be significantly important for India. Moreover, SOC stock values generated in this study will increase the total data pool values which can act as input parameters in, and for validating, simulation models and will also be helpful for better understanding the significance of Gulmarg forest soil in climate change. In India, particularly in Kashmir, to reduce the increasing concentration of atmospheric $CO_2$, only few studies have been conducted in temperate forests of southern Kashmir Himalayas on the potential of soil C sequestration [11, 15]. But, work on SOC stock in temperate forests of northern Kashmir Himalayas is not still reported. The purpose of this study was to figure out dynamics of SOC in five major temperate forest types of northern region of Kashmir Himalaya, India.

## II. MATERIALS AND METHODS

### *A. Study Area*

The study area, Gulmarg forest Range lies in special forest division, Tangmarg of Baramullah district and is situated north and north - westerly part of Jammu and Kashmir. Geographically, it lies between 34˚ 26’ 99" to 34˚ 10’ 95" N and 74˚ 75’ 75" to 74˚ 51’ 07” E with an elevation gradient of 2400-4300 m above mean sea level (Fig. 1). The area in general is mountainous, covered mostly by coniferous forests with sprinkled broad leaved species. This area is having continental climate with annual precipitation of 66-167 cm. The area has moderate summer and severe cold winter receiving heavy snowfall. The area is characterized by forest types which include Group 12/C1 lower western Himalayan temperate forest, Group 13/C3 Himalayan dry temperate forest, Group 14/C1 Himalayan sub alpine forests and Group 15/C3 Himalayan moist alpine forests [16]. For the present study, five different forest types were selected based on the dominant tree species: *Pinus wallichiana* (PW), *Abies pindrow* (AP), *Picea simithiana* (PS), *Cedrus deodara* (CD) and *Betula utilis* (BU). A total of 50 plots of 1ha each were for the detailed study.

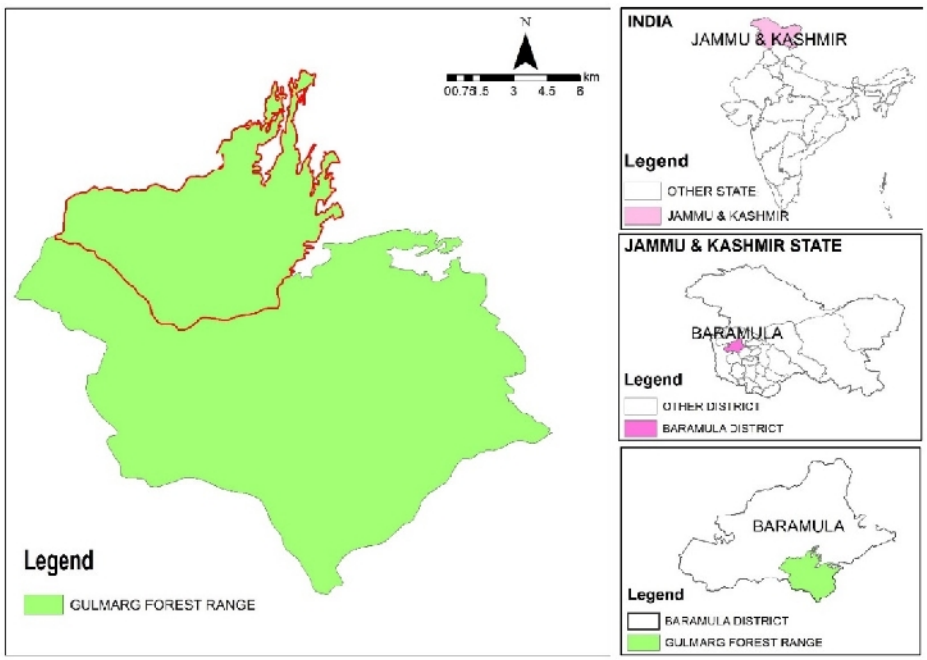


**Fig. 1.** Study area.

### *B. Soil Sample Collection*

Soil samples were collected during June and October of 2015 from each forest site by using soil core sampler. Top organic matter was removed manually and soil samples were taken from the depths (0-10 cm, 10-20 cm and 20-30 cm) from ten randomly selected points and mixed together to form composite soil sample in each forest type. Three replicate samples from collected composite soil were then transferred to laboratory for physic-chemical analysis after storing them in polythene bags. The sampled soils were air dried, mixed thoroughly and passed through 0.5 mm mesh sized sieve for subsequent physic-chemical analysis after storing powdered samples in well labeled bags.

### *C. Soil Analysis*

Collected soil samples are analyzed for physico-chemical parameters. pH and electrical conductivity (EC) of the soil samples was estimated using a soil: water ratio of 1:2 with pH meter Eutech PH 700 and electric-conductivity meter Eutech CON 700 respectively by adopting the standard procedures as outlined by Gliessman [17].

Percent moisture content for the fresh composite soil samples at three different depths (0-10, 10-20 and 20-30 cm) was calculated on oven dry weight basis as per the method of Michael [18] with the help of the following formula:

$$\text{Moisture (\%)} = \frac{\text{Wt. of fresh soil} - \text{Wt. of oven dry soil}}{\text{Wt. of oven dry soil}} \times 100$$

Bulk density (BD) of the soil samples was estimated by following the method of Gupta [19] and was determined by the formula:

$$\text{Bulk Density } (\text{g/cm}^3) = \frac{\text{Dry weight of soil sample (g)}}{\text{Volume occupied by soil sample } (\text{cm}^3)} \times 100$$

Organic carbon (OC) was estimated by using Walkley and Black's method [20], which is most widely used procedure [21, 22]. In Walkley and Black's method, it is assumed that about 60–86% of soil organic carbon (SOC) is oxidized; therefore, correction factor of 1.58 are multiplied to the OC values in order to obtain corrected SOC values [23, 24]. Soil carbon stock ($\text{Mgha}^{-1}$) was then calculated based on the results obtained on bulk density, thickness of the soil layer and SOC concentration for different soil depths by following the method of IPCC [25]. Total C content of 30 cm depth was finally calculated by adding SOC stock of all three layers [21].

$$\text{SOC } (\text{Mgha}^{-1}) = [(\text{soil bulk density } (\text{gcm}^{-3}) \times \text{soil depth (cm)} \times \text{C \%})]$$

SOC $CO_2$ mitigation density was calculated by multiplying SOC for each forest type with a factor of 3.67 (C equivalent of $CO_2$). The values acquired exhibited the amount of $CO_2$ mitigated by soil under forest type [15].

*D. Statistical analysis*

The data obtained for all physic-chemical properties and SOC density was examined with statistical analysis using analysis of variance (ANOVA). Soil property values were considered significant that differed at p ≤/0.05. The statistical analysis were examined by using Graph Pad Prism software.

## III. RESULTS AND DISCUSSION

*A. Soil pH*

Values of soil pH differed significantly ($p<0.0001$) at different forest types in present study with highest value for BU forest (6.8±0.22) and lowest for PW forest (5.54±0.34) (Table 1). Lower pH value of PW forest soil may be attributed to availability of high organic matter in addition to litter decomposition (vegetation, leaves etc.). The pH value indicates lightly acidic nature of soil which is the characteristics of coniferous soils and is most suitable condition for availability of nutrients [26]. With the increase in depth pH values increased, this may be due to the reason of corresponding decrease in organic matter with depth [27]. pH value of present study show harmony with the results recorded by Wani *et al.,* [15] in temperate coniferous forest soils of southern Kashmir Himalaya (6.64±0.39) and Jehangir *et al.*, [28] in soils of north western Himalaya.Tangmarg, J & K (6.33±0.05).

*B. Electrical conductivity*

Electrical conductivity (EC) is relative measure of concentration of soluble salts in the soil sample. In present study soil EC values varied significantly ($p<0.0001$) in different forest types with highest EC248.48±17.91μS/cm for BU forest type and lowest EC 148.88±7.02 for PW forest type (Table 1). EC values exhibited may be attributed to mineral under different regimes of moisture and temperature, thus releasing different ions [29]. With increase in depth EC values decreased which may be related to nutrient leaching from soil surfaces, consequently their concentration increases in lower layers of soil. Soluble salt accumulation in mountainous regions is unlike due to regional climatic conditions *e.g.* heavy snowfall and rainfall. Wani *et al.,* [15] have reported electric conductivity values of (218.63±41.71μS/cm) for coniferous temperate forest soils in southern region of Kashmir Himalaya which is similar to the present study.

*C. Moisture content*

Moisture content, tabulated in table 1 shows significant variation ($p<0.0023$) from one forest type to another. Moisture content can be correlated with high forest density as soil moisture is conserved both by litter and forest cover. Prevalence of shady conditions in the forest floor due to forest canopy and overlying litter covers slows down transpiration and evaporation, thus results in the less loss of moisture [30].

*D. Bulk density*

In present study, bulk density values differed significantly ($p<0.0277$) across all forest types (PW, AP, CD, PS and BU) as given in Fig. 2. Variation of bulk density across all forest types is due to presence of high concentration of organic matter as soil bulk density is mainly effected by organic matter [31]. With increasing depth bulk density values increased, which may be attributed to the corresponding decrease in organic matter with depth and mixing with mineral material in the profile [32]. Wani *et al.,* [15] reported bulk density value of 1.01±0.08 $\text{gcm}^{-3}$ for temperate coniferous forests soils in southern region of Kashmir Himalaya which is in harmony with present result.

**Table 1: Depth wise variation of physical and chemical characteristics of soil of five forest types of Northern Kashmir Himalayas.**

| Parameters studied | PW | AP | CD | PS | BU | ANOVA | |
|---|---|---|---|---|---|---|---|
| | Mean± S.D. | Mean± S.D. | Mean± S.D. | Mean± S.D. | Mean± S.D. | P- value | Sign. |
| pH | | | | | | | |
| 0-10 cm | 5.34±0.34 | 6.09±0.07 | 6.46±0.28 | 6.49±0.06 | 6.53±0.26 | | |
| 10-20 cm | 5.64±0.32 | 6.17±0.09 | 6.58±0.27 | 6.54±0.02 | 6.75±0.03 | 0.0001 | *** |
| 20-30 cm | 5.84±0.15 | 6.27±0.08 | 6.66±0.27 | 6.59±0.02 | 6.80±0.02 | | |
| Conductivity (μS/cm) | | | | | | | |
| 0-10 cm | 161.32±7.06 | 192.69±5.07 | 210.76±18.46 | 181.03±3.51 | 248.48±17.91 | | |
| 10-20 cm | 155.44±7.43 | 182.69±2.48 | 190.07±7.38 | 173.17±5.15 | 242.49±17.16 | 0.0001 | *** |
| 20-30 cm | 148.88±7.02 | 178.84±4.74 | 189.42±13.29 | 166.19±6.35 | 238.87±15.54 | | |
| Moisture content (%) | | | | | | | |
| 0-10 cm | 61.07±14.02 | 42.75±3.65 | 25.7±8.14 | 36.11±5.92 | 19.63±1.49 | | |
| 10-20 cm | 48.96±14.12 | 32.73±4.41 | 20.28±3.32 | 31.35±7.45 | 17.74±1.88 | 0.0023 | ** |
| 20-30 cm | 40.67±15.46 | 23.22±5.84 | 16.86±0.68 | 23.25±6.27 | 16.21±1.61 | | |
| Organic carbon (%) | | | | | | | |
| 0-10 cm | 1.89±0.02 | 1.88±0.07 | 1.88±0.06 | 1.52±0.09 | 2.13±0.01 | | |
| 10-20 cm | 1.68±0.03 | 1.67±0.04 | 1.67±0.05 | 1.32±0.03 | 1.94±0.13 | 0.0692 | ns |
| 20-30 cm | 1.38±0.06 | 1.42±0.08 | 1.42±0.04 | 1.19±0.13 | 1.79±0.17 | | |

*** P<0.001; ** P<0.01; * P< 0.05; ns = not significant; Mean ± SD, Sig= Significance Where BU = *Betula utilis*, CD = *Cedrus deodara*, AP = *Abies pindrow*, PS = *Picea smithiana* and PW = *Pinus wallichiana.*

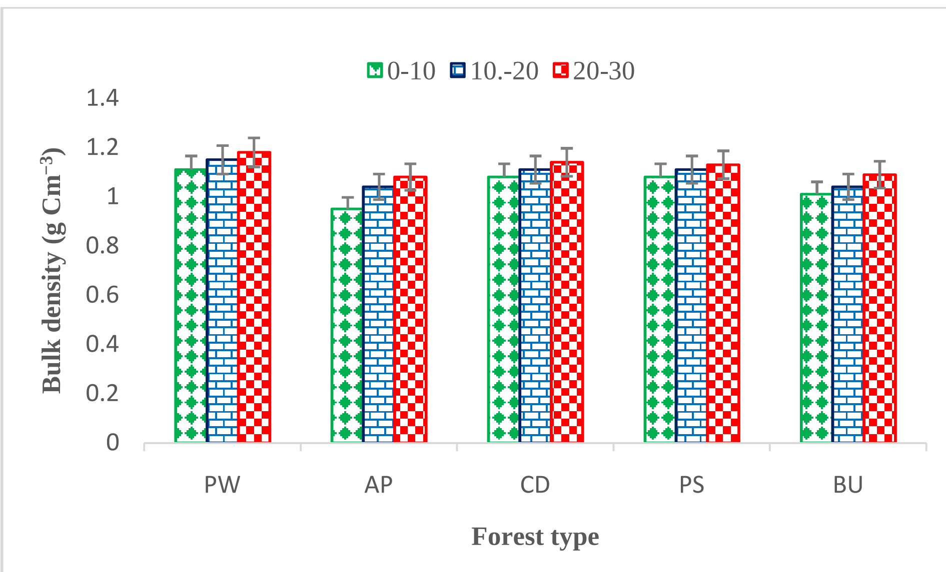


**Fig. 2.** Soil bulk densitydepth wise in five forest types of Northern Kashmir Himalayas.

*E. SOC stock and SOC $CO_2$ mitigation density*

Mean SOC stock values varied from 46.21±1.84 Mgha$^{-1}$ to 67.09±1.23 Mgha$^{-1}$ in temperate forest of Northern Kashmir Himalaya in 0-30 cm depth (Table 2). The highest SOC stock value in 0-30 cm depth was observed in BU (67.09 Mgha$^{-1}$) forest type whereas the lowest was observed in PS (46.21 Mgha$^{-1}$) forest type. Mean range of SOC stock values in different soil depths of five different forest types was 17.22 to 23.65 MgCha$^{-1}$ at 0-10 cm, 15.46 to 22.25 MgCha$^{-1}$ at 10-20 cm and 15.07 to 21.19 MgCha$^{-1}$ at 20-30 cm. A negative correlation was observed between SOC and bulk density across all forest types (Fig. 3). SOC concentration and spatial variation of soil bulk density are the main factors responsible for variation in total SOC [33]. Plant litter production as well as its decomposition determines SOC content in forest ecosystem [34].

BU forest type being present at highest altitude was having highest SOC stock because decomposition mainly determines C stock, which generally goes on decreasing with increase in altitude [22]. Lower values of SOC stock values of other coniferous forest types being situated at lower altitudes where sharp increase in temperature raises decomposition rate and other biological activity, ultimately reducing C accumulation in soil. In acidic soils of coniferous forests, forest floor is having more materials due to slow activity of soil fauna which decreases the mixing amount of humus with mineral soil [35]. Further, owing to shallower rooting systems of conifers, more organic C is accumulated in forest floor [36].

**Table 2: Soil organic carbon (SOC) stock at different depths in five forest types of Northern Kashmir Himalayas.**

| Forest type | C Mg ha$^{-1}$ (0-10 cm) | C Mg ha$^{-1}$ (10-20) cm | C Mg ha$^{-1}$ (20-30 cm) | Total C Mg ha$^{-1}$ (0-30 cm) |
|---|---|---|---|---|
| PW | 19.14±0.79 | 17.65±0.97 | 15.07±0.4 | 51.86±2.05 |
| AP | 17.92±0.94 | 17.36±0.3 | 15.34±0.17 | 50.62±1.35 |
| CD | 20.72±0.34 | 18.52±0.19 | 16.18±0.15 | 55.42±2.27 |
| PS | 17.22±0.7 | 15.46±1.29 | 13.53±1.44 | 46.21±1.84 |
| BU | 23.65±0.46 | 22.25±0.39 | 21.19±1.02 | 67.09±1.23 |

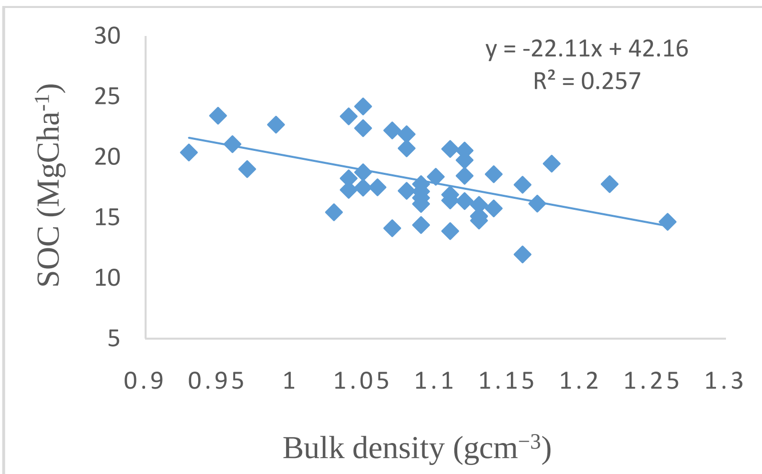


**Fig. 3.** Correlation between SOC and bulk density in five forest types of Northern Kashmir Himalayas.

In present study, at all forest types significant differences in SOC stock values ($p<0.0079$) were found in three different depths, which could be attributed to the forest type changes, quantity and quality of litter produced and biomass of vegetation. In addition to this, change in climate, vegetation, mean annual change in temperature and precipitation also plays a significant role in controlling distribution of SOC values vertically in different forest types. Similar results i.e. trend of deceasing SOC values with increase in depth have also been reported by Dar and Somaiah [11] and Jobbagy and Jackson [37].

Values of SOC stock in present study are in conformity with other studies. For temperate forests soils of Western Himalaya of J & K, SOC stock values of 50.37 MgCha$^{-1}$ to 55.38 MgCha$^{-1}$ were reported [11]. Another study conducted in temperate coniferous forests of southern Kashmir Himalaya reported a mean SOC density value of 39.74±5.63 Mgha$^{-1}$ [15], which is in accordance with present study. Present study values of SOC stock is well within the range (12.1-184.3 Mgha$^{-1}$) obtained for temperate montane forests of India [38].

$CO_2$ mitigation density values calculated on the basis of SOC density for different forest types varied significantly ($p<0.05$) from 169.6±6.77 Mgha$^{-1}$ to 246.2±4.53 Mgha$^{-1}$ in temperate forest of Northern Kashmir Himalaya (Fig. 4). $CO_2$ mitigation density values of (70.16-210.72 Mgha$^{-1}$) in temperate coniferous forest soils in southern region of Kashmir Himalaya by Wani *et al.*, [15] shows harmony with $CO_2$ mitigation density results of present study.

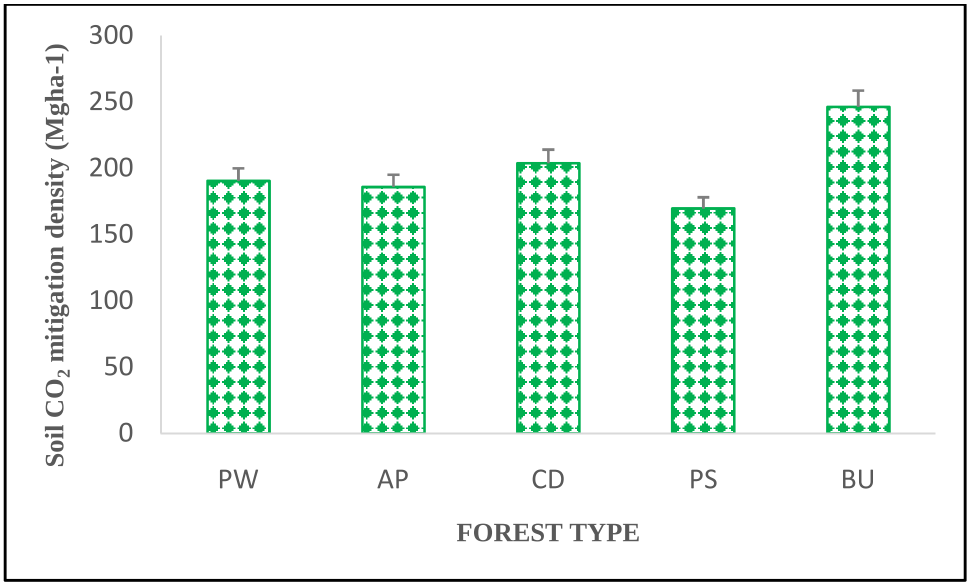


**Fig. 4.** Soil $CO_2$ mitigation density ($Mgha^{-1}$) at different depths in five forest types of Northern Kashmir Himalayas.

## IV. CONCLUSION

Soil organic carbon stock were different for different forest types and SOC density decreased with increase in depth of soil. Present results reveal that BU forest type soil of Northern Kashmir Himalaya has high C sequestration potential. Forest type quality is indicated by the variation in SOC density. Higher carbon storage in soil of BU forest emphasizes the significance of maintaining or managing these type of forests for reducing atmospheric $CO_2$ as such areas act as major sinks.

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