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Content, Density, Illuviation Mode and Depth of $CaCO_3$ in Soils of Semiarid-Arid Qilian Mountains—An Altitude Sequence Study of the Hulugou Watershed

Ka Lin[1,2], Decheng Li[1*], Ganlin Zhang[1], Yuguo Zhao[1], Jinling Yang[1], Feng Liu[1], Xiaodong Song[1]

[1]State Key Laboratory of Soil and Sustainable Agriculture, Institute of Soil Science, Chinese Academy of Sciences, Nanjing, China
[2]University of the Chinese Academy of Sciences, Beijing, China

Email: klin@issas.ac.cn, *dcli@issas.ac.cn

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Abstract

The parental material of soils in the Qilian Mountains of northwest China is mainly aeolian loess containing $CaCO_3$ which may remain in soils under the semiarid-arid climate. To disclose the $CaCO_3$ characteristics change with the altitude and the terrain attributes, we surveyed 18 soil profiles in an altitude sequence from 3076 m to 4510 m in the Hulugou Watershed in the Qilian Mountains, measured $CaCO_3$ contents of all genetic horizon samples, analyzed the densities, illuviation modes and depths of $CaCO_3$ in the profiles, extracted values of the terrain attributes of the profiles including altitude slope, aspect, plane curvature, profile curvature and terrain wetness index (TWI) from the 90 m resolution SRTM3 DEM data on ArcGIS 9.3 platform. We found that $CaCO_3$ weighted content of the profiles ranged from 1.30 $g \cdot kg^{-1}$ to 93.09 $g \cdot kg^{-1}$, $CaCO_3$ density from 0.05 kg/m^2 to 75.69 kg/m^2, $CaCO_3$ illuviation depth from 12 cm to 54 cm. $CaCO_3$ illuviation modes could be divided into three types, *i.e.*, no illuviation mode in which the profile has only A horizon or $CaCO_3$ content < 5 $g \cdot kg^{-1}$, middle illuviation mode in which $CaCO_3$ accumulated in a middle horizon, and down illuviation mode in which $CaCO_3$ content increases with the depth. $CaCO_3$ weighted content, density and illuviation depth had significant correlation with certain terrain attributes. In general, the altitude sequence is an effective way to study $CaCO_3$ characteristics in the alpine region, and the data of terrain attributes which can influence the precipitation and its redistribution in soil are potential in predicting soil $CaCO_3$ characteristics in the alpine region.

Keywords

$CaCO_3$, Altitude Sequence, Terrain Attributes, The Hulugou Watershed, The

Qilian Mountains

1. Introduction

The Qilian Mountains is located in the northeast fringe of Tibetan Plateau of northwest China. It is the important source of water for the famous Hexi Green Corridor, one of the most important agricultural regions in northwest China. The Qilian Mountains belong to the semiarid-arid region with the annual mean precipitation less than 400 mm and evaporation higher than 800 mm, the parental materials of soils usually contain aeolian loess with high $CaCO_3$ content [1] which may be not leached out completely from soils under the semiarid-arid climate. $CaCO_3$ quantity and illuviation in soil are generally dominated by precipitation [2]-[8] and are also influenced by other factors, such as topography, land use type, soil organisms and microbes [9] [10] [11] [12] [13]. Thus, understanding $CaCO_3$ can disclose the characteristics of regional climate, landscapes, soil genesis and evolution as well as soil other properties [6] [14]-[23].

The altitude sequence is often used in soil studies in the hilly and mountainous regions [24] [25] [26], and is potential to study soil $CaCO_3$ characteristics in the Qilian Mountains whose elevation spans from 2800 m to 5808 m and shows obvious vertical differences in climatic condition and landscape [27] [28]. So far, a lot of soil information in altitude sequence is available in the Qilian Mountains, for example, soil organic matter, total nitrogen, water retention and microbe [1] [29] [30] [31] [32], but little reference is found on soil $CaCO_3$ there. Therefore, this paper mainly aims at: 1) select a typical watershed in the Qilian Mountains; 2) survey and sample typical soil profiles in an altitude sequence; 3) disclose $CaCO_3$ content, density, illuviation mode and depth of $CaCO_3$, and their relation with the terrain attributes.

2. Methods and Materials

2.1. Study Area

The Hulugou Watershed (38˚12'N - 38˚17'N, 99˚50'E - 99˚54'E) is regarded as the most typical watershed in the arid and semi-arid Qilian Mountains [33] [34], it is located at the Qilian Alpine Ecology and Hydrology Research Station of the Cold and Arid Regions Environmental and Engineering Research Institute (CAS), occupies 23.1 km^2 in area, spans from 2960 m to 4820 m in altitude, and belongs to alpine periglacial landform influenced by the continental alpine climate with the annual temperature from −18.4˚C to 19.0˚C with a mean of 0.2˚C and annual precipitation from 300 mm to 400 mm. The aeolian silty loess is the dominant parental materials of soils, mixed with various glacial debris. Vegetation is mainly alpine shrubs and grasses. The dominant herb species of the profiles are *Carex melantha*, *Kobresia capillifolia* and *Polygonum viviparum*. Soils are relative young and mostly poorly developed, Entisols, Inceptisols and Mollisols are the dominant soil orders [35], Gelisols only appear above 3600 m and

Histosols are sporadically distributed in depressions [1].

2.2. Typical Profile, Survey and Sampling, Analytical Methods

The watershed DEM map (**Figure 1**) was formed by using the 90 m resolution SRTM3 DEM data, assisted with the information of the parental material, vegetation, terrain and foot accessibility. Eighteen typical profiles of alpine grassland with the same parental material were selected in an altitude sequence (red points in **Figure 1**).

Sampling was conducted from June to July in 2013. The longitude and latitude of each profile was obtained by portable GPS (Mode: Garmin GPS map 629sc). Each profile was dug to the appearance of parental rocks. Profile thickness and gravel (>2 mm in diameter) volumetric percentage (%) were estimated visually in the field. Soil samples of all genetic horizons were collected and ground to pass 0.149 mm diameter sieve for measuring $CaCO_3$ content by the calcimeter method. The cutting ring samples of 17 horizons with no or little gravels or grass roots were collected to measure bulk density by the oven drying method [36], bulk densities of other 37 horizons without cutting ring due to dense gravels or roots were inferred from the correlation between bulk density (y) and organic matter content (x) of 50 genetic horizon samples sampled within and near the watershed ($y = 1.4503e^{-0.01x}$, $R^2 = 0.847$, $p < 0.01$, $n = 50$).

The weighted mean content of $CaCO_3$ (X) of each profile was calculated as:

$$X = \sum \frac{Hi \times Xi}{H} \tag{1}$$

where Hi is the thickness of i horizon, Xi is the measured $CaCO_3$ content ($g \cdot kg^{-1}$)

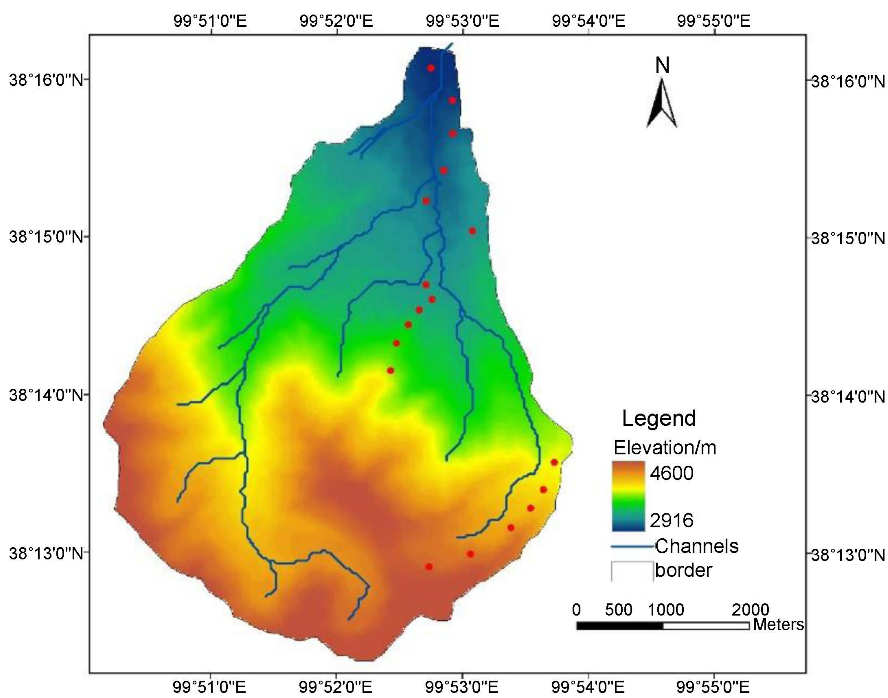

Figure 1. DEM and typical profile sites of the Hulugou Watershed in the Qilian Mountains.

of i horizon, H is the profile thickness.

$CaCO_3$ density ($CaCO_{3D}$) of each profile was calculated as:

$$CaCO_{3D} = \sum_{i=1}^{k} \left[\frac{Xi \times Bi \times Hi \times (1 - Gi)}{100} \right] \tag{2}$$

where Bi is the bulk density of i horizon, Gi is the volumetric percentage of gravels (>2 mm in diameter), k is the horizon number of a profile.

2.3. Data of Terrain Attributes

According to the information the longitude and latitude of each profile, the values of the terrain attributes including the altitude, slope, aspect, plane curvature, profile curvature and terrain wetness index (TWI) were obtained from the 90 m resolution SRTM3 DEM data on ArcGIS 9.3 platform (Table 1).

2.4. Statistical Analysis

IBM SPSS Statistics 20 was used to test for curve estimation. Origin Lab 8.0 was used to depicted the illuviation mode of $CaCO_3$.

3. Results and Discussion

3.1. Terrain Attributes

Results of Curve Estimation between terrain attributes showed that a significant quadratic correlation existed between slope (y), TWI and altitude (x)

Table 1. Information of terrain attributes of the profiles in the Hulugou Watershed.

Profile	Altitude (m)	Gradient (˚)	Aspect (˚)	Plane curvature	Profile curvature	TWI
P1	4510	18	64	−0.1785	−0.0427	4.7581
P2	4424	15	105	0.0446	−0.0295	5.4725
P3	4310	17	89	−0.1101	−0.0114	5.4775
P4	4257	15	69	0.1314	−0.0044	5.6348
P5	4129	20	44	−0.2736	0.1214	5.4450
P6	4064	20	14	−0.0445	0.0913	5.2302
P7	3699	30	47	0.3084	0.0738	3.5356
P8	3510	31	13	0.1754	−0.0715	3.8893
P9	3364	18	17	−0.0613	0.2226	4.2333
P10	3359	18	13	0.0214	0.0707	4.3501
P11	3352	17	6	−0.0983	0.1733	4.3935
P12	3345	11	31	−0.0553	0.0558	4.4346
P13	3260	17	304	0.0225	0.1830	5.1328
P14	3187	9	15	0.0406	0.0036	6.3796
P15	3152	8	315	−0.071	0.0031	6.5090
P16	3076	17	6	0.3555	−0.0272	4.4001
P17	3064	16	327	0.1247	0.0383	5.7977
P18	3008	8	53	−0.0452	−0.0328	6.8721

($y_1 = -289.130 + 0.163x - 2.134 \times 10^5 x^2$, $R^2 = 0.429$, $p < 0.05$; $y_1 = 852.903 - 0.476x + 6.821 \times 10^{-5} x^2$, $R^2 = 0.564$, $p < 0.01$; $\mathrm{TWI} = 49.422 - 0.024x + 3.176 \times 10^{-6} x^2$, $R^2 = 0.355$, $p < 0.05$), significant exponential correlation between slope and TWI ($y = 81.588e^{-0.320\mathrm{TWI}}$, $R^2 = 0.623$, $p < 0.01$). The above results indicated the complex and irregular spatial distribution pattern of terrain attributes in the Hulugou Watershed.

3.2. Profile Thickness (PT), Grave Volumetric Percentage GV(%) and Bulk Density (BD)

PT, GV(%) and BD are the three parameters in calculating $CaCO_3$ density. Table 2 showed the statistical information of the three parameters of the 18 profiles. PT ranged from 10 cm to 135 cm with a mean of 62 cm, GV(%) ranged from 5% to 95% with a mean of 40%, and BD ranged from 0.30 g/cm^3 to 1.73 g/cm^3 with a mean of 1.02 g/cm^3.

Results of Curve Estimation between PT, GV(%), BD and terrain attributes were presented in Table 3, which indicated that altitude, gradient and aspect can be used to predict the PT, GV(%) and BD, while altitude had a higher prediction efficiency in comparison with gradient and aspect. The significant correlation with altitude can mainly be due to the geological erosion process caused by water, gravity and wind. All the 18 profiles actually are located on the hillsides with

Table 2. Statistic information of PT, GV(%) and BD of the profiles in the Hulugou Watershed.

Profile	Horizon number	Profile thickness (cm)	Gravel percentage (V%)		Bulk density (g/cm^3)	
			Range	Weighted mean	Range	Weighted mean
P1	1	10	95	95	1.43	1.43
P2	1	15	95	95	1.40	1.40
P3	1	15	95	95	1.40	1.40
P4	1	18	95	95	1.42	1.42
P5	1	19	95	95	1.40	1.40
P6	1	20	95	95	1.41	1.41
P7	1	20	90	90	1.13	1.13
P8	3	40	15 - 90	56	0.39 - 1.37	1.02
P9	6	120	35 - 65	54	0.69 - 1.37	1.21
P10	3	60	10 - 85	52	0.30 - 1.18	0.89
P11	3	40	10 - 95	70	0.73 - 1.07	0.80
P12	6	120	5 - 85	77	0.30 - 1.18	0.94
P13	4	100	5 - 55	7	0.83 - 1.38	0.95
P14	4	110	5 - 10	20	0.59 - 1.16	1.00
P15	4	60	5 - 40	47	0.45 - 1.34	1.04
P16	4	110	5 - 90	21	0.55 - 1.29	1.13
P17	6	135	5 - 15	10	0.65 - 1.73	1.22
P18	4	130	5 - 80	40	0.74 - 1.36	1.12

slope ranged from 8˚ to 31˚ (Table 1), thus, erosion is inevitable even with dense grass coverage, besides, comparatively soil particles are easier to be eroded and move fast from the high place to low place than the gravels.

3.3. Illuviation Mode and Depth of $CaCO_3$ in Profiles

The illuviation depth of $CaCO_3$ in the profiles were ranged from 12 cm to 54 cm in the profiles (20 cm, 12 cm, 15 cm, 38 cm, 40 cm, 28 cm, 54 cm and 35 cm for P8, P9, P11, P13, P15, P16, P17 and P18, respectively, Figure 2(a) and Figure 2(b)). These 18 profiles can be categorized into three kinds of illuviation modes of $CaCO_3$ according to $CaCO_3$ contents of different horizons (Figure 2): 1) No illuviation mode, for examples of the profiles above 3600 m in altitude only had one horizon (P1 to P7) or profiles where $CaCO_3$ leached out intensively from the soil (<lower than 5 $g \cdot kg^{-1}$ in $CaCO_3$ content, P10, P12 and P14); 2) Middle illuviation (Figure 2(a)), $CaCO_3$ leached down but accumulated in a certain middle horizon, which were 12 cm - 31 cm, 38 cm - 74 cm and 54 cm - 76 cm in P9, P13 and P17, respectively. $CaCO_3$ content in the accumulated horizon were about 7.0, 1.9 and 2.9 times as much as the mean contents of up and down horizons for P9, P13 and P17, respectively); 3) Down illuviation mode (Figure 2(b)), $CaCO_3$

Table 3. Correlation between PT, GV(%), BD and terrain attributes in profiles of the Hulugou Watershed.

Curve model	Variable	R^2	p
$PT = e^{(2.522+22448.423/x)}$	x: altitude	0.875	<0.01
$PT = 231.358 - 60.724\ln(x)$	x: gradient	0.235	<0.05
$PT = 87.925e^{-0.017x}$	x: aspect	0.284	<0.05
$GV(\%) = -294.188 + 0.415x - 4.828\times10^{-5}x^2$	x: altitude,	0.788	<0.01
$GV(\%) = 45.476 + 0.799x - 0.03x^2$	x: aspect	0.558	<0.05
$BD = 4.748 - 0.02x + 3.421\times10^{-7}x^2$	x: altitude	0.686	<0.01
$BD = 1.031 + 8.110\times10^{-5}x^2 - 4.707\times10^{-7}x^3$	x: aspect	0.342	<0.05

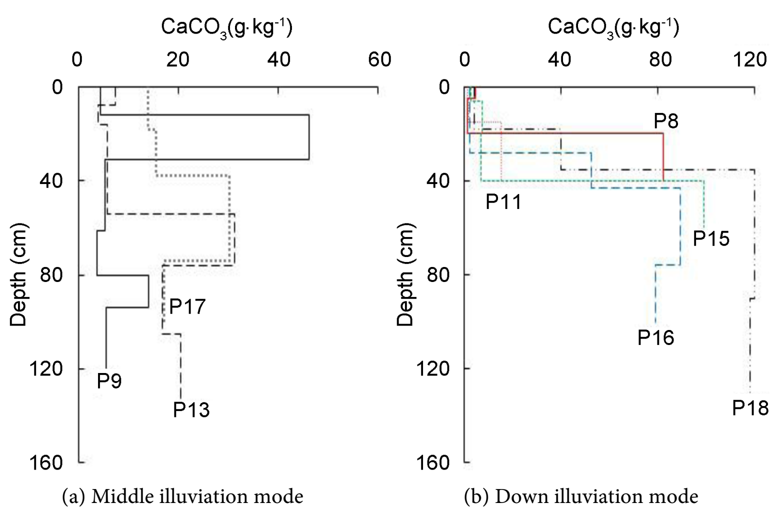

Figure 2. Illuviation mode of $CaCO_3$ in the profiles in the Hulugou Watershed.

content increased with the increase of profile depth (P8, P11, P15, P16 and P18), the initial depth of illuviation was 20 cm, 15 cm, 40 cm, 28 cm and 18 cm for P8, P11, P15, P16 and P18, respectively, $CaCO_3$ content was about 9 - 29.5 times as much as the up horizons.

For the three kinds of illuviation modes of $CaCO_3$, the results of one-way ANOVA LSD tests (Table 4) showed that a significant difference existed only in profile curvature between no illuviation mode and down illuviation mode of $CaCO_3$ ($p < 0.05$), which indicated that it was difficult to predict the illuviation mode of $CaCO_3$ by terrain attributes in the Hulugou Watershed.

Results of Curve Estimation between the illuviation depth and terrain attributes were presented in Table 5, which indicated that altitude and TWI can be used to predicate the illuviation depth of $CaCO_3$ in the profiles in this area, while TWI is better than altitude and aspect in the accuracy of prediction.

$CaCO_3$ illuviation depth significantly correlated with altitude and TWI, which can be attributed to the significant correlation between altitude with precipitation and TWI. Three models are available to contact $CaCO_3$ illuviation depth (D, cm) with precipitation (P, mm), *i.e.*, Retallack model [5]: $p = 137.240 + 6.450D + 0.013D^2$ ($R = 0.52$, $n = 807$), Zhao model [4]: $p = 3.057D + 168.5$ ($R = 0.96$, $n = 15$), and Pan and Huang model [8]: $p = 68.4990 + 12.063D - 0.0693D^2$ ($R = 0.725$, $n = 48$). Because no measured precipitation data is available for the 18 profiles, we used the rough information of the lowest and highest precipitation (300 mm and 400 mm) in the Hulugou Watershed to calculate the theoretical $CaCO_3$ illuviation depth, which was 24 cm - 37 cm, 43 cm - 76 cm, and 22 cm - 34 cm for Retallack model, Zhao model and Pan and Huang model, respectively. Compared with real 12 cm - 54 cm of $CaCO_3$ illuviation depth of the our profiles, the Retallack model and Pan and Huang model can be regarded more feasible than the Zhao Model which overestimated $CaCO_3$ illuviation depth. We

Table 4. Differences in terrain attributes between different illuviation modes.

$CaCO_3$ illuviation mode		Altitude (m)	Gradient (˚)	Aspect (˚)	Plane curvature	Profile curvature	TWI
No illuviation.	Mean	3324A	17A	17A	−0.0181A	−0.0181A	0.1423A
	Std.	45	0	139	0.0567	0.0508	0.3592
Middle illuviation.	Mean	3168A	17A	117A	0.1396A	0.0779AB	4.8104A
	Std.	139	1	149	0.1705	0.1058	0.7015
Down illuviation.	Mean	3240A	13A	85A	0.0089A	−0.0084B	5.6169A
	Std.	172	9	116	0.0918	0.0424	1.2112

*No illuviation: P10, P12 and P14; Middle illuviation: P9, P13 and P17; Down illuviation: P8, P11, P15, P16 and P18; Std.: standard deviation, A, AB and B stands for different significance.

Table 5. Correlation between illuviation depth of $CaCO_3$ with terrain attributes of the Hulugou Watershed.

Curve model	Variable	R^2	p
$y = 3.680\times10^{25} x_1^{-6.880}$	y: $CaCO_3$ illuviation depth, x: altitude	0.514	<0.05
$y = -178.383 + 56.479\text{TWI} - 0.534\text{TWI}^3$		0.746	<0.05

attributed it to the least or insufficient number of soil profiles used in Zhao model.

Zhao [4] pointed out when two, three layers or unusually thick $CaCO_3$ illuvial horizon exists under the same paleosol or weathering profile, it indicates that there are two or more soil-forming periods and corresponding climate change at that time, but so far, there is no information or model of terrain attributes available on the $CaCO_3$ illuviation mode in soil profile. Our study also found it is hard to indicate $CaCO_3$ illuviation mode by the terrain attributes in the irregular and complex alpine region.

3.4. Weighted Content and Density of $CaCO_3$

For 18 profiles, $CaCO_3$ mainly exists in the form of mottles and powders in the profiles. No pseudomycelium or concretion was found, which means it is hard for $CaCO_3$ to crystallize under the semiarid-arid climate of the Qilian Mountains. Table 6 showed that $CaCO_3$ weighted content of the profiles ranged from 1.30 $g \cdot kg^{-1}$ to 93.09 $g \cdot kg^{-1}$ with mean of 23.53 $g \cdot kg^{-1}$ and standard deviation of 24.19 $g \cdot kg^{-1}$, while $CaCO_3$ density ranged from 0.05 kg/m^2 to 75.69 kg/m^2 with a mean of 9.79 kg/m^2 and standard deviation of 18.05 kg/m^2. Results of Curve Estimation between the weighted content and density of $CaCO_3$ with terrain attributes were presented in Table 7, which revealed that slope, plane curvature, profile curvature and TWI can be used to predicate weighted content of $CaCO_3$ in these profiles. Besides, altitude, aspect, gradient and TWI can be used to predicate the

Table 6. $CaCO_3$ weighted content and density of profiles in the Hulugou Watershed.

Profile	Horizon number	Weight content of $CaCO_3$ ($g \cdot kg^{-1}$)	Density of $CaCO_3$ (kg/m^2)
P1	1	6.97	0.05
P2	1	4.51	0.05
P3	1	13.53	0.14
P4	1	31.57	0.4
P5	1	10.25	0.27
P6	1	54.94	1.55
P7	1	2.05	0.05
P8	3	42.25	2.44
P9	6	12.54	7.72
P10	3	4.03	1.83
P11	3	4.28	0.49
P12	6	10.54	0.31
P13	4	1.30	1.28
P14	4	37.5	18.02
P15	4	57.06	22.31
P16	4	21.00	19.09
P17	6	16.16	24.49
P18	4	93.09	75.69

Table 7. Correlation between $CaCO_3$ weighted content, density and terrain attributes in the Hulugou watershed.

Parameter	Curve model	Variable	R^2	p
$CaCO_3$ weighted content (y_1)	$y_1 = 360.169 - 57.602x + 3.007x^2 - 0.048x^3$	x: slope	0.563	<0.01
	$y_1 = e^{(2.647 - 0.030/x)}$	x: plane curvature	0.235	<0.05
	$y_1 = 17.898 \times 0.001^x$	x: profile curvature	0.236	<0.05
	$y_1 = 93.871 - 11.454\ \mathrm{TWI}^2 + 1.630\mathrm{TWI}^3$		0.631	<0.01
$CaCO_3$ density (y_2)	$y_2 = e^{(-14.119 + 51216.690/x)}$	x: altitude	0.686	<0.01
	$y_2 = -21.160 + 458.338/x$	x: gradient	0.460	<0.01
	$y_2 = e^{-0.042x}$	x: aspect	0.265	<0.05
	$y^2 = 79.049 - 10.494\mathrm{TWI}^2 + 1.460\mathrm{TWI}^3$		0.734	<0.01

$CaCO_3$ density. Obviously, TWI had the highest prediction efficiency in comparison with other terrain attributes.

$CaCO_3$ weighted content had significant negative correlation with profile curvature, it is because the higher of profile curvature, the higher of the change rate of gradient, which may cause more $CaCO_3$ to be moved away from soil through water.

$CaCO_3$ density had significant negative correlation with gradient, usually the increase of gradient accelerates the movement of moisture, which promotes the eluviation of $CaCO_3$. In general, precipitation is higher in the shady slope than the sunny slope, so $CaCO_3$ density in shady slope should be lower than that of sunny slope. But our study showed a negative correlation between $CaCO_3$ and aspect, which means that the shady slope contains higher $CaCO_3$ than the sunny slope. To some extent it can be attributed to the significant negative correlation between the profile thickness and aspect. Significant nonlinear correlation existed between $CaCO_3$ density and altitude, which is not only attributed to PT, GV(%) and BD, but also to the changes of precipitation and TWI with altitude.

Liu *et al.* [37] showed that $CaCO_3$ density of 1 m depth profile ranged from 1.0 kg/m^2 to 137.6 kg/m^2 in the alpine grassland of Qinghai Province (the same province as the Hulugou Watershed). Zhang [10] showed $CaCO_3$ density in 1 m depth profiles in the Loess Plateau ranged from 8.3 kg/m^2 to 291.7 kg/m^2. $CaCO_3$ density in our profiles ranged from 0.05 kg/m^2 to 75.69 kg/m^2, which can be regarded within the above ranges.

$CaCO_3$ illuviation depth is related to altitude and TWI. $CaCO_3$ weighted content is related to slope, plane curvature, profile curvature and TWI, $CaCO_3$ density related to altitude, gradient, aspect and TWI, which indicated the data of the terrain attributes are feasible in predicting $CaCO_3$ content and density in the alpine region. But almost all these correlations are nonlinear and some even with low value of R^2. This can be attributed to the irregular and complex spatial distribution of terrain attributes. In general, the factors influencing $CaCO_3$ behaviors in soil is complex, beside precipitation, other factors include topography, parental materials, etc. [8] [38] [39] [40]. Usually precipitation increases with altitude increases, but Niu *et al*. [41] found that in the north slope of the Qilian Mountains (similar as the Hulugou watershed), the average annual rainfall increases about 17.41 mm from 1700 m to 3300 m in altitude; while decreases about 30.21 mm when the altitude increases 100 m from 3300 m to 3800 mm. It is due to the increase of the wind speed and the decrease of the temperature which cause the rainfall mainly in solid phase, thus, the precipitation actually reduces. Thus using only precipitation it is difficult to predict $CaCO_3$ characteristics in the alpine region because of the irregular and complex spatial distribution of terrain attributes.

Moreover, the $CaCO_3$ data of each profile in our study only represent a pedon in 90 m × 90 m pixel of SRTM3 DEM. Actually a 90 m × 90 m pixel usually contains many pedons with different terrain units, the extracted value of a terrain factor used for a profile actually is the mean value of the different pedons in the pixel, this is not the strict one-to-one correspondence and will weaken the accuracy of the study consequences, so DEM data with higher resolution should be found and used in further study.

4. Conclusion

The large span of altitude and loess parental material of soils in the arid and semiarid-arid Qilian Mountain enable altitude sequence to be a potential way in studying $CaCO_3$ characteristics. Our study of 18 typical profiles in an altitude sequence in the Hulugou Watershed showed that $CaCO_3$ weighted content, density and illuviation depth had significant nonlinear correlations with the some terrain attributes, which on one hand indicated that the data of terrain attributes extracted from DEM are a potential to be used in predicating $CaCO_3$ characteristics in the alpine region because the terrain factor influences precipitation and its redistribution in soil, but on the other hand it meant that for the irregular and complex alpine region, further attention should focus on how to set up models based on precipitation combined with terrain attributes in order to predicate $CaCO_3$ characteristics with high accuracy.

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