The equations for the different SWRC models are listed as follows:

The Van Genuchten equation is calculated as equation (1):

$$\theta(h) = \theta_r + (\theta_s - \theta_r)[1 + (\alpha h)^n]^{\left(\frac{1}{n}-1\right)} \quad (1)$$

The Brook-Corey model is calculated using equation (2):

$$\theta(h) = \theta_r + (\theta_s - \theta_r)\left(\frac{h_d}{h}\right)^{\lambda} \quad (2)$$

The Kosugi model is calculated using equation (3):

$$\theta(h) = \theta_r + \frac{1}{2}(\theta_s - \theta_r) erfc\left[\frac{\ln(h/h_m)}{\sigma\sqrt{2}}\right] \quad (3)$$

The Clapp and Hornberger model is calculated using equation (4)：

$$h = h_S(\theta/\theta_S)^{-1/\lambda} \quad (4)$$

The Gardner model is calculated using equation (5):

$$\theta(h) = \mathrm{a}h^{-b} \quad (5)$$

Where, the $\theta(h)$ and h represent the experimental soil water content and specific matrix potential data obtained for each undisturbed soil sample, and the other parameters are obtained through fitting the experimental SWRC data using different SWRC models.

θ_s and θ_r represent the saturated soil water content and the residual soil water content, respectively. α (cm^{-1}) and n (dimensionless) in the Van Genuchten model are fitting parameters related to the air entry pressure and pore size distribution of the soil, respectively. h_d (cm) and λ (dimensionless) of the Brook-Corey model represent the air entry pressure and pore-size distribution index, respectively. h_m (cm) and σ (dimensionless) of Kosugi model are parameters related to the median pore radius and the width of the pore radius distribution, respectively. *erfc* in the Kosugi model is a complementary error function. h_s and λ in the Clapp and Hornberger model are the saturated capillary potential (cm) and pore-size distribution index (dimensionless), respectively. *a* and *b* in the Gardner model are two fitting parameters.

Figure S1. Photos to show the harsh natural environment and challenges of fieldwork in the Qilian Mountains. (a), (b) The road near the river was destroyed by rush of water. (c) The road was dangerous because of snow cover during fieldwork in October. (d) The road to access the field sites is steep and mountainous. (e)-(g) Some of the road was threatened by both rockfall from above, and the steep cliff on the other side.

Figure S2. Photos to show the position and surrounding environment of D1 to D16

Figure S3. Photos to show the position and surrounding environment of D17 to D32

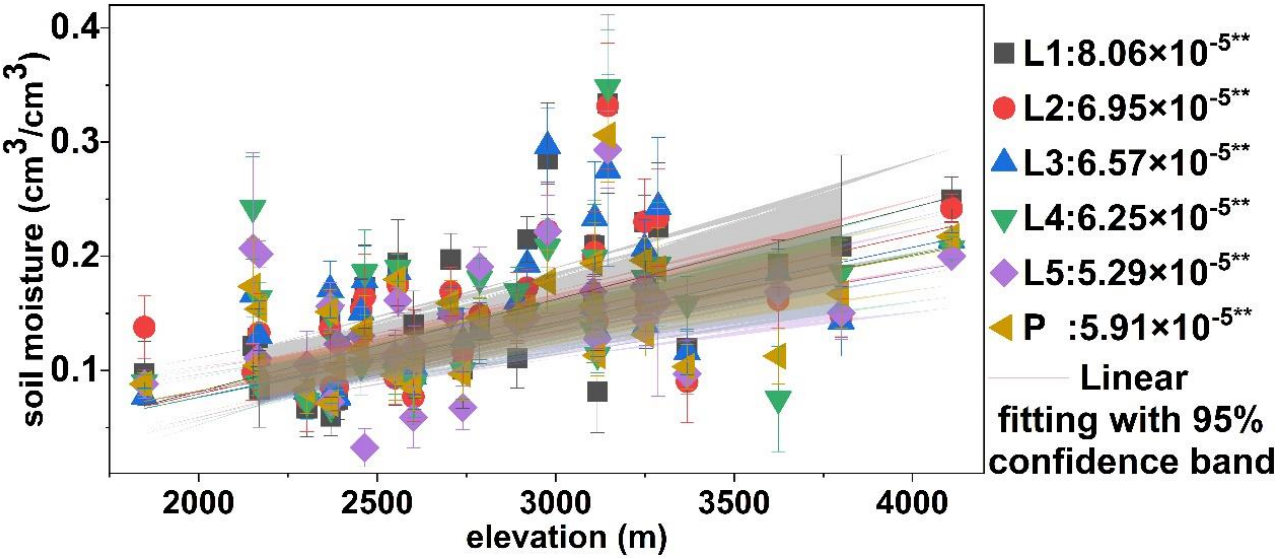

Figure S4. The variability of soil moisture with elevation for different soil depths based on the observed temporal mean value (and standard deviation) at each station and the station elevation, including the linear fitting result with the 95% confidence band. L1 represents soil moisture for layer 1, ** indicates where the slope of the linear regression is significant at the 0.01 level.

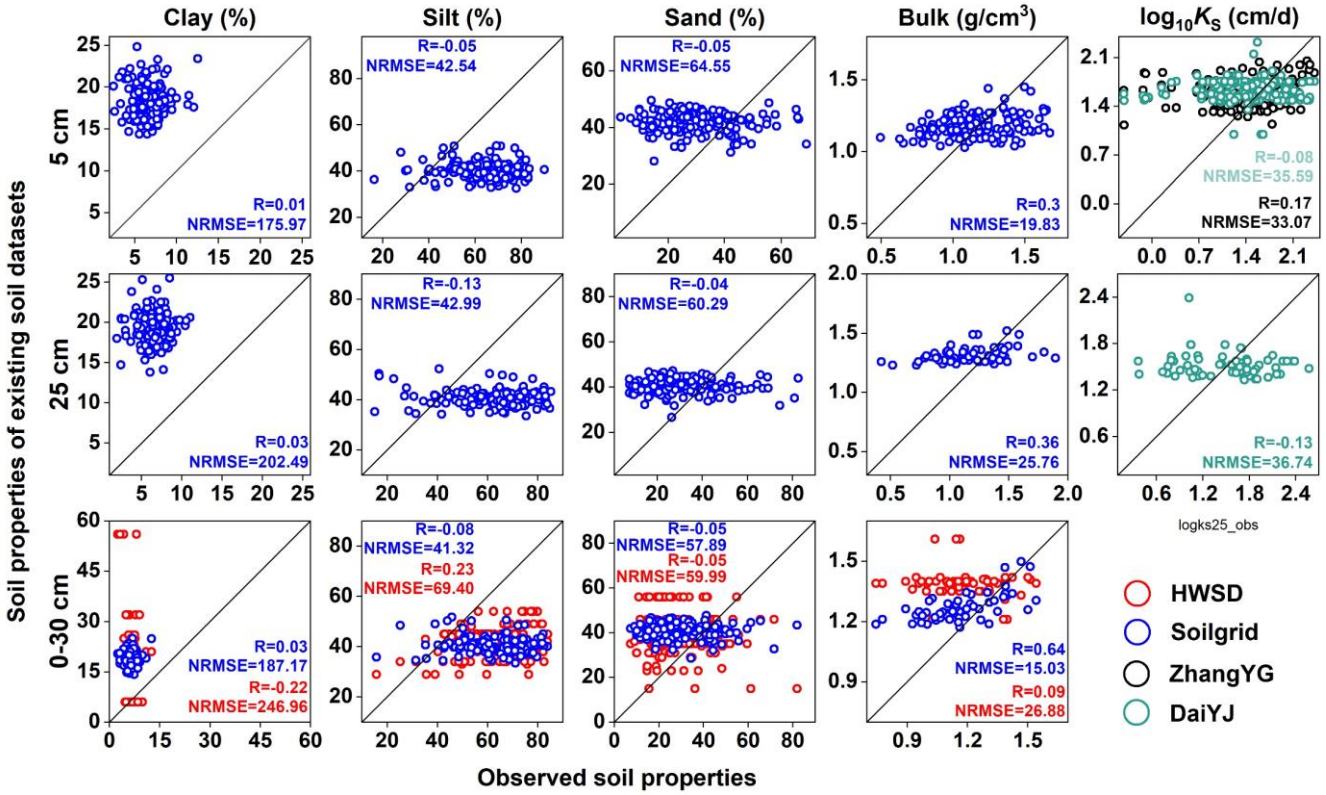

Figure S5. Scatterplots compare the observed soil properties with soil properties from different soil datasets.