Data Article

Soil profile photograph dataset from central Mexico to delineate horizons and quantify coarse fragments

Ángeles Gallegos, Francisco Bautista*

Centro de Investigaciones en Geografía Ambiental, Universidad Nacional Autónoma de México, Antigua Carretera a Pátzcuaro No. 8701, Col. Ex-Hacienda de San José de la Huerta, C.P., Morelia, Michoacán 58190, México

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ABSTRACT

This database consists of a digital photograph set of soil profiles from the physiographic provinces of the Trans-Mexican Neovolcanic Axis and Sierra Madre del Sur of central Mexico. Although the official and government databases of soil profiles from Mexico do not contain the percentage of coarse fragments (stoniness), they contain soil profile photographs from which the percentage of coarse fragments can be extracted. The dataset has two data source types: (a) Soil profile photographs taken in the field and (b) soil profile photographs from the official database of the government of Mexico. The images were analyzed using the Gallegos-Bautista (GB) method. In the GB method, the horizon delineation of the soil profiles includes preprocessing the profile image with k-means segmentation; conversion of the preprocessed image to CIE L*a*b* (lightness, red/green value, blue/yellow value) and HSV (hue, saturation, value) color systems; k-means segmentation of HSV and CIE L*a*b* images, delineation of horizons, and clarity and topography determinations of the outlined horizons. The soil groups studied correspond to the Andosol, Cambisol, Luvisol, Alisol, Kashtanozem, Phaeozem, Umbrisol, and Solonchak groups, some of which had contrasting color horizons, allowing us to iden-
Specifications Table

| Subject | Agricultural Sciences |
|---------|-----------------------|
| Specific subject area | Soil Science, Digital soil morphometrics |
| Type of data | Table, Images, and Figures |
| How data were acquired | Photographs of two data sources are presented: (a) Soil profile photographs taken in the field and (b) soil profile photographs from the official database of the government of Mexico [1]. The soil profile photographs taken in the field were captured using a Canon Powershot Sx530 camera with the auto mode activated. The photographs’ target area was delimited with Adobe Photoshop CS6 software. |
| Data format | Raw and analyzed |
| Parameters for data collection | Image selection was carried based on the soil profile locations. The available images of the soils were taken in two large areas of central Mexico, the Trans-Mexican Neovolcanic Axis and Sierra Madre del Sur. |
| Description of data collection | The soil profile photographs taken in the field were captured by reducing their surface roughness with a brush and attempting to capture them in direct sunlight to obtain good lighting. The camera was positioned perpendicularly to the face of the soil profile, focusing on the entire depth of the pit. The images of the soil profiles have a resolution of 2351 × 2752 pixels. The images of the soil profiles were analyzed with a horizon delimitation method and quantification of coarse fragments (GR method). |
| Data source location | The origin institutions of the soil profiles photograph data set are the Center for Environmental Geography Research (CIGA) of the National Autonomous University of Mexico located in Michoacan, Mexico, and the National Institute of Statistics and Geography (INEGI) located in Aguascalientes, Mexico. Table 1 shows the soil photographic sampling locations and their origin institution. |
| Data accessibility | The soil profile photo dataset can be downloaded from the Mendeley Data repository at: http://dx.doi.org/10.17632/v9krcvzv27.1 |
| Related research article | A. Gallegos, F. García-Oliva, A. Pereira Corona, F. Bautista, Digital soil morphometrics of coarse fragments and horizon delineation in contrasting soil profiles from Central México, Geoderma Regional, 26 (2021), e00403. https://doi.org/10.1016/j.geodrs.2021.e00403 |

Value of the Data

- Due to their high quality, the photographs of the soil profiles are a scientific database with various pedological features.
- Soil profile photographs could be used to assess soil quality, e.g., compaction, topsoil thickness, estimate organic matter, quantify root abundance and size, internal drainage, structure, among other things.
- The database can be used by researchers and students interested in both soil genesis and soil degradation processes.
- The database could also be used by farmers and government staff working on sustainable soil management.
Table 1
Soil profiles locations of the photograph dataset.

| ID  | Reference soil group | X        | Y        | UTM zone | Institution |
|-----|----------------------|----------|----------|----------|-------------|
| Andosol | Alisol              | 237127.81 | 2174538.75 | 14N       | CIGA        |
| Cambisol | Alisol              | 266364.63 | 2190845.40 | 14N       | CIGA        |

1. Data Description

Photographs of the soil profiles are of utmost importance for the extraction of profile data, such as the horizon delimitation and the quantification of the coarse fragments, both of which are necessary to carry out the edafoecological evaluation (quantification of the properties of soil profiles expressed in surface units, usually ha or square meters) before evaluating the environmental functions of soils. The dataset presented was generated to develop and test a method for horizon delineation and coarse soil fragment quantification by image processing of soil profiles (GB method) [2].

The dataset consisted of processed and unprocessed soil profile figures. The processed figures correspond to the soil profiles treated using the GB method. These figures add value to the research article “Digital soil morphometrics of coarse fragments and horizon delineation in soil profiles from Central Mexico” [2]. Unprocessed figures can be useful for other soil studies or for testing new processing methods, such as quantifying root density, types and sizes of galleries, size and quantity of gravels and stones, estimation of organic matter content by color, estimation of the intensity of the reducing conditions by red and black colors, the measurement of the thickness of the compacted horizons, and the identification of main minerals by color, among other pedological features. Figures are in TIFF and JPG formats. Table 2 lists the chemical and physical sol properties also included in the dataset.

Fig. 1 shows the spatial location of the photographic sampling sites. Most of the sites are located north of the state of Michoacan, in the physiographic province of the Trans-Mexican Neovolcanic Axis.

The horizon delineation of the profiles was carried out in the field based on changes in the soil properties along the profile, such as the color, root density, volume of thick fragments, and bulk density. In Fig. 2, the identification of the horizons was carried out based on the color differences found along the soil profile using the GB method. Fig. 2 shows the field delimitation and its comparison with the horizons delineated from the CIE L*a*b* and HSV color systems of 18 soil profile images. Fig. 2 was divided into six parts to achieve better visualization of the information.
Table 2
Soil profiles properties of the photograph dataset.

| ID      | Used in            | Horizon | Depth (cm) | EC(dS m\(^{-1}\)) | pH\(_{\text{H}_{2}O}\) | Ca\(^{2+}\) | Mg\(^{2+}\) | Na\(^{+}\) | K\(^{+}\) | CEC(cmol kg\(^{-1}\)) | OM(%) |
|---------|---------------------|---------|------------|-------------------|-----------------|----------------|---------------|-------------|-------------|------------------------|-------|
| Andosol | Development of the  | Ah      | 0-29       | 0.07              | 6.33            | 1.56           | 28.18         | 0.77         | 2.78         | 40.13                  | 5.97  |
|         | method              | Bw1     | 29-65      | 0.06              | 6.69            | 1.57           | 30.03         | 0.97         | 2.53         | 31.30                  | 2.47  |
|         |                     | Bw2     | 65-104     | 0.03              | 7.25            | 1.56           | 27.14         | 1.09         | 1.89         | 37.82                  | 0.52  |
|         |                     | BC      | 104-163    | 0.03              | 6.85            | 1.65           | 28.53         | 1.97         | 1.89         | 39.74                  | 0.78  |
| Cambisol|                     | A       | 0-9        | 0.19              | 7.41            | 8.89           | 2.79          | 0.39         | 1.98         | 46.50                  | 4.63  |
|         |                     | B1      | 9-15       | 0.13              | 7.58            | 13.65          | 2.99          | 0.43         | 2.62         | 32.70                  | 0.00  |
|         |                     | Bw      | 15-72      | 0.12              | 7.73            | 14.28          | 3.09          | 0.57         | 1.07         | 44.40                  | 0.64  |
|         |                     | B2      | 72-113     | 0.14              | 7.77            | 14.52          | 3.03          | 0.51         | 0.66         | 42.00                  | 0.39  |
| AL1     | Test of the method  | A       | 0-22       | 0.00              | 5.70            | 1.10           | 0.40          | 0.20         | 0.10         | 7.20                   | 1.03  |
|         |                     | Bt1     | 22-43      | 0.00              | 5.70            | 1.30           | 0.90          | 0.10         | 0.20         | 13.50                  | 0.52  |
|         |                     | Bt2     | 43-72      | 0.00              | 5.60            | 1.00           | 0.80          | 0.10         | 0.20         | 23.60                  | 0.34  |
|         |                     | Bt3     | 72-102     | 0.00              | 6.30            | 0.70           | 0.50          | 0.00         | 0.10         | 22.00                  | 0.17  |
| AN1     |                     | Ah      | 0-40       | 0.08              | 6.05            | 1.68           | 18.11         | 0.36         | 0.67         | 27.26                  | 9.61  |
|         |                     | Bw      | 40-79      | 0.03              | 6.84            | 1.40           | 13.90         | 0.34         | 0.91         | 29.95                  | 4.55  |
|         |                     | C       | 79-142     | 0.02              | 6.85            | 1.55           | 18.19         | 0.43         | 0.39         | 34.37                  | 3.51  |
| AN2     |                     | Ah1     | 0-34       | 0.12              | 5.44            | 1.07           | 0.02          | 0.34         | 0.25         | 31.93                  | 3.47  |
|         |                     | Ah2     | 34-44      | 0.09              | 5.32            | 0.05           | 0.01          | 0.34         | 0.13         | 12.77                  | 8.24  |
|         |                     | CBw1    | 44-67      | 0.09              | 5.41            | 0.14           | 0.03          | 0.32         | 0.21         | 17.92                  | 3.22  |
|         |                     | CBw2    | 67-79      | 0.08              | 5.69            | 0.34           | 0.03          | 0.50         | 0.13         | 16.07                  | 0.90  |
|         |                     | C       | 79-86      | 0.08              | 5.88            | 0.19           | 0.02          | 0.32         | 0.21         | 17.51                  | 1.42  |
|         |                     | 2C1     | 86-97      | 0.07              | 5.61            | 0.34           | 0.02          | 0.37         | 0.16         | 11.33                  | 0.90  |
|         |                     | 2C2     | 97-120     | 0.08              | 5.60            | 0.42           | 0.02          | 0.50         | 0.17         | 15.24                  | 0.13  |
|         |                     | 2C3     | 120-143    | 0.09              | 5.53            | 0.27           | 0.01          | 0.44         | 0.16         | 14.21                  | 0.13  |
|         |                     | 3C      | 143-176    | 0.11              | 5.96            | 1.18           | 0.05          | 0.43         | 0.39         | 16.69                  | 0.00  |
|         |                     | 4CA     | 176-218    | 0.10              | 6.05            | 1.46           | 0.05          | 0.48         | 0.38         | 11.12                  | 0.00  |

(continued on next page)
| ID  | Used in | Horizon | Depth (cm) | EC(dS m$^{-1}$) | pH H$_2$O | Ca$^{2+}$ | Mg$^{2+}$ | Na$^+$ | K$^+$ | CEC(cmol kg$^{-1}$) | OM(%) |
|-----|---------|---------|------------|----------------|-----------|----------|----------|-------|-------|---------------------|--------|
| AN3 | A       | 0-20    | 0.25       | 5.64           | 4.03      | 1.93     | 0.34     | 1.05  | 66.00 | 8.24                |
| B1  | 20-51   | 0.13    | 6.66       | 2.34           | 1.09      | 0.28     | 0.91     | 56.40 | 2.45  |
| B2  | 51-87   | 0.09    | 6.84       | 2.35           | 1.46      | 0.30     | 1.05     | 60.00 | 1.29  |
| B3  | 87-129  | 0.10    | 6.86       | 6.21           | 1.55      | 0.48     | 0.82     | 69.30 | 1.42  |
| B4  | 129-162 | 0.11    | 6.99       | 12.99          | 3.15      |          |          |       | 75.30 | 1.80                |
| AN4 | Ap      | 0-14    | 0.13       | 5.42           | 0.50      | 0.00     | 0.27     | 0.30  | 89.40 | 7.85                |
| B1  | 14-56   | 0.11    | 5.91       | 1.32           | 0.04      | 0.23     | 0.07     | 78.60 | 8.24  |
| B2  | 56-106  | 0.13    | 6.21       | 4.43           | 2.33      | 0.30     | 0.04     | 59.40 | 6.43  |
| B3  | 106-169 | 0.08    | 6.94       | 3.39           | 1.99      | 0.62     | 0.49     | 67.80 | 2.06  |
| AN5 | Ah      | 0-12    | 0.09       | 6.74           | 1.70      | 24.03    | 0.36     | 1.09  | 29.18 | 3.12                |
| Bw1 | 12-28   | 0.04    | 6.58       | 1.61           | 27.60    | 0.86     | 1.19     | 48.19 | 2.34  |
| Bw2 | 28-53   | 0.04    | 6.67       | 1.68           | 21.15    | 0.56     | 0.66     | 41.28 | 2.73  |
| Bw3 | 53-78   | 0.04    | 6.62       | 1.67           | 28.43    | 0.86     | 0.94     | 37.82 | 1.30  |
| Bw4 | 78-104  | 0.03    | 6.67       | 1.57           | 28.80    | 0.79     | 0.65     | 49.54 | 0.78  |
| C   | 104-140 | 0.04    | 6.76       | 1.50           | 29.55    | 0.99     | 0.35     | 57.98 | 0.65  |
| CM1 | A       | 0-25    | 0.10       | 7.00           | 7.00      | 2.40     | 0.50     | 0.70  | 15.00 | 2.76                |
| Bw  | 25-50   | 0.00    | 7.00       | 6.00           | 2.20     | 0.20     | 0.10     | 14.00 | 0.86  |
| B1  | 50-75   | 0.00    | 6.70       | 5.00           | 2.10     | 0.20     | 0.10     | 25.00 | 0.52  |
| B2  | 75-100  | 0.00    | 6.60       | 4.00           | 2.00     | 0.20     | 0.10     | 21.00 | 0.17  |
| CM2 | A1      | 0-15    | 0.20       | 6.00           | 11.50    | 5.30     | 0.40     | 0.90  | 27.00 | 1.72                |
| A2  | 15-30   | 0.10    | 6.50       | 11.40          | 5.70     | 0.70     | 0.50     | 36.20 | 0.86  |
| Bw1 | 30-50   | 0.00    | 6.60       | 12.80          | 6.50     | 0.80     | 0.40     | 35.70 | 0.86  |
| Bw2 | 50-75   | 0.00    | 6.90       | 11.90          | 6.80     | 1.20     | 0.20     | 25.60 | 0.52  |
| Bw3 | 75-100  | 0.00    | 7.10       | 11.50          | 7.30     | 1.10     | 0.20     | 26.30 | 0.52  |
| Bw4 | 100-135 | 0.00    | 7.10       | 13.30          | 9.00     | 1.10     | 0.30     | 32.40 | 0.52  |

(continued on next page)
| ID   | Used in | Horizon | Depth (cm) | EC(dS m⁻¹) | pH H₂O | Ca²⁺ | Mg²⁺ | Na⁺  | K⁺  | CEC(cmol kg⁻¹) | OM(%) |
|------|---------|---------|------------|------------|--------|-------|-------|-------|-----|----------------|-------|
| CM3  | Ah      | 0-18    | 0.27       | 5.92       |        | 1.66  | 16.38 | 0.39  | 0.23| 28.80          | 4.16  |
|      | Bw1     | 18-59   | 0.16       | 5.91       | 1.68   | 19.68 | 0.54  | 0.23  | 18.62|                | 2.73  |
|      | Bw2     | 59-89   | 0.10       | 6.21       | 1.61   | 25.04 | 0.79  | 0.10  | 25.92|                | 2.86  |
|      | C       | 89-127  | –          | –          | 1.58   | 25.87 | 1.18  | 0.08  | 33.79|                | 1.82  |
| CM4  | Ah      | 0-18    | 0.17       | 5.85       |        | 6.62  | 2.74  | 0.48  | 0.93| 42.44          | 7.21  |
|      | B       | 18-66   | 0.10       | 6.68       | 5.14   | 2.50  | 0.67  | 1.85  | 66.60|                | 0.13  |
|      | Bx      | 66-107  | 0.09       | 6.73       | 5.46   | 2.70  | 0.76  | 1.98  | 60.30|                | 0.00  |
|      | CBm     | 107-152 | 0.10       | 7.00       | 3.23   | 2.08  | 0.78  | 0.43  | 76.20|                | 0.00  |
| KS1  | A       | 0-30    | 0.30       | 7.10       | 37.00  | 3.00  | 0.10  | 1.30  | 42.40|                | 2.76  |
|      | Bk      | 30-60   | 0.20       | 7.70       | 44.50  | 5.10  | 0.10  | 1.60  | 39.30|                | 0.52  |
|      | Ck1     | 60-90   | 0.10       | 7.70       | 41.70  | 6.60  | 0.10  | 1.80  | 42.50|                | 0.17  |
|      | Ck2     | 90-125  | 0.00       | 7.70       | 32.20  | 8.40  | 0.10  | 1.90  | 43.00|                | 0.17  |
| LV1  | Ah      | 0-15    | 0.03       | 6.48       | 1.64   | 18.53 | 0.49  | 1.08  | 51.65|                | 4.55  |
|      | Bt      | 15-46   | 0.02       | 6.89       | 1.68   | 24.51 | 0.66  | 2.53  | 59.71|                | 0.52  |
|      | B1      | 46-63   | 0.02       | 7.02       | 1.66   | 25.54 | 1.01  | 2.02  | 49.73|                | 0.78  |
|      | B2      | 63-81   | 0.01       | 7.02       | 1.62   | 26.77 | 1.05  | 0.85  | 45.70|                | 1.30  |
|      | B3      | 81-113  | 0.06       | 6.49       | 1.65   | 27.76 | 1.35  | 1.20  | 51.26|                | 0.00  |
|      | Bx      | 113-150 | 0.03       | 7.05       | 1.69   | 21.82 | 1.50  | 0.77  | 51.07|                | 0.00  |
| PH1  | A       | 0-45    | 0.10       | 6.00       | 15.80  | 6.90  | 0.10  | 0.30  | 26.70|                | 1.03  |
|      | CR1     | 45-85   | 0.00       | 6.20       | 14.30  | 6.50  | 0.10  | 0.20  | 25.60|                | 0.34  |
|      | CR2     | 85-120  | 0.10       | 5.70       | 9.60   | 5.60  | 0.20  | 0.10  | 16.00|                | 1.21  |

(continued on next page)
### Table 2 (continued)

| ID | Used in | Horizon | Depth (cm) | EC (dS m\(^{-1}\)) | pH\(_{\text{H2O}}\) | Exchangeable Bases | CEC (cmol kg\(^{-1}\)) | OM (%) |
|----|---------|---------|------------|----------------------|----------------|-------------------|----------------------|--------|
|    |         |         |            |                      |                | Ca\(^{2+}\) | Mg\(^{2+}\) | Na\(^{+}\) | K\(^{+}\) |                      |
| RG1|         | Ah      | 0-6        | 0.18                 | 6.84           | 18.69  | 3.04   | 0.37   | 1.20   | 43.50                 | 7.59   |
|    |         | A       | 6-18       | 0.10                 | 6.77           | 12.82  | 3.40   | 0.35   | 0.69   | 47.10                 | 1.03   |
|    |         | C       | 18-47      | 0.11                 | 6.52           | 13.61  | 3.55   | 0.64   | 0.44   | 44.40                 | 1.03   |
| RG2|         | Ah      | 0-35       | 0.12                 | 7.11           | 6.14   | 2.86   | 0.28   | 0.55   | 35.70                 | 2.96   |
|    |         | A       | 35-65      | 0.08                 | 6.67           | 7.60   | 3.43   | 0.53   | 0.31   | 34.20                 | 1.29   |
| SC1|         | A       | 0-24       | 25.00                | 8.00           | 29.00  | 16.00  | 59.00  | 0.90   | 22.00                 | 2.07   |
|    |         | Bw1     | 24-45      | 12.00                | 8.00           | 19.00  | 17.00  | 42.00  | 1.00   | 39.00                 | 1.72   |
|    |         | Bw2     | 45-63      | 13.00                | 8.00           | 34.00  | 17.00  | 43.00  | 1.00   | 46.00                 | 1.72   |
|    |         | Bw3     | 63-85      | 13.00                | 8.00           | 69.00  | 25.00  | 55.00  | 2.00   | 40.00                 | 0.69   |
| ST1|         | Ap1     | 0-27       | 0.15                 | 5.87           | 5.81   | 2.40   | 0.50   | 0.44   | 25.96                 | 2.06   |
|    |         | Ap2     | 27-38      | 0.15                 | 6.20           | 3.61   | 2.07   | 0.41   | 0.12   | 36.05                 | 2.32   |
|    |         | B1      | 38-53      | 0.11                 | 6.56           | 7.31   | 2.28   | 0.46   | 0.08   | 25.96                 | 0.77   |
|    |         | B2      | 53-72      | 0.09                 | 6.84           | 5.77   | 2.64   | 0.55   | 0.11   | 22.04                 | 0.77   |
|    |         | B3      | 72-82      | 0.10                 | 6.96           | 4.29   | 2.18   | 0.50   | 0.09   | 35.43                 | 0.26   |
|    |         | Bg      | 82-100     | 0.10                 | 7.06           | 3.46   | 2.11   | 0.46   | 0.07   | 29.46                 | 0.51   |
| UM1|         | Ah      | 0-26       | 0.11                 | 6.62           | 3.80   | 0.08   | 0.35   | 0.31   | 22.50                 | 2.32   |
|    |         | B1      | 26-59      | 0.08                 | 6.84           | 2.91   | 3.59   | 0.39   | 0.39   | 12.30                 | 1.54   |
|    |         | B2      | 59-94      | 0.08                 | 7.06           | 3.57   | 1.54   | 0.51   | 0.62   | 23.40                 | 0.77   |
|    |         | BC      | 94-110     | 0.09                 | 7.21           | 3.96   | 2.18   | 0.53   | 0.52   | 32.40                 | 0.26   |

EC = Electric conductivity; CEC = Cation exchange capacity; OM = organic matter.
In the CIE L*a*b* color system, L* represents the image's brightness; a* and b* indicate variations from green - to red + and blue - to yellow +, respectively. In the HSV color measurement system, H is the hue; S (saturation) refers to the amount of gray, and V (Value) represents the brightness or intensity of the color.

Fig. 3 shows images of the soil profiles with visible coarse fragments used in the GB method test. This figure compares the coarse fragment quantification obtained from (a) visual field estimation, (b) supervised processing with RGB images, (c) unsupervised processing with RGB images, and (d) unsupervised processing with component S of the HSV color system. In this case, the values obtained with supervised processing were considered accurate values. Fig. 3 was divided into four parts to achieve better visualization of the information.

The raw images correspond to soil profile photographs without the application of the GB method. Images 1 and 2 correspond to soils enriched with clay in the subsurface part of the profile. Image 1 corresponds to an Alisol, according to World Reference Soil Base classification [3], characterized by low base saturation, and image 2 shows a Luvisol.

On the other hand, images 4–8 show soils developed from volcanic ash. These soils, called Andosols, have low bulk density, high water retention, and high phosphorus fixation. In the Andosol images, these soils significantly vary in their morphology, despite belonging to the same reference group.

Images from 9 to 13 were obtained from the soil profiles of the Cambisol group; they also showed noticeable differences in their morphology. These soils have little profile differentiation and are moderately developed. Images 14 and 15 show the soil profiles of the Regosol group; they are also soils with little profile development.

Images 16 to 18 correspond to soils with a high accumulation of organic matter in the surface horizon. The soils shown in these images differ in that Kastanozem (image 16) has secondary carbonates, while Phaeozem (image 17) does not have secondary carbonates but has a high base saturation. Umbrisol (image 18) has a low base saturation.

Image 19 corresponds to a Solonchak, a soil with a high concentration of soluble salts. The image shows limited rooting. Image 20 corresponds to a Stagnosol characterized by accumulated water that leads to the formation of reducing conditions and stagnic properties in the soil profile.
Fig. 2. Soil profiles horizon delineation with the GB method.
Fig. 2. Continued
Fig. 2. Continued
Fig. 2. Continued
Fig. 2. Continued
Fig. 2. Continued
Fig. 3. Identification of soil profiles coarse fragments with the GB method.
Fig. 3. Continued
Fig. 3. Continued
Fig. 3. Continued
2. Experimental Design, Materials and Methods

The soil survey in the state of Michoacán, Mexico, was carried out in 2019. The sampling sites were selected in municipalities without information on soil profiles, based on their geomorphological attributes: plains, hills, mountains, high hills, and low hills [4]. The pits were opened, and the profiles were described following the procedure recommended by the FAO [5]. Photographs of the profiles were taken from the front with sufficient illumination, reducing the surface roughness with a brush [6]. A Canon Powershot Sx530 camera was used with the automatic mode activated; the camera was positioned perpendicular to the profile face, focusing on the entire soil profile [7].

In the field, the percentage of coarse fragments per soil horizon was visually determined using the reference graphs of the percentage of the covered area proposed by [8]. In the laboratory: (a) electrical conductivity and pH were measured using a 1:2 ratios of soil and water; (b) the exchangeable bases and cation exchange capacity were measured with the ammonium acetate method [9]; and (c) the organic matter with the Walkley and Black method [10].

Soil profiles were classified based on the specifications of the World Reference Base [3]. The soil horizon delimitation and designation of the raw images were carried out using a template created in PowerPoint [11]. The image sizes were standardized, and the target area for analysis was extracted using Adobe Photoshop CS6 [12].

The images were analyzed using the GB method. In the GB method, the horizon delineation of soil profiles includes five steps: (1) Preprocessing the profile image with k-means segmentation, (2) conversion of the preprocessed image to CIE L*a*b* and HSV color systems, (3) k-means segmentation of HSV and CIE L*a*b* images, (4) delineation of horizons, and (5) determination of the clarity and topography of the outlined horizons.

The coarse fragment quantification of the soil profiles with the images and using the GB method includes three steps: (1) Super-pixel analysis of the image to eliminate the texture and highlight the differences between its components, (2) classification of the objects in the image using the gray intensities of the histogram, and (3) extraction and quantification of the coarse fragments identified in the image (Fig. 4).

![Fig. 4. Flowchart of the GB method, used for the analysis of the images of the soil profiles.](image-url)
Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that have or could be perceived to have influenced the work reported in this article.

CRediT Author Statement

Ángeles Gallegos: Conceptualization, Methodology, Software, Data curation, Writing – original draft; Francisco Bautista: Conceptualization, Methodology, Investigation, Writing – review & editing.

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