# MultiSoils: A Digital Platform for Information Search and Project Management in Soil Science

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## 1 Introduction

The Brazilian territory has continental dimensions (8,510,345.540 $km^2$) with a great diversity of biomes and represents a significant challenge for the survey and mapping of soils. Despite the importance of soil information for territorial planning and management, data and maps are mostly generated at a low-detailed scale (1:250,000 or smaller). In some regions (associated with large centers or specific and located demands), there are more detailed data and maps (greater than 1:100.00). In addition, the little that exists is not easily accessible to society and does not gather, in a single database management system (DBMS), the wide range of soil infor-

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**Table 1** Types of databases developed by soil scientists and institutions in Brazil

| Initiatives | Classification/Language | Available data |
|---|---|---|
| BDSolos (EMBRAPA) | DBMS<br>PostgreSQL | https://www.bdsolos.cnptia.embrapa.br/ |
| *BDiA (IBGE)* | Repository | https://bdiaweb.ibge.gov.br/#/consulta/pedologia |
| febr | Repository | https://www.pedometria.org/soildata/ |
| Hybras (CPRM) | DBMS<br>Microsoft Access 2007 format. | https://www.sgb.gov.br/en/Hydrology/HYBRAS |

A data repository, often referred to as a data file or data library, is generic terminology referring to a segmented dataset used for reporting or analysis. A DBMS is a database management system, a set of software for creating, editing, storing, and retrieving data in tables

mation (general and morphological description of soil observations, characteristics physical, chemical, heavy metals, hydrocarbons, radionuclides, hydropedological analysis, among others). Also noteworthy is the lack of a platform that allows the planning and management of projects in soil science, integrating all project stages (planning, collection and analysis of soil, and generation of reports).

Table 1 presents the main Brazilian initiatives of soil scientists and institutions to organize soil data. BDSolos is a relational DBMS that stands out for being the oldest, gathers the greatest diversity of data, and allows the consultation of soil profile information (Simões, 2015). The IBGE's Environmental Information Database (BDiA) was launched in 2018 and brought together the collection of thematic cartographic databases produced by the IBGE over the last 20 years, based on fieldwork of the natural resources mapping project, also incorporating the database of the RADAMBRASIL project, who carried out the environmental survey in the 1970s and 80 s. The BDiAWeb portal, a platform for viewing and consulting the Environmental Information Bank, brings together the collection of thematic databases of natural resources in the national territory, adjusted to a scale of 1:250,000, produced by the IBGE within the scope of the Mapping of Natural Resources project. These data were produced in four thematic areas: Geology, Geomorphology, Pedology, and Vegetation ("BDIA – Banco de Dados de Informações Ambientais," n.d.). The Free Brazilian Repository for Open Soil Data – febr is a centralized repository of soil information that allows both the search for data and the download of results (Samuel-Rosa et al., 2018). Hybras is a database focused on hydrophysical data of soils in Brazil (Ottoni et al., 2018).

In this context, the MultiSoils platform (www.multisoils.org) is presented. The term MultiSoils expresses the notion of a diversity of soils, their functions, and dimensions. The purpose of this work is to present the MultiSoils Platform to the soil science community, which allows not only the search, upload, and download of soil data but also the creation and management of projects in the following areas: digital agriculture, contaminant assessment and environmental risk, soil science education, hydropedological studies, soil survey and mapping, soil moisture monitoring, and

radionuclide studies. The platform offers solutions for the following common issues associated with soil data information:

1. Limitations about metadata descriptors and no public interfaces to allow the insertion of new data. Poor interfaces to query data;
2. Disperse datasets organized in spreadsheets/or specific databases with few soil attributes (data silos), which hampers the global view of soil information and the relationships between attributes and soil types, as well as those with other areas of knowledge;
3. The data provenance and its curation – The users must check not only whether the data is repeated but also whether it is valid for use;
4. The data available is not open – The available data fails to fulfill the eight Open Data and the FAIR principles;
5. Lackness of an efficient system to collect new data in situ. There are no Apps for data collection in the field nor to integrate them with new soil proximal sensors;
6. Lackness of an efficient system to manage projects in diverse areas of soil science;

## 2 Methodology

### *2.1 The Initiative, its Assumptions, and the architecture of the Platform*

The MultiSoils platform is an initiative of professors from the Federal Rural University of Rio de Janeiro (Dept. of AgroTechnologies and Sustainability and Dept. of Soils- Institute of Agronomy-UFRRJ) and from the Federal Center for Technological Education Celso Suckow da Fonseca (CEFET-RJ), in partnership with the Leopoldo Américo Miguez de Mello Research Center (CENPES-Petrobrás).

The fundamental assumption of the platform is to offer a public and collaborative space for consultation and project management in the field of soil science. The MultiSoils platform is free for users with a collaborative purpose (providing data to make available on the platform's public panel). Once registered on the platform, users will be able to create and manage projects in the following areas: (a) Soil survey and mapping; (b) Assessment of soil contaminants and environmental risk; (c) Digital agriculture; (d) Hydropedological studies; (e) Radionuclide inventories; (f) Soil moisture monitoring in real time; (g) Education in soil science and; (h) Rural extension. The platform offers a robust tool to search for soil data and create and manage projects in real time (integrating activities with apps in the field, on the web, and in analysis laboratories). To meet this proposal, so far, the platform was structured to gather in a single environment a great diversity of soil data (general and morphological description, chemical, physical, and hydraulic properties of the soil, heavy metals and micronutrients, mineralogical analysis, paste extract saturated,

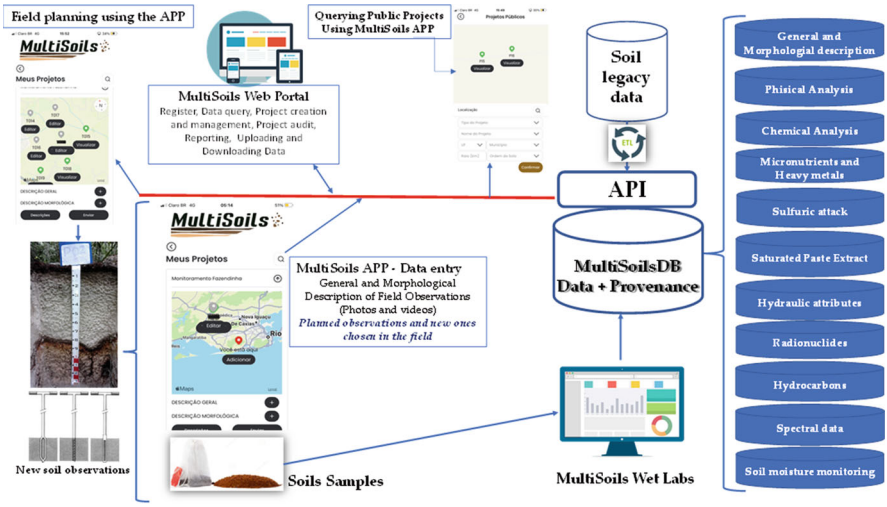



**Fig. 1** An overview of the MultiSoils Platform architecture

spectral data, hydrocarbons, radionuclides, and soil moisture monitoring in real-time).

The MultiSoils platform was developed in PHP and JavaScript using Laravel Framework version 10.20.0. The database was implemented in PostgreSQL version 15.4. The system is hosted in the AWS Cloud platform. To help with activities carried out in the field, a mobile version of the system has been developed for Android and iOS-based operating systems. Figure 1 presents an overview of the MultiSoils Platform architecture.

## 2.2 *The rationale of MultiSoils platform*

The MultiSoils platform provides users with two interaction interfaces: via the web and an app. On the web, the user can perform the following functionalities: (a) Register; (b) Data query; (c) Project creation and management; (d) Plan field activities; (e) Monitor field activities and laboratory analyses; (f) Generate reports and; g) Upload and Download data.

Through the app, the user can perform the following activities: (a) Consult online the data of public projects on the platform; (b) Make the general and morphological description of soil observations (allows working offline); (c) Send the descriptions for the project registered on the web;

### 2.3 The References and Manuals Adopted by the Platform

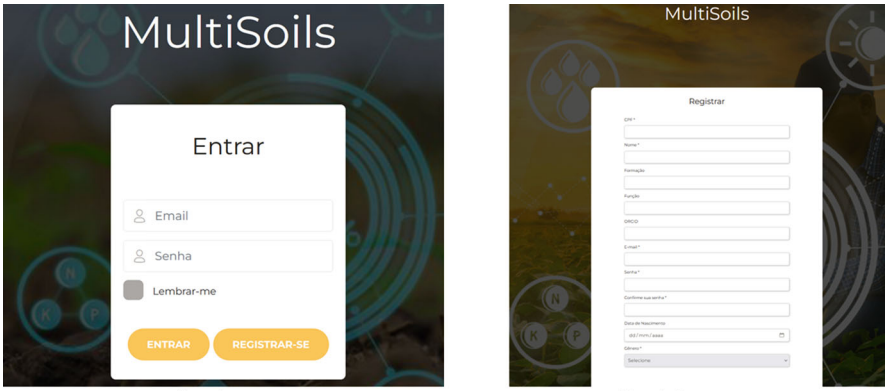
All criteria adopted on the platform (attributes of the general description, morphology, and soil analyses) are adapted from manuals widely referenced in the literature. The source documents used: (1) Soil Description and Collection Manual in the Field (Santos et al., 2015); (2) Pedology Technical Manual. (IBGE, 2007); (3) Brazilian Soil Classification System (Santos, 2018). (4) Munsell Soil Color Chart (Munsell Color (Firm), 2010); (5) Guidelines for Soil Profile Descriptions (*Guidelines for soil description*, 2006); (6) Soil Survey Manual ("Soil Survey Manual 2017," n.d.). (7) Soil Analysis Methods Handbook (Teixeira et al., 2017).

## 3 Results and Discussion

### 3.1 The Utilities of the Platform

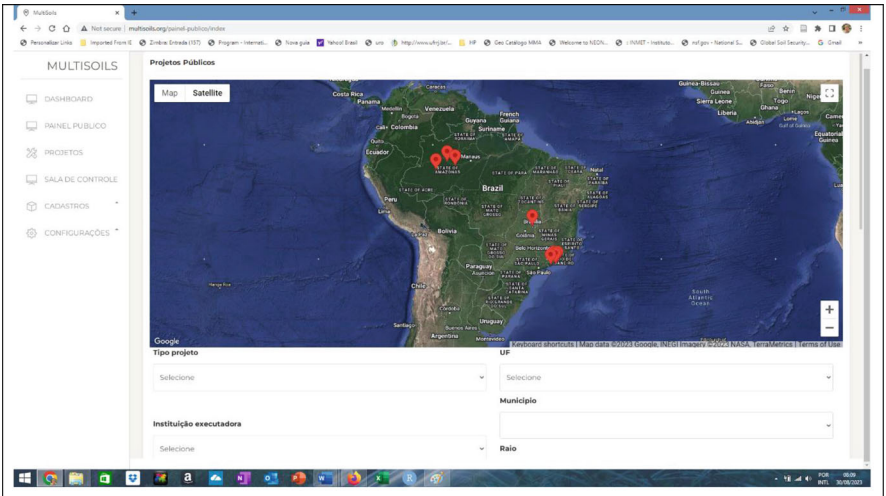
Figure 2 shows the first screen of the web platform. Registration on the MultiSoils platform is required. When registering, personal information will be requested, some mandatory (name, individual taxpayer registration – cpf in portuguese, and e-mail) and others optional (function, education, ORCID, and gender). All this information will be used by the MultiSoils platform to authenticate and maintain the user's activity history. It will not be shared with any third-party organization except with the user's express consent.

After registration, the user will have access to the platform's central panel (DASHBOARD) (Fig. 3). In this step, the user will have an access level called Basic User. The basic user is anyone who only searches for soil data and information.

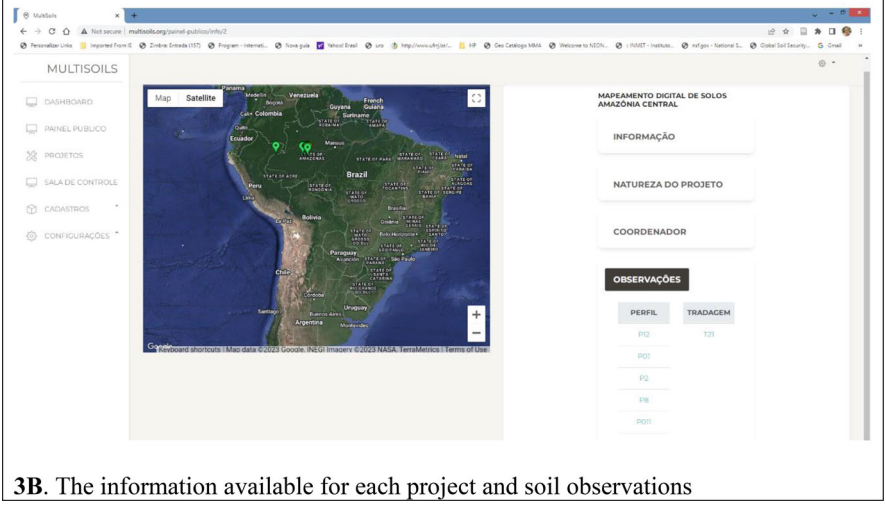



Login screen Register screen

**Fig. 2** MultiSoils platform entry screens




**3A.** The public panel and the search options




**3B**. The information available for each project and soil observations

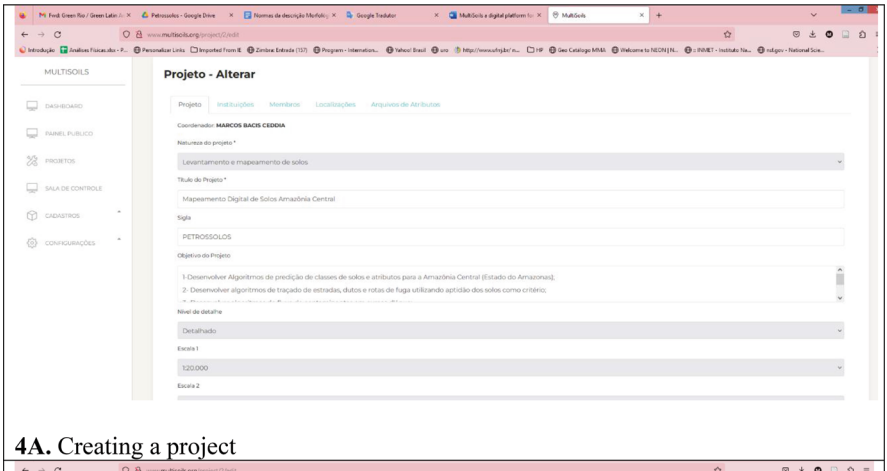
**Fig. 3** Searching soil information using the Public Project's panel in the MultiSoils Web Portal

The platform provides registration and access interfaces that allow advanced search for soil data and information already available to the public. In this case (Basic User), data considered to be in the public domain will be freely available (Fig. 3). As an example, the basic user will be able to download the field App (only for consultation) and use the web platform to search for information on soils that have been published. Examples of consultation are the following: (1) Search for soils and attributes by project registered on the platform; (2) Search for soils and attributes

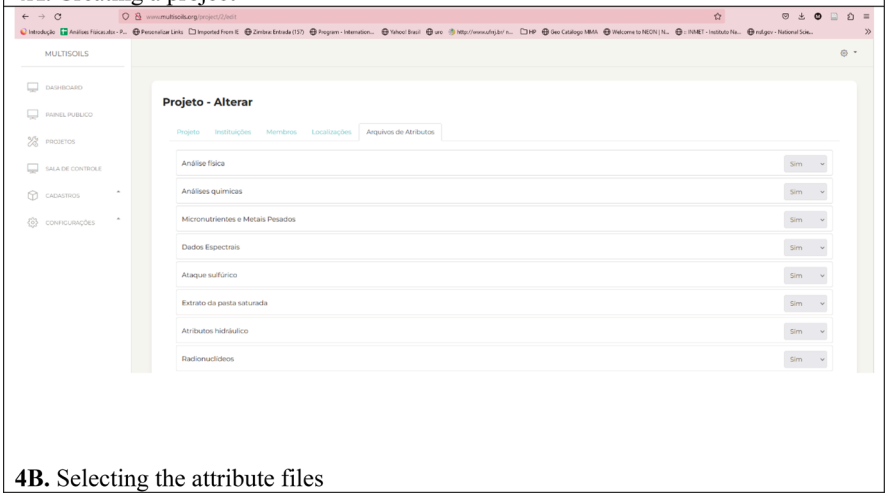
by country (3) Search for soils and attributes by State of the Federation (4) Search for soils and attributes by municipality (5) Soil search by search radius (Fig. 3a); These functions are available on the web platform and in the field App. In the case of searches via the web, the user will be able to see all soil observations of each project (soil profiles and soil boreholes), generate reports, and export the searched data via files in rtf, pdf, and Excel format.

The MultiSoils platform also distinguishes two more user categories (advanced and intermediate users). Advanced user refers to project coordinators. These users (students, researchers, professors, and professionals in general, working for public or private companies) use the platform to conduct projects and now have access to all the platform's functionalities. To become an Advanced User, the user requests a change of category and signs a specific disclaimer. When becoming an advanced user, the coordinator has access to the "Projects" and "Control Room" tabs (Figs. 4 and 5).

In the "Projects" panel, the project coordinator can create a research project (Fig. 4a). At this stage, the coordinator fills in information such as: (a) the characteristics of the project (nature, title, objectives, scale, coverage area, start and end date, and whether it will become public or private); (b) Participating institutions; (c) project members; (d) project locations (state and municipalities covered) and; (e) attribute files. In attribute files, the coordinator can customize his project by choosing which analyzes will be edited in his project, such as General and morphological description, physical analyses, chemical analyses, micronutrients and heavy metals, spectral data, sulfuric attack, saturated paste extract, hydraulic attributes (soil water retention, model parameters fitted to water retention curves and hydraulic conductivity), radionuclides, hydrocarbons, and soil moisture monitoring (Fig. 4b). A coordinator can have more than one project and, in each project, include several team members. These team members are considered the intermediate users, who can enter field and laboratory data (using field and web platform Applications). In this case, unlike the advanced user, he is not allowed to delete project data or register new project team members. After creating the projects, the coordinator will have access to the "control room" panel, where it will be possible to view all the projects coordinated (Fig. 5a). In this panel, the coordinator and team can insert soil observations (whether from legacy data or a new project being started). The project may refer to the digitization of a project already carried out in the past (legacy data) or a new project being started. In this second case, the coordinator and his team can only insert the identification code and coordinates and part of the general description of each observation via the web. These new observations will appear with the status "planned point" (green pins), as seen in Fig. 5b. These planned points can be edited in the field (through the app – MultiSoils) and/or on the web. When editing the planned points is started, the color of the pin changes to orange. This functionality allows the coordinator to remotely monitor the project's performance in real-time (Fig. 5b). On the web, the coordinator and his team can generate reports of each observation (according to the Brazilian Society of Soil Science rules – rtf and pdf format) and download data in rtf, pdf, and Excel format (Fig. 5b).




**4A.** Creating a project

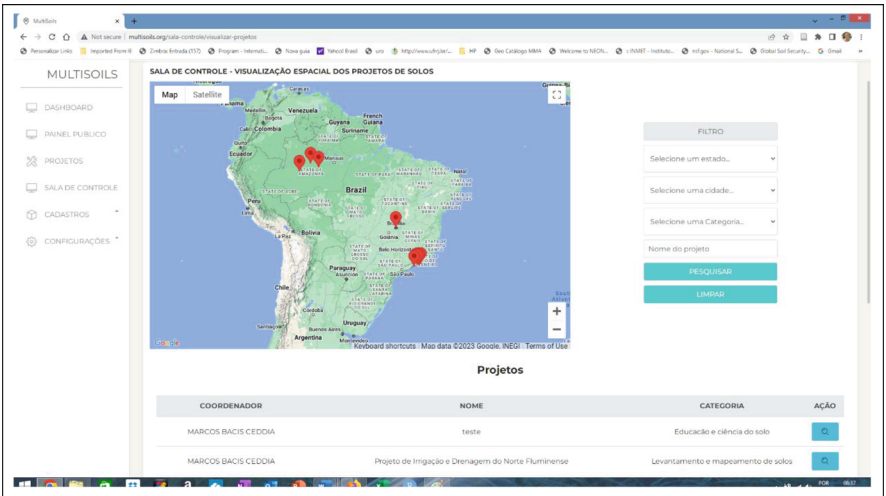



**4B.** Selecting the attribute files

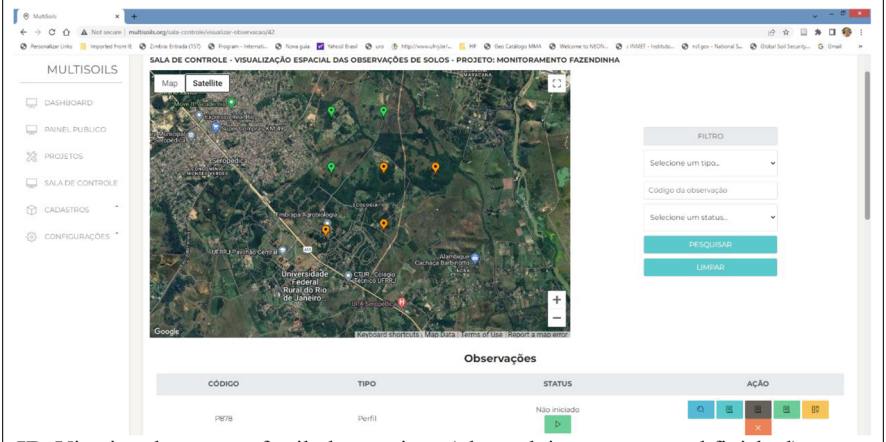
**Fig. 4** The Project panel to customize a research project using the MultiSoils Platform. (**a**) Creating a project. (**b**) Selecting the attribute files

Figure 6 shows the screen containing the general description of a soil observation. On this screen, the coordinator and his team can spatially visualize the observation together with the chosen profile picture (editable – Fig. 6a). On this screen, all fields of the general description of the soil are organized (according to Santos et al., 2015; IBGE, 2007), offering bars for choosing predefined fields or editing. It is also possible to insert photos and videos on this screen (Fig. 6b). It is essential to highlight that the entire general description can be filled in in the field through the MultiSoils app. In this case, all fields of a soil observation will already be filled in and can be edited on the web.

In the sequence (Fig. 7a), the user can visualize and edit the horizons and layers of each observation (soil profile and hole). By opening the icon of each



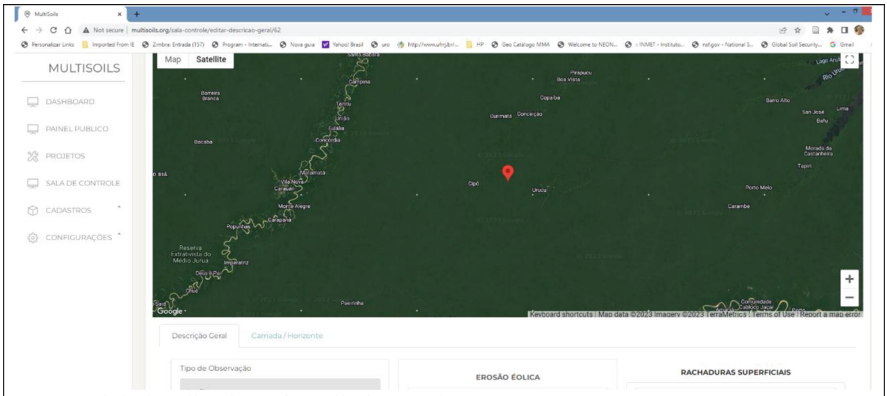

**5A.** Project visualization by a coordinator



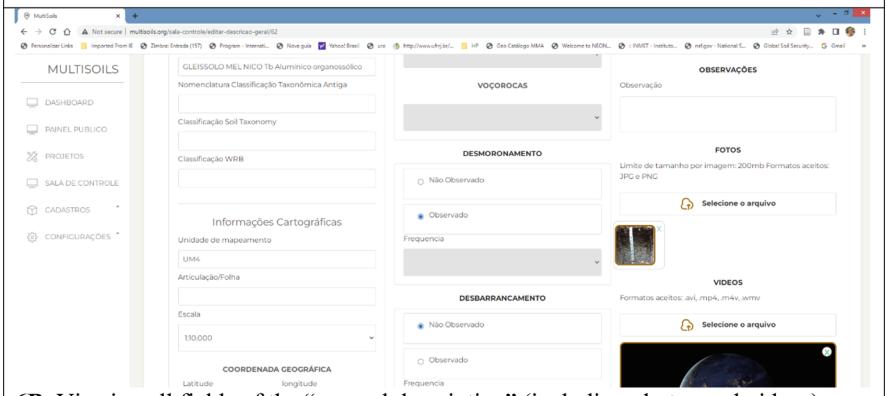

**5B.** Viewing the status of soil observations (planned, in progress, and finished)

**Fig. 5** The "Control Room" panel for managing projects, editing data and tracking activities. (**a**) Project visualization by a coordinator. (**b**) Viewing the status of soil observations (planned, in progress, and finished)

horizon/layer, the user can visualize and edit the morphological description and all the analyses planned for that specific project. It should be noted that the morphological description can be edited on the web when dealing with a project with legacy data. In the case of new projects, the coordinator and his/her team can enter data in the field using the MultiSoils app and via the web. As much for the




**6A.** Spatial visualization of a soil observation




**6B.** Viewing all fields of the "general description" (including photos and videos)

**Fig. 6** Viewing and editing the general description of soil observation. (**a**) Spatial visualization of a soil observation. (**b**) Viewing all fields of the "general description" (including photos and videos)

general description as for the morphological description and all the soil analyses, the platform offers Batch files for uploading data (Fig. 7b).

Figure 8 shows the basic screens of the MultiSoils app. The app was developed to carry out three functions in the same environment: (1) Search and view soil data in public projects registered on the MultiSoils platform; (2) Viewing, edit, and sending the general and morphological description of planned soil observations to the MultiSoils platform database; (3) Insertion, editing and sending the general and morphological description of a new observation in a project registered on the platform. Figure 8a, b show the first screens of the app. When opening the app, the user will have access to the following icons: (a) public projects; (b) my projects; (c) help; (d) who we are; and (e) terms of use. When accessing public projects, the user can visualize their location with two options of background maps (physiographic with relief or satellite image).

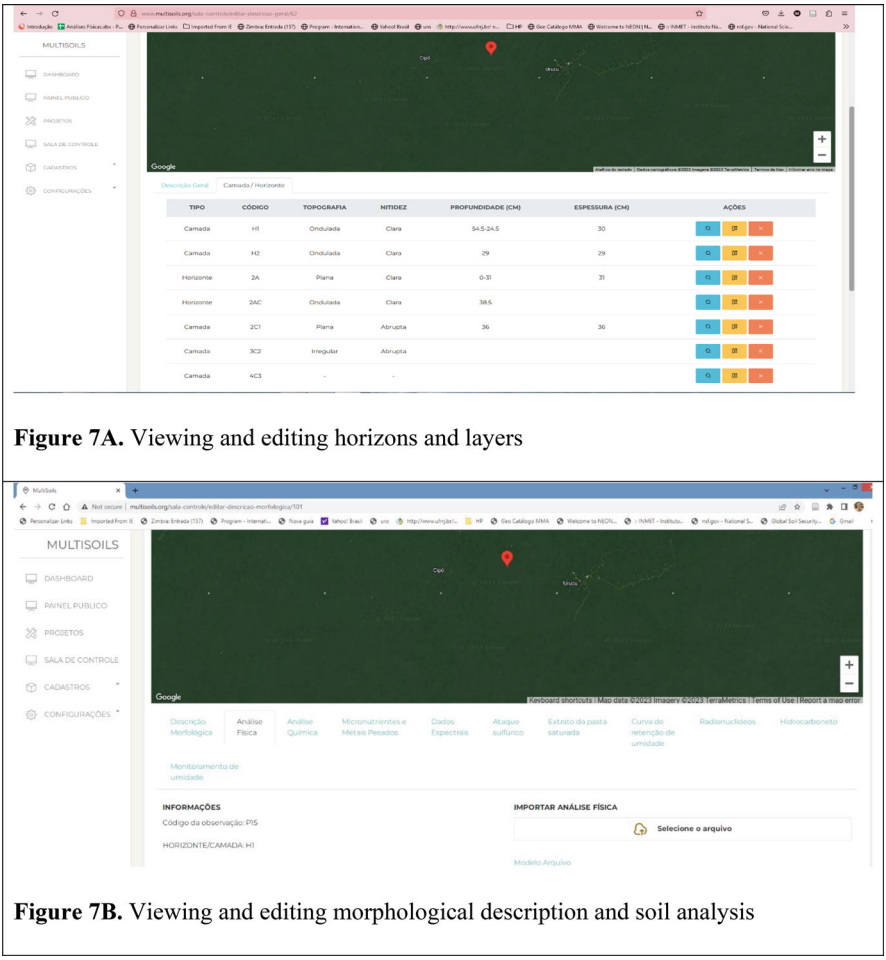



**Figure 7A.** Viewing and editing horizons and layers




**Figure 7B.** Viewing and editing morphological description and soil analysis

**Fig. 7** Viewing and editing horizons and layers in the MultiSoils platform. (**a**) Viewing and editing horizons and layers. (**b**) Viewing and editing morphological description and soil analysis

On this screen, while connected to the internet, the user can click on the search indicator and make queries using the following pre-established options: (a) by type of project. (b) by project title; (c) by federation unit; (d) by municipality; (e) by search radius; and (f) by soil order (Fig. 8c). In addition to searches, the app offers the user explanatory material about the 13 soil orders of the Brazilian classification system (order definitions, territorial expression, and photos). When accessing the "My Projects" icon, the user can view the list of projects he/she coordinates or participates in (Fig. 8d). It is important to note that this screen only allows viewing and editing of projects registered on the platform under the "non-public projects" category. Once selecting a project, the user can view the soil observations planned

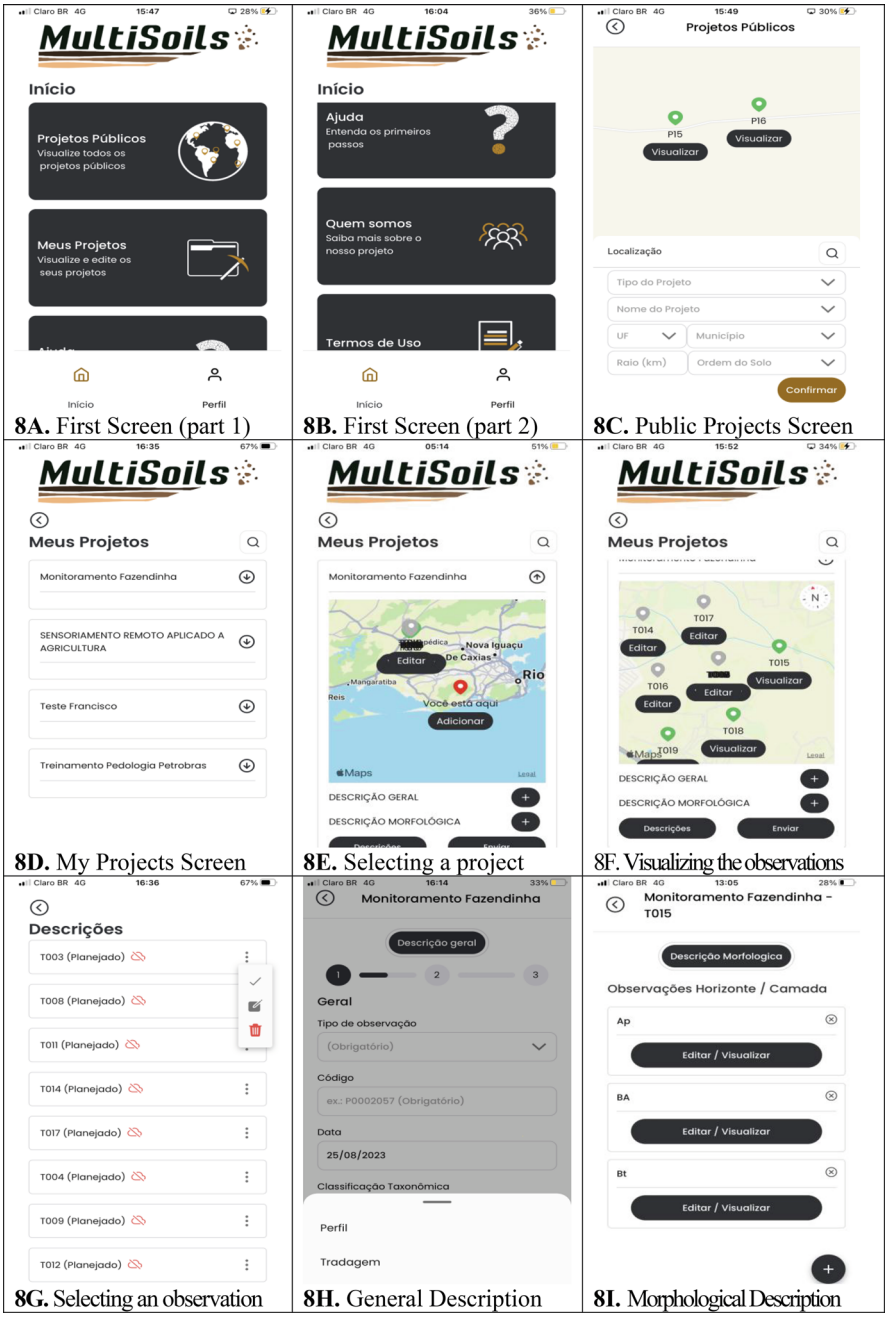



**Fig. 8** Some screenshots of the MultiSoils app. (**a**) First Screen (part 1). (**b**) First Screen (part 2). (**c**) Public Projects Screen. (**d**) My Projects Screen. (**e**) Selecting a project. (**f**) Visualizing the observations. (**g**) Selecting an observation. (**h**) General Description. (**i**) Morphological Description

to be carried out in the field (Fig. 8e). The user can select a planned observation (by touching the mobile device screen or choosing from the observations menu). The user can also create a new observation (extra observation) and proceed to editing (Fig. 8e). The user can enlarge the view of the soil observations and choose the point to edit (both using the mobile device screen – Fig. 8f and accessing the list of descriptions to be carried out – Fig. 8g). When starting editing, the app will lead the user to sequential screens where it will be possible to edit both the general description of the observation (Fig. 8h) and the morphological description of horizons and layers (Fig. 8i). In the final part of the general description, the user will be able to insert photos and videos of the profile and the landscape to improve the understanding of the environment and the characteristics of the soil. At the end of the morphological description, the user can check all the description screens and send the observation to the web platform. It is important to note that all fieldwork on the "My Projects" screen can be conducted without internet access (offline). Thus, the user can work remotely and send observations when he accesses the internet. The app stores the observations described in the offline condition.

## 4 Conclusions

The MultiSoils Platform is ready to be made available to the soil science community in Brazil (www.multisoils.org). The proposal of the developers (UFRRJ/CEFET-RJ/PETROBRAS) is to make its use free and within a proposal of cooperation with users and respective institutions.

The field app is available on Android and iOS platforms and can be downloaded for free. Like every digital platform, the system is in continuous improvement. Other modules are being developed, and we are open to cooperative interaction with national and international researchers and institutions.

The platform can be widely used to support the Pronasolos program.

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