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Geotechnology applied to the remote mapping of coffee and digital currency investment simulations

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Abstract

Coffee production is an activity of great economic and social importance in Brazil. This agribusiness segment stands out in the economy of small cities in southern Minas Gerais, as it involves family farming and the permanence of the rural population in the countryside. This study aimed to contribute and adapt geotechnology-based methods for the remote mapping of coffee and the strengthening of the permanence of this population, providing an online platform to simulate coffee trading. The municipality of Inconfidentes/MG was the study area. Orbital images of the Sentinel-2A satellite were used in the development of the study. Images were classified in a supervised way with the random forest classifier in Google Earth Engine (GEE) and later used as a data source in the online platform developed in the Application Programming Interface (API) Leaflet to simulate coffee trading involving the cryptocurrency Coffee Coin. Results allowed the identification and mapping of coffee growing areas by remote sensing and, also, to demonstrate that the online platform can help in the planning of new investments in coffee production, in addition to presenting an overview of the economic importance of coffee to the municipality.

Keywords: Coffee production; coffee coin; Google Earth Engine; Web Mapping; agriculture.

Introduction

Brazil underwent an intense process of rural exodus in the 1970s and 1980s. The mechanization of agricultural production unemployed rural workers, who moved to the cities in search of job opportunities. According to data from the Pesquisa Nacional por Amostra de Domicílios (PNAD) performed in 2015, most of the Brazilian population (84.72%) live in urban areas with 15.28% living in rural areas. This displacement from the countryside to the city continues, even if in smaller percentages (IBGE, 2015).

In general, in small cities in Southern Minas Gerais, this percentage of the population is still balanced, since their main economic sources are shopping tourism, textile industry, and mainly agribusiness, in which coffee production stands out. Even with the expected reduction of 42.8% in the total volume of harvested coffee compared with 2020, coffee production takes Minas Gerais to a prominent position. The estimated production for southern Minas Gerais is about 10,1 to 10,9 bags, which makes the region the largest producer in Brazil (CONAB, 2021).

According to Companhia Nacional de Abastecimento (Conab) (2021), this reduction in productivity is due to the physiological effects of negative biennially observed in several producing regions, as well as the adverse climatic conditions in certain localities, which directly influence both to reduce the average yield and the production area. This is usually smaller in negative biennial cycles, due to the most intense crop treatments used in order to recover the vegetative potential of plants.

However, according to Conab (2022), for the 2022 crop, an increase compared to the last year is expected, reaching a little more than 1 million total hectares (1.02 million hectares), with emphasis on the expansion in the Zona da Mata region and the significant maintenance of the area in Southern Minas Gerais. Regarding the average yield for Minas Gerais, the estimate is close to 24,3 bags/ha, which is higher than the 22,6 bags/ha obtained in the last season (2021), but still well below the 33,3 bags/ha obtained in 2020, which was the last positive biennially crop in the state (CONAB, 2022).

Moreira, Barros and Rudorff (2008) state that knowing the spatial distribution of coffee is essential for both crop forecasting and agricultural planning at the municipal, state, and federal levels due to its socioeconomic importance. In this sense, some factors, such as the globalization of the economy, the increase in world population, global climate change, and the issue of food security, raised concerns related to the planted area estimation and the rapid and precise productivity of large agricultural crops for various governments (MOREIRA et al., 2007).

According to Bolfe, Castro Jorge, and Sanches (2022), digital transformation has been taking the lead in rural areas, becoming an important guiding thread of demands of consumer markets attentive to the sustainability of field production. However, data gaps to support strategic decisions in the development of new research, innovations, and markets, especially focused on small and medium-sized rural producers, still exist.

Coffee Coin, released in July 2021 by the Minasul Agroindustrial Cooperative, is one of the initiatives related to these technological advances in coffee production. It is the first coffee-based collateralized stablecoin (MINASUL, 2017). According to Minasul (2017), the cooperative sells more than 1,5 million bags of coffee per year. It is located in the municipality of Varginha/MG, and has about 8,5 cooperative members distributed in more than 200 municipalities. Coffee Coin makes the purchase possible from a single kg of coffee, allowing a commercial fractionation of the supply without the need for greater market knowledge and its price variables (MINASUL, 2021).

According to Mita et al. (2019), this stablecoin aims to introduce a stabilization mechanism, controlling the exchange rate between cryptocurrency and fiat currency. Stablecoins can be tied to cryptocurrency, fiat currency, precious metals, such as gold and silver, or commodities, such as coffee. Stablecoins redeemable in currencies and commodities are considered backed, whereas those linked to an algorithm are non-backed. Thus, redeemable Stablecoins offer greater security to investors.

This study aimed to contribute to remote sensing studies applied to the mapping of coffee, classifying different coffee crops in southern Minas Gerais, more specifically in the municipality of Inconfidentes/MG, with Sentinel-2A multispectral images in the Google Earth Engine (GEE) processing platform, besides strengthening the permanence of small coffee producers in the countryside, developing and providing an online platform to simulate coffee trading, considering the digital currency Coffee Coin.

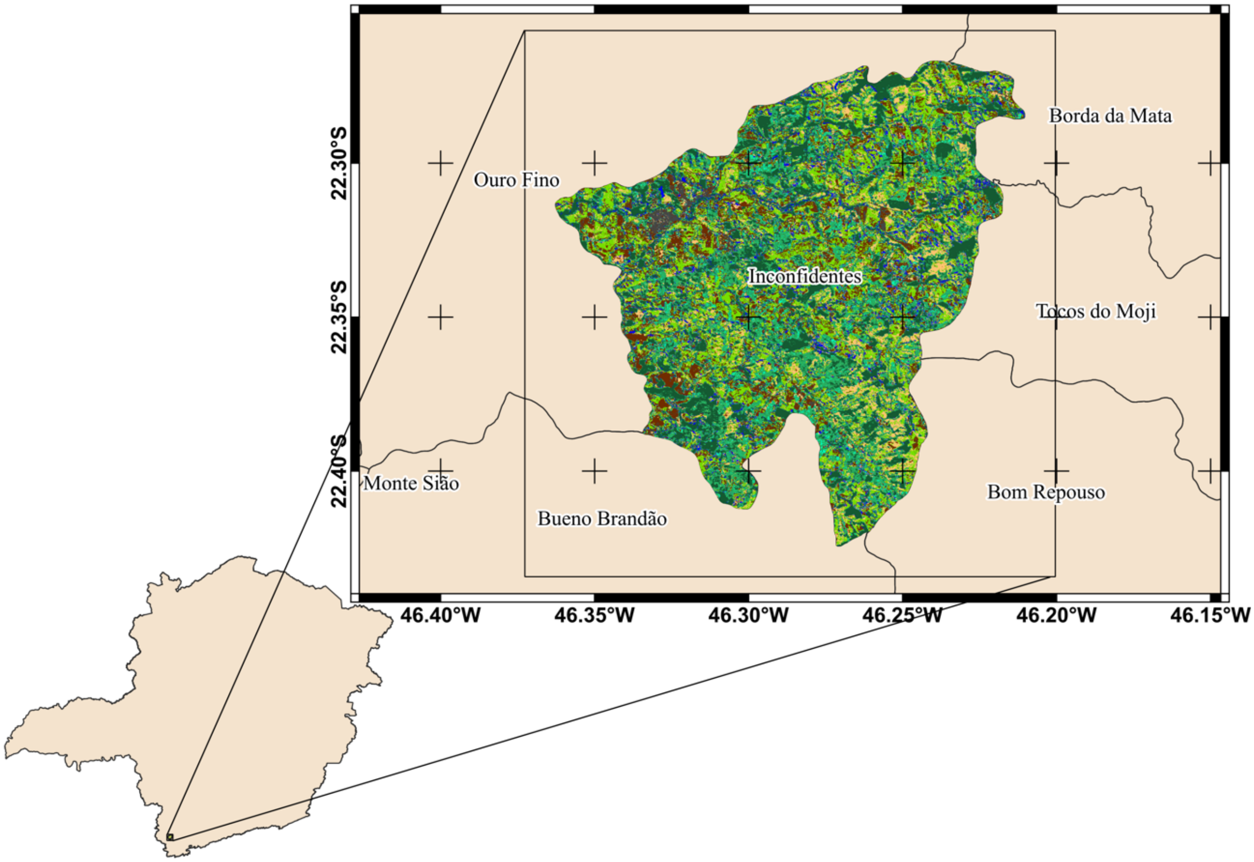
Material and methods

This study was performed within the boundaries of the municipality of Inconfidentes, southern Minas Gerais. Inconfidentes has an average altitude of 869 meters, an area of about 150 km^2, and is located between the geographic coordinates 22,42S 46,36W (Figure 1).

According to Conab (2021), the southern mesoregion of Minas Gerais, where Inconfidentes is located, stands out in coffee cultivation and productivity in the country. For the remote mapping of coffee in the study area, Sentinel-2A images from the Copernicus Earth Observation program were used. This program systematically acquires images with a spatial resolution ranging from 10 m to 60 m.

The image acquisition period was from January 6, 2021, to October 31, 2021, in accordance with Moreira, Adami, and Rudorff

Figure 1 – Study area: municipal boundary of Inconfidentes/MG.



Source: Prepared by the authors (2022).

(2004) and Moreira et al. (2007), which corresponds to the dry season. It resulted in 12 images. These images were made available on GEE, a geospatial analysis platform, which is based on the concept of cloud storage and processing, making it easier for users to view and analyze satellite images from all over the planet. Table 1 presents all materials used in this study. It is organized into three categories: 1) mapping data; 2) digital images; and 3) software.

Table 1. Materials used in the development of the proposed solution.

Category	Description	Quantity	Date	Source
1.0	**Mapping Data**	**-**	**-**	**-**
1.1	Municipal Boundary	01	2020	IBGE (1:250000)
2.0	**Digital Images**	**-**	**-**	**-**
2.1	23 bands	21*	2021	GEE (COPERNICUS/S2_SR)
3.0	**Software**	**-**	**-**	**-**
3.1	Google Earth Engine	-	-	Google (2017)
3.2	QGIS	-	-	QGIS (version 3.16.9, Hannover, 2020)
3.3	Leaflet	-	-	Leaflet (version 1.7.1 2020)

* Image filtering with cloud percentage less than or equal to 10 was considered.
Source: Prepared by the authors (2022).

The methodology used was based on supervised classification, using random forest and GEE. This methodology provided information on coffee growing areas in Inconfidentes/MG, providing a data source for the online platform that allows the simulation of what would be the return on the productivity of the planted area, considering the conversion to Coffee Coin.

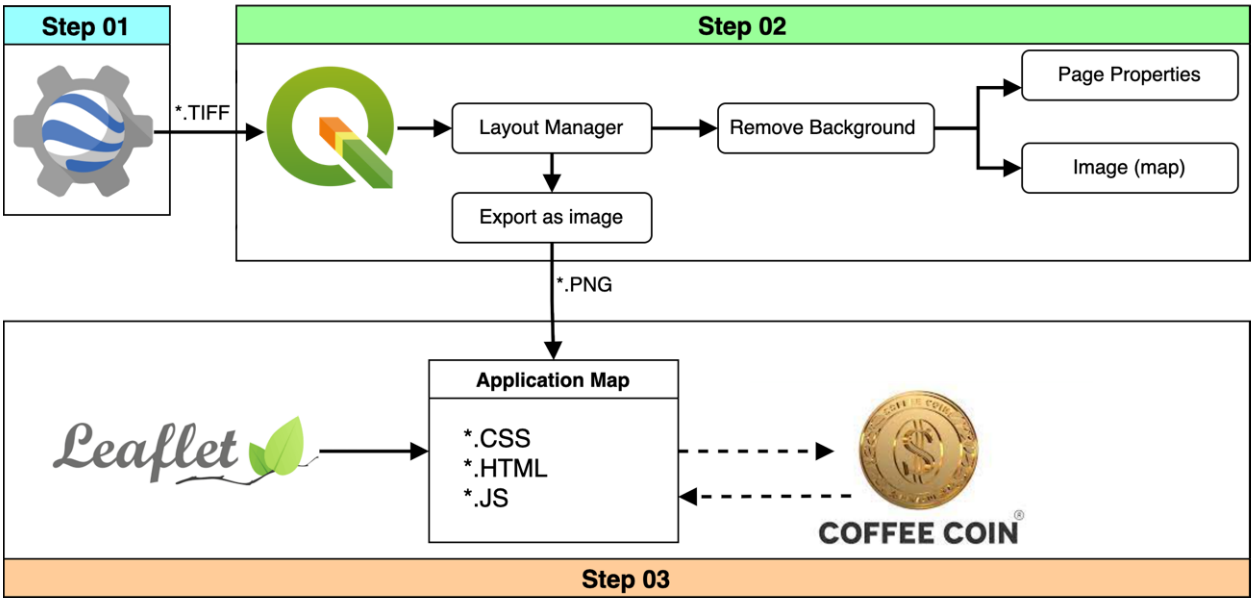
Besides this simulation, producers could also simulate the creation of plots and estimate the return based on the expected productivity of this plot and the Coffee Coin exchange rate. This latter feature may help rural producers to expand the planted area (especially small producers). The flowchart of the platform implementation steps is shown in Figure 2.

Step 1 was entirely developed in GEE. For the mapping of coffee growing areas, samples of the classes defined for supervised classification were created. In total, eight classes were created, of which two were directed to coffee production (coffee under development and coffee under production). These two classes were defined in line with MOREIRA (2003) and MOREIRA, BARROS, and RUDORFF (2008). Exposed soil, pasture, forests, water bodies and rivers, urbanization areas, and other planting areas were other classes assigned for the mapping.

Sample indication was performed considering the high-resolution images available in the "Satellite" layer in GEE. The number of samples in each class was in accordance with OLOFSSON et al. (2014), which suggest at least 50 points for each class in a general case and 100 points if the evaluated area is too large or the number of classes is greater than 12.

To assess the accuracy of the classification, 30% of samples were considered in each class used in the training of the classifier (random forest) and kappa statistics were used. Other classifiers available on the platform, such as Classification and Regression Trees (CART), the minimum Euclidean distance, and even random forest, considering the Normalized Difference Vegetation Index (NDVI), were tested, but none of them had better accuracy than kappa. This step was completed by the export of a Tagged Image File Format (TIFF) image with the classification result along with a graphic report showing the percentage of each class for the municipality in square meters.

Figure 2 – Stages of development of the proposed solution.



Source: Prepared by the authors (2022).

To include the result of the first step in the web application, converting the classification result from TIFF to Portable Network Graphics (PNG) was necessary. This conversion was performed in step 2, using the “Layout Manager” tool in the QGIS software, which allows the background removal of images and their export in PNG format. This option is available in the properties of the page and map object inserted from the TIFF image.

In step 3, the web platform was created. The platform construction was based on the use of the API Leaflet, which is an open-source JavaScript library to build interactive maps compatible with mobile devices with many mapping capabilities. The code snippet responsible for embedding the classification layer in the interactive map can be seen in Figure 3.

Basically, the imageOverlay object inserts the image from the path where it is stored and its borderline coordinates (step 2, Figure 2). Other parameters can be considered, but they are not mandatory, such as image opacity. Besides the JavaScript language, HyperText Markup Language (HTML) was used to build the graphical user interface and the Cascading Style Sheets (CSS) language to style the platform.

In the graphical interface, users find tools to interact with the map and tools to simulate productivity and exchange based on Coffee Coin, also can consult the exchange rate of this cryptocurrency at any time by accessing its website with a single click. Besides these features, which are available in the top menu, tools in the top right-hand corner also allow users to interact with the map by changing its background layer to a high-resolution satellite image and drawing plots to simulate productivity and the expected return in a Coffee Coin-based trading.

Results and discussion

In Inconfidentes/MG, coffee is grown in small to medium-sized areas. This hinders the performance of the classifier, considering the spatial resolution of the images of 10 meters used. However, in this study, both the accuracy of the classifier and kappa statistics had mean values of 95%, which are excellent values, according to Congalton and Green (2019) and Queiroz et al. (2017). Classes responsible for the mapping of coffee were similar to the Native Vegetation class. According to Moreira, Barros, and Rudorff (2008), this is because these classes have very similar phenology. The classification of coffee growing areas was spectrally similar to areas classified as Agriculture, mainly for newer crops and areas recently planted with eucalyptus. The percentage area for each class obtained in the classification and the corresponding values in hectares are listed in Table 2.

In general, the classification results were excellent for all classes, ranging from 89% to 98%. However, the classification performance was far from the actual representation of coffee production when the classification was superimposed on a high spatial resolution image (Figure 4).

According to Moreira, Adami, and Rudorff (2004), this heterogeneity in the spectral behavior of coffee crops is related to agronomic parameters of crop management, such as spacing, crop treatments, and post-harvest defoliation. Moreover, Figure 4 shows that lighting

Figure 3 – Code to insert the classified image.

```
var bounds_image = [[-22.424, -46.397],[-22.268, -46.176]];
classification = L.imageOverlay('../classification/classification_qgis_ibge_2020.png',
    bounds_image, {opacity: 0.5}).addTo(map);
```

Source: Prepared by the authors (2022).

Table 2. Areas of classes obtained in the classification.

Class	Area (ha)	% of Area
Coffee Under Production	3 226,920	21.6
Coffee Under Development	533,103	3.6
Native Vegetation	3 072,061	20.5
Agriculture	1 590,689	10.6
Pasture	3 083,647	20.6
Exposed Soil	2 045,620	13.7
Urbanization	613,757	4.1
Water	795,229	5.3

also contributes to this spectral mixture, a very common topographic characteristic in southern Minas Gerais. However, to obtain the final map with the coffee classes, no manual editing of the coffee areas was performed, since the planted area estimation was sufficient, considering that the platform has a simulation feature based on drawing coffee plots. The graphical interface of the web application, to which the image resulting from the classification was added, can be seen in Figure 5.

Some application features are in the top menu. From left to right, users can: a) change the opacity of the classification layer; b) consult the current Coffee Coin exchange rate directly on its website; c) simulate the digital currency trading, considering all coffee growing areas of the municipality, informing the currency exchange rate and average productivity; and d) access the application developers' contact information. In the features available on the right side (on the map), users can interact with the map, modifying the scale ("Zoom in" and "Zoom out" buttons), changing the background layer to a high spatial resolution satellite image, and drawing plots to individually simulate the trading of their coffee production (Figure 6).

Rural producers can use the feature of individualized trading simulation for each plot to make decisions on a possible expansion of their growing area or an investment to fertilize a planted area. Finally, the last two buttons allow, respectively, the editing of the drawing of the plot and the removal of this map. The platform is available for open access at http://200.131.80.158/TCCs/TCC-Estela.

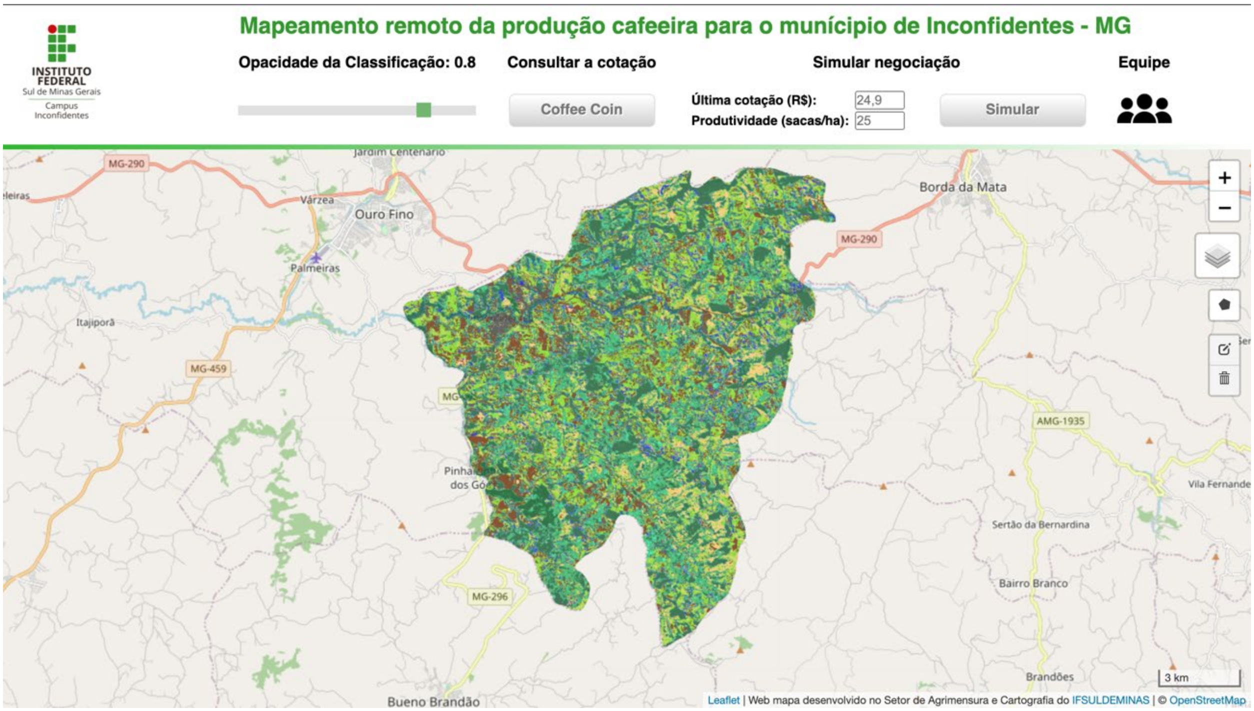
Conclusions

Regarding the classification map and the correspondence observed in Google high spatial resolution images, the use of higher spatial resolution images would make the classification result very close to reality. However, the use of

Figure 4. Visual comparison of the classification, using a high spatial resolution image.

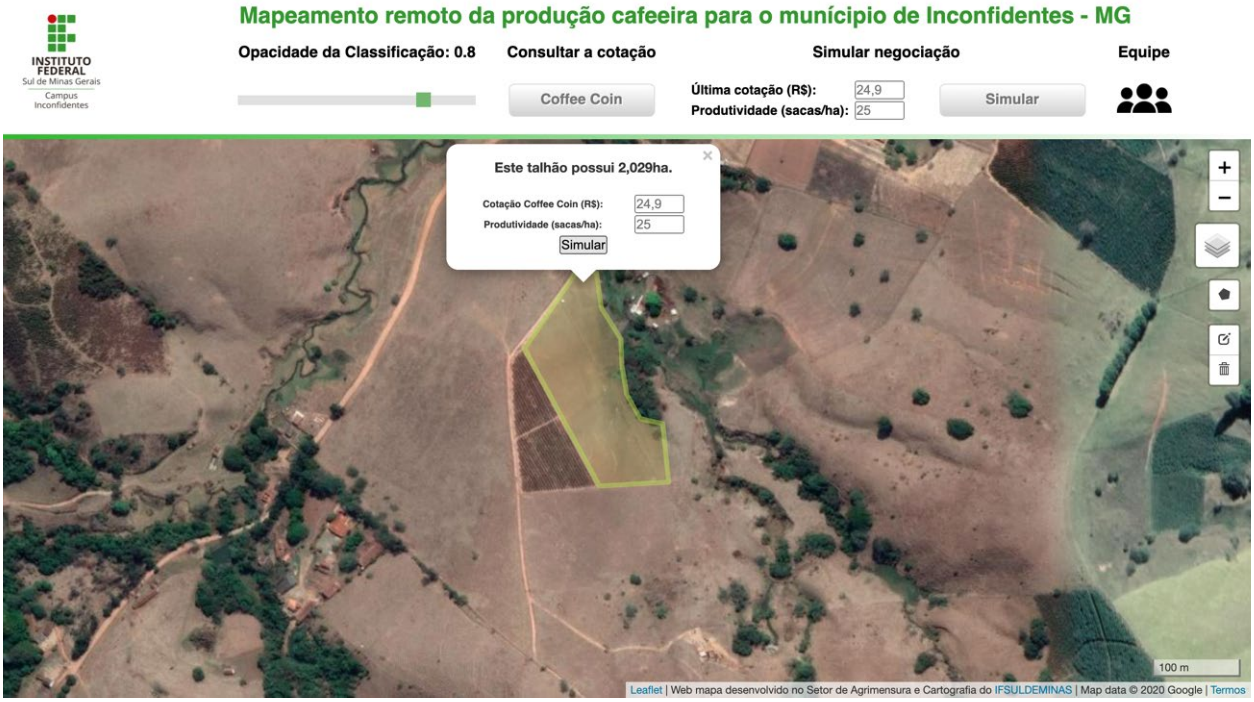
A. Classification B. Sentinel-2 – 5(R) 4(G) 3(B) C. Google – RGB

Figure 5. Online platform to simulate coffee trading.



Source: Prepared by the authors (2022).

Figure 6 – Picture of a plot for the simulation of coffee trading.



Source: Prepared by the authors (2022).

Sentinel-2A images was satisfactory for the land use classification system used in this study, as this classification aims to simulate coffee trading in the municipality of Inconfidentes/MG, in general.

The relief of the municipality negatively influenced the result of the classifier, since coffee growing areas were added to other classes due to the shading effect of the relief. Moreover, the use of GEE facilitates the visual interpretation of coffee areas, as the high-resolution images provided by the platform replace the need for field visits in areas that mainly produce coffee, which makes remote mapping a feasible process in any location.

Finally, the remote mapping of coffee was effective, considering the aforementioned statistical results, and the classification map provided technical inputs for the development of a platform to simulate the trading of the productivity of coffee crops based on digital currency, which strengthens the Minasul initiative to disseminate Coffee Coin, besides facilitating the understanding for small producers of how a possible trading of their production would work. Moreover, the proposed method and web technology can be used for other types of crops, such as corn and sugarcane, which encourages the permanence of rural producers in the countryside field and the maintenance of agribusiness in the municipality.

Recommendations for future studies

As a suggestion for future studies, we recommend using a higher spatial resolution image collection, such as PLANET images, which were recently made available in GEE. Thus, the spatial resolution would increase significantly, as the resolution of PLANET images is 4,77 m while that of Sentinel-2A images is 10 m.

Secondly, we recommend collecting the sampling points used to assess the accuracy of the classifier in the field, so that this value has a greater meaning of the classification result, although all executions of the algorithm, which considered a random sample of 30% of the points used in the classifier, showed an average value of 95%, which is satisfactory. Thus, the use of points collected in the field can support the method or suggest a random sample greater than 30%.

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