Scientific Research Publishing

International Journal of Geosciences, 2024, 15, 12-24
https://www.scirp.org/journal/ijg
ISSN Online: 2156-8367
ISSN Print: 2156-8359

Multicriteria Analysis by Codification for the Determination of Soil Landscape Units in Forest and Pre-Forest Zones of Cote D'Ivoire: The Case of the Square Degrees of M'Bahiakro and Daloa

Guy Fernand Yao[1], Derving Baka[2], Koffi Emmauel Kassin[3], Bala Mamadou Ouattara[4], Nestor Kouman Yao Kouakou[2], Kouadio Amani[1], Jean Lopez Essehi[1], Brou Kouame[1], Albert Yao-Kouame[5]

[1]National Agricultural Research Center (CNRA), Central Laboratory, Soils, Water and Plants (LCSEP), Sustainable Soil Management and Water Control Program, Bouaké, Ivory Coast
[2]Earth Sciences and Mining Resources Training and Research Unit (UFR STRM), Soil, Water and Geomaterials Sciences Laboratory (LS2EG), Félix Houphouët-Boigny University, Cocody-Abidjan, Abidjan, Côte d'Ivoire
[3]Mondelez International, Abidjan, Côte d'Ivoire
[4]Training and Research Unit (UFR) Communication, Environment and Society, Department of Geography, University Alassane Ouattara, Bouaké, Côte d'Ivoire
[5]Soil, Water and Geomaterials Sciences Laboratory (LS2EG), Earth Sciences and Mining Resources Training and Research Unit (UFR STRM), Félix Houphouët-Boigny University, Abidjan, Ivory Coast
Email: guyfernandyao.2014@gmail.com

How to cite this paper: Yao, G.F., Baka, D., Kassin, K.E., Ouattara, B.M., Kouakou, N.K.Y., Amani, K., Essehi, J.L., Kouame, B. and Yao-Kouame, A. (2024) Multicriteria Analysis by Codification for the Determination of Soil Landscape Units in Forest and Pre-Forest Zones of Cote D'Ivoire: The Case of the Square Degrees of M'Bahiakro and Daloa. *International Journal of Geosciences*, **15**, 12-24.
https://doi.org/10.4236/ijg.2024.151002

Received: August 24, 2023
Accepted: November 20, 2023
Published: January 29, 2024

Abstract

The present study, carried out in the forest (Daloa) and pre-forest (M'Bahiakro) zones of Cote d'Ivoire, aims to determine soil landscape units using the coding method. Geological maps and satellite images (SRTM and Landsat) were used for this purpose. The methodological approach adopted consisted in producing maps of slope, geology, land use and topography using the codification method. These various maps, integrated into a GIS using the coding aggregation method, were used to generate soil landscape maps. Twenty-seven (27) soil landscapes have been identified for the pre-forest zone (M'Bahiakro), with a strong dominance of acid rock over a moderate relief under savannah, forest/degraded forest and crops/fallow. However, the forest zone (Daloa), with forty-one (41) soil landscapes identified over the entire zone, is characterized by a majority of mafic rocks on a medium altitude under forest/degraded forest, water and crops/fallow. The criteria used from the codification method (sum of aggregations) made it possible to predict the spatial distribution of soil map units according to agro-ecological environments in the humid inter-tropical zone. This is essential for the orientation and reinforcement of soil survey tools. However, a comparative evaluation of the different multicriteria analysis methods for coding and weighting soil landscape unit mapping would enable us to identify the most suitable and efficient method for drawing up base maps for soil surveys.

Keywords

GIS, Multicriteria Analysis by Coding, Soil Landscapes, Daloa, M'Bahiakro, Cote D'Ivoire

1. Introduction

In Côte d'Ivoire, population growth and the need to secure the sustainability of economic (agricultural growth, energy needs), social and cultural processes mean that natural resources, particularly the soil, are increasingly being used [1]. With the importance of agricultural activities, the Daloa and M'Bahiakro degrees squares (located in the forest and pre-forest zones) contribute to Côte d'Ivoire's economic development [2]. These areas have thus become a preferred destination for many people in search of land suitable for industrial crops (coffee, cocoa, rubber, oil palm, etc.). Cocoa production accounts for 40% of the world market [3]. Cocoa alone generates nearly 44% of export earnings, or over 15% of Gross Domestic Product [4]. Coffee and cocoa employ 60% of the working population. The sustainability of these two crops and the volume of exports are compromised by the ageing of orchards [5], accentuated by the combined action of biotic [6], climatic [7] and soil [8] hazards, which considerably reduce the economic life of orchards. Consequently, the sustainability of cocoa and coffee growing depends on sustainable soil management. Soil surveys are necessary to make the right choice of plants to grow and to initiate suitable cultivation techniques. Soil characterization based on pedological surveys requires knowledge of a large amount of multi-disciplinary, multi-source and often multi-format geoscientific information [1]. Processing this information requires mastery of tools and methods such as Spatial Reference Information Systems (SIRS), Remote Sensing (RS) and Multicriteria Analysis (MA). SIRS specialize in the capture, storage, spatial analysis and cartographic restitution of information. The availability and control of homogeneous, synoptic information in digital form that remote sensing provides, facilitates storage and manipulation operations, and makes it possible to cross-reference data from several sources. AM methods are designed to provide synthetic information, so that decision-makers are not overwhelmed by an excess of information [1] [9] [10]. This system is based on satellite images (Landsat Oli 8 and SRTM) and cartographic images. The aim of this work is to determine soil landscape units by applying the multicriteria analysis method by coding in these square degrees in order to reinforce soil survey tools using more suitable and efficient base maps.

2. Materials and Methods

2.1. Study Area

The study area covers two square degrees (M'Bahiakro and Daloa) according to the map of Côte d'Ivoire (**Figure 1(a)** and **Figure 1(b)**).

The M'Bahiakro square degree is located in central-eastern Côte d'Ivoire, between 7˚ and 8˚ north latitude and 5˚ and 4˚ west longitude, and covers some 12,000 km^2. It has a humid tropical climate with a marked dry season and low winds [11]. The terrain is generally flat, with a maximum altitude of 200 m. Temperatures in the study area range from 14˚C to 33˚C, with humidity varying between 40% and 70% [12]. The area's geology is composed of a complex of igneous, metamorphic and volcano-sedimentary rocks [13]. The flora is dominated in the pre-forest zone by shrubs interspersed with groves and forest islands. The Daloa square degree, with a surface area of around 12,000 km^2, is located in central-western Côte d'Ivoire between 6˚ and 7˚ north latitude and 6˚ and 7˚ west longitude. The landscape is characterized by lower elevations (200 to 300 m) in a NE-SW direction, with tabular or rounded interfluves. Plains and low plateaus dominate the landscape, with a tropical climate and an average temperature of 25.6˚C. Average annual rainfall is 1317 mm/year [14], with average monthly temperatures fluctuating between 24˚C and 28˚C. The geological bedrock of the Daloa square degree is characterized by Middle Precambrian formations, dominated by granites, migmatites and schists.

2.2. Data Used

The data used in this study concern, on the one hand, satellite images (Landsat OLI 8 and SRTM) and, on the other hand, geological maps of the areas covered.

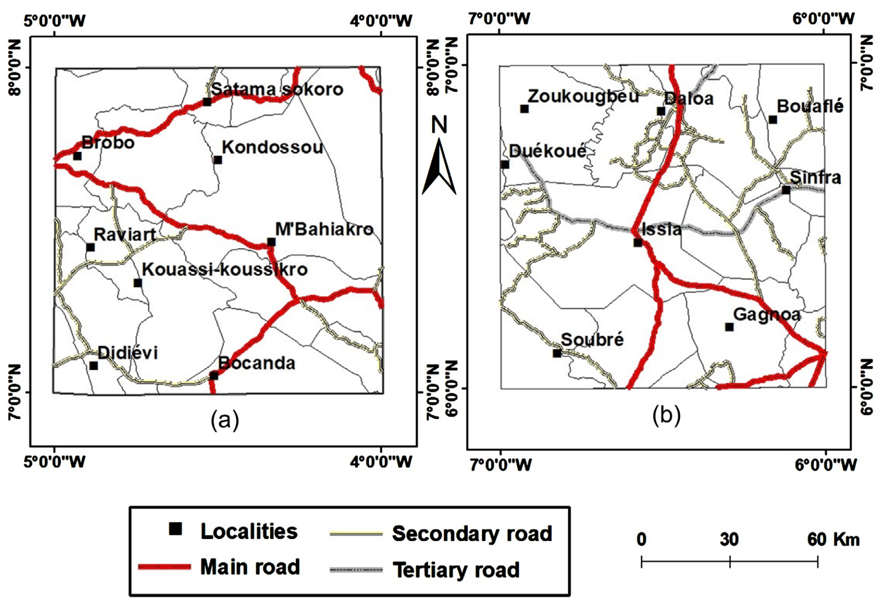

Figure 1. Presentation of the square degrees of M'Bahiakro (a) and Daloa (b) according to the square degree map of Côte d'Ivoire.

Landsat images were used to map land use, while SRTM images were used to map relief in terms of slopes and altitudes. As for the geological maps, they were used to understand the geological structures of the areas studied. It should be noted that radiometric and atmospheric processing were used to enhance the quality of Landsat images.

2.3. Study Methodology

The methodological approach adopted in this study is based on the use of multi-criteria analysis methods to draw up soil-landscape maps [15] [16] [17].

2.3.1. Identification of Criteria

According to Youan and *et al.* (2011), the identification of criteria is a decisive and delicate phase, which influences the quality of the information generated for decision-making [17]. Thus, with reference to the work of Youan (2008), a number of criteria are identified, selected and evaluated in order to achieve the fixed objective of determining cartographic units [16]. For this study, the criteria deemed most important are: slope, geology, land use and altitude.

2.3.2. Classification of Criteria

The criteria for identifying soil landscapes were classified on the basis of work carried out by Youan and *et al.* (2015) [18]. In this method, codes were assigned to the different criteria classes (sub-criteria). Geology was coded as 10, 20, 30, 40, taking into account the chemical composition of geological structures. Codes 100, 200, 300, 400 for the slope criteria and codes 1000, 2000, 3000, 4000 for the relief criteria. Meanwhile, codes 1, 2, 3, 4 and 5 have been assigned to land cover according to its predefined classes. Combining these codes or classes into a single code will define a soil landscape type. In this methodology, the ranking order of the criteria is not mandatory (**Table 1** and **Table 2**).

2.3.3. Combination of Criteria

In order to identify and map soil landscape units, it was necessary to combine all these previously codified criteria. To facilitate interpretation of the codified soil landscape map, an interpretation was made by combining the codes derived from the reclassification of the following criteria: geology, relief, slope and land use. For example, code “1132” was used to define a soil landscape with codes “1000”, “100”, “30” and “1” corresponding to a type of geology (30 equals mafic rock), relief (1000 equals valley), slope (100 equals gentle slope) and land use (2 equals degraded forest).

3. Results

3.1. Analysis of the Spatial Distribution of the Major Factors Used in the Modeling Process

3.1.1. Landform Characteristics in the Square Degrees of M’Bahiakro and Daloa

Figure 2 shows that the relief is variable, consisting of a vast, monotonous

Table 1. Reclassification of soil landscape criteria by weighting (M'Bahiakro).

Criteria	Rank	Code	Subclasses	Value
Geology	1	10	Acid rock	-
	2	20	Mafic rock	-
Altitude	1	1000	Valley	95 - 177 m
	2	2000	Watershed	177 - 254 m
	3	3000	Middle slope	254 - 374 m
	4	4000	Summit	374 - 467 m
Solpe	1	100	Low	0% - 5%
	2	200	Medium	5% - 10%
	3	300	High	10% - 15%
	4	400	Very high	>15%
Land use	1	1	Degraded forest - forest	-
	2	2	Savannah	-
	3	3	Crop/fallow	-
	4	4	Habitat/bare soil	-
	5	5	Water	-

Table 2. Reclassification of soil landscape criteria by weighting (Daloa).

Criteria	Rank	Code	Subclasses	Value
Geology	1	10	Acid rock	-
	2	20	Intermediate rock	-
	3	30	Mafic rock	-
	4	40	Sedimentary rock	-
Altitude	1	1000	Valley	146 - 200 m
	2	2000	Watershed	200 - 250 m
	3	3000	Middle slope	250 - 300 m
	4	4000	Summit/Platform	300 - 393 m
Slope	1	100	Low	0% - 5%
	2	200	Medium	5% - 10%
	3	300	High	10% - 15%
	4	400	Very high	>15%
Land use	1	1	forest	-
	2	2	Degraded forest	-
	3	3	Crop/fallow	-
	4	4	Habitat/bare soil	-
	5	5	Water	-

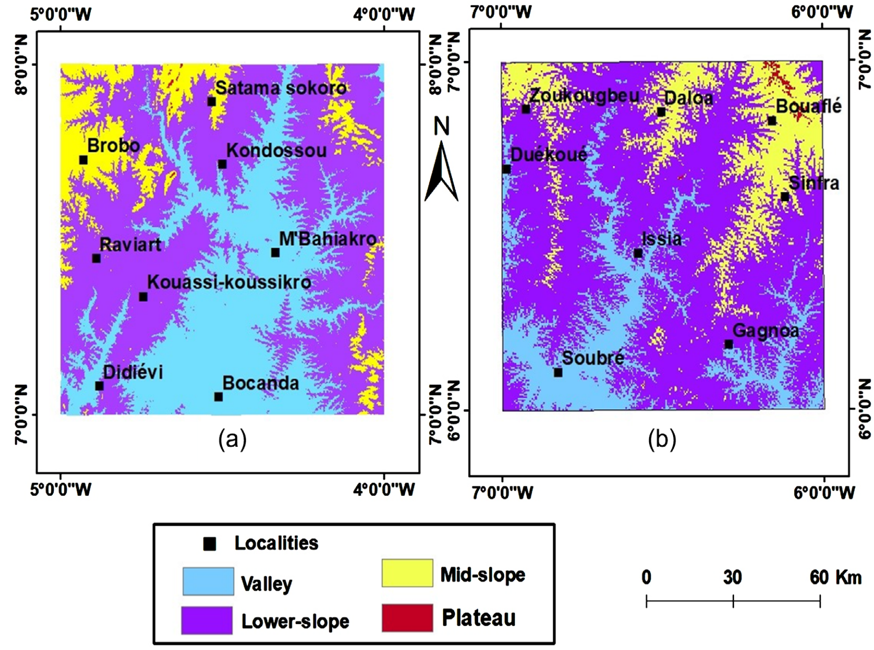

Figure 2. Relief of the square degree of M'Bahiakro (a) and Daloa (b).

peneplain with few irregularities over the whole of the study area. Altitude ranges from 50 to 649 meters. Altitudes are highest in the north, decreasing towards the center, where they are lowest. Slopes in the square degrees range from 0% to 44%. Gentle slopes cover almost all square degrees, with a proportion ranging from 77% to 93%. Medium slopes are between 5% and 8.5% and cover the territory moderately. As for steep slopes, they are located mainly approximately the study areas to the north and center. There are steep slopes to the north and south-east of the two square degrees. Low-slope areas correspond to valley relief. Medium-slope regions correspond to low- and mid-slope areas. Steeply sloping areas are characterized by plateaus, especially in the north and center of the square degrees (**Figure 3**).

3.1.2. Geological Characteristics of the M'Bahiakro and Daloa Square Degrees

The geological map shows a great diversity of surface formations, with four (4) formations. Sedimentary rocks (with 31.60% of surface area) in Daloa, result from the accumulation of various sediments (clasts: mineral fragments, shell fragments, etc.). Intermediate rocks account for a very small proportion (4.33% of surface area) and are composed of andesites and dacites. They are rich in aluminum, iron and silicon and are found around the Daloa area. Mafic rocks, made up of basic to intermediate lavas and pegmatite gabbro in Daloa, cover 63.93% of surface area, compared with 23.47% in M'Bahiakro, where these rocks are rich in ferromagnesium. As for acid rocks, they cover almost all (76.53%) of M'Bahiakro and are very sparsely represented in the Daloa zone (with 0.14% of surface area) (**Figure 4**).

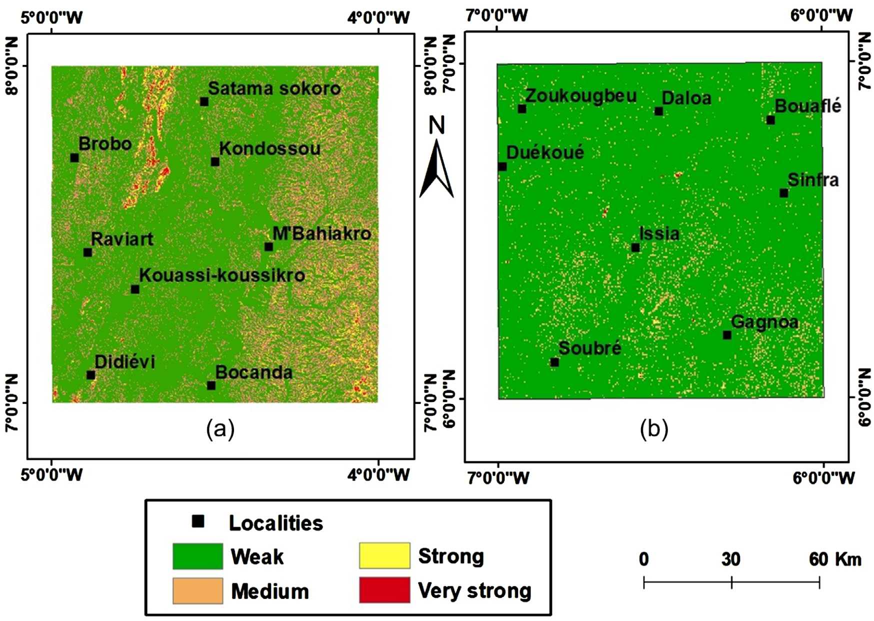

Figure 3. Elevation map of the square degree of M'Bahiakro (a) and Daloa (b).

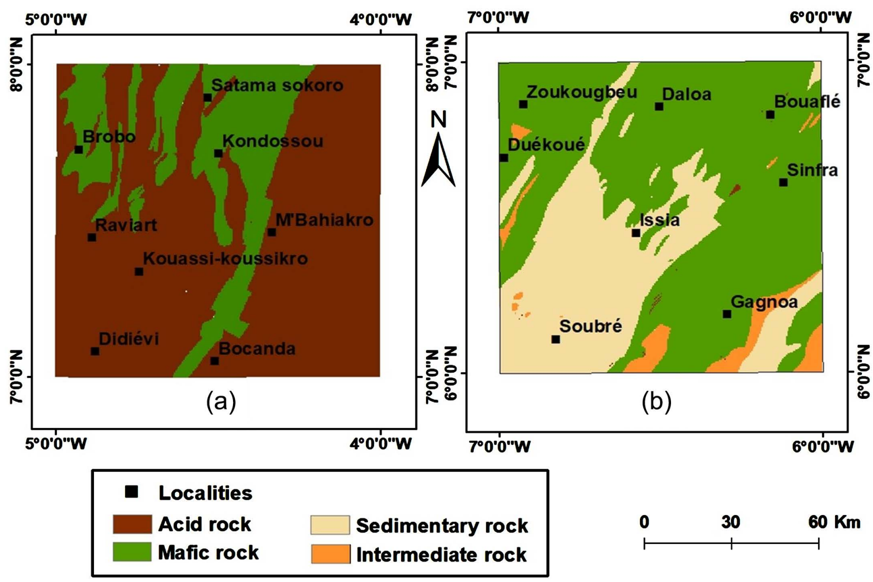

Figure 4. Geological map of the square degree of M'Bahiakro (a) and Daloa (b).

3.1.3. Land Use in the Square Degrees of M'Bahiakro and Daloa

Figure 5 shows the land cover with five (5) classes: forest/degraded forest, sa-vane, crop/fallow, habitat/bare ground and water. The savannah class is the most predominant (51.57%) throughout the M'bahiakro area. The same is true of degraded forest in Daloa (61.67%). The forest class is weakly concentrated in the south and south-east of the study areas. In addition, on average, all square degrees are covered by crop/fallow land, which is more concentrated in the North and Centre. The habitat and bare soil classes are sparsely distributed throughout the study areas. Finally, the water class is poorly represented in almost all zones.

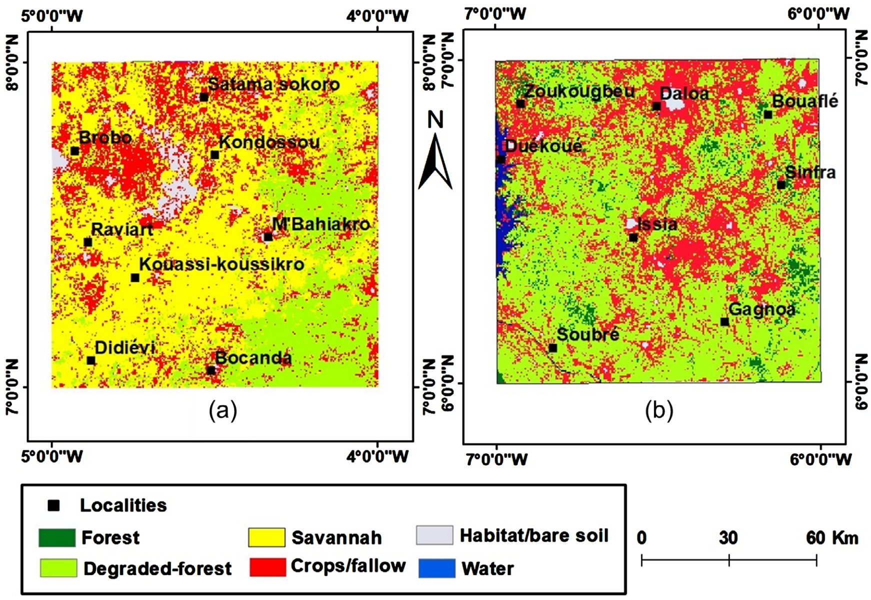

Figure 5. Map of land use in the square degree of M'Bahiakro (a) and Daloa (b).

3.2. Soil Landscape Mapping by Coding

Figure 6 and Figure 7 show the result of combining the four (4) criteria that model the soil landscape. The result is twenty-seven (27) soil landscapes for the M'Bahiakro area.

Of these, the most dominant are acidic rocks on a moderate relief under savannah and crop/fallow land. After that, mafic rocks make their appearance with a moderate relief under forest, another type of land use. The Daloa area comprises forty-one (41) soil landscapes.

At this level, the different soil landscapes are dominated by mafic rocks with a moderate relief under degraded forests and crops/fallow land. Next come the sedimentary rocks with an equally moderate relief under forests/degraded forests and crops/fallow land. Lastly, intermediate rocks with moderate relief under forest/degraded forest.

4. Discussion

The implementation of GIS based on the multicriteria analysis method using codification has made it possible to determine soil landscape units. Four (4) criteria (geology, relief, slope and land use) that best define soil landscapes were taken into account in the GIS implementation. These criteria influence the spatial distribution of soil landscapes in both forest and pre-forest environments. Eimberck M. and Joly B. (2008) have used these four (4) soil landscape criteria in the digitization of medium-scale soil surveys in France [19]. Indeed, the influence of geology on pedogenesis has long been demonstrated [20] [21]. The authors conclude that a pedological study resulting from the alteration of rocks presents great difficulties due to their heterogeneity, responsible for the variation in facies.

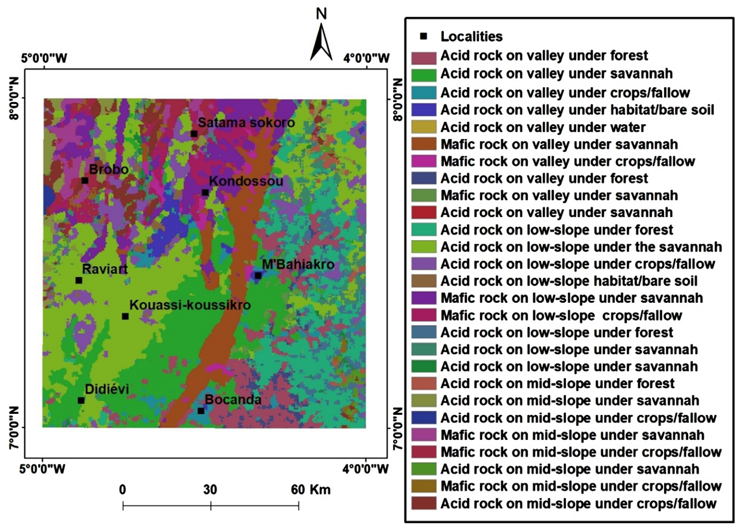

Figure 6. Soil landscape map by coding of M'Bahiakro.

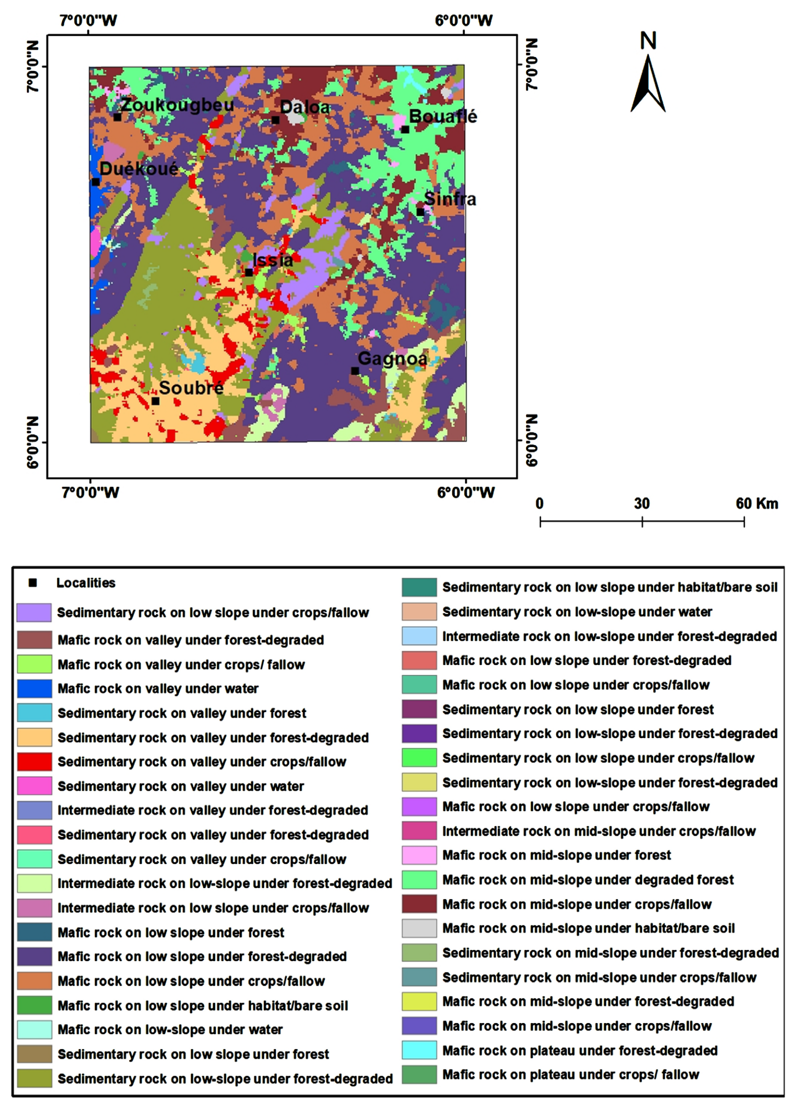

Figure 7. Soil landscape map by coding of Daloa.

The results obtained show a total of one hundred and three (103) soil landscapes for the M'Bahiakro square degree and one hundred and thirty (130) soil landscapes for the Daloa square degree. It was therefore necessary to reduce the number of classes by grouping them together using the most relevant variables, as was done by Eimberck M. and Joly B. (2008) [19]. The result is twenty-seven (27) and forty-one (41) soil landscapes for the square degrees of M'Bahiakro and Daloa respectively. It should be noted that each soil landscape obtained provides information on the participation of the criteria involved in modelling the soil cover of the environment. The M'Bahiakro square degree shows a soil-landscape cover dominated by acidic rocks at medium altitudes under savannah; forest/degraded forest and cultures/fallow. Mafic rocks follow this on moderate relief under savannah, water and crops/fallow. The Daloa area, on the other hand, has forty-one soil landscapes, with mafic rocks dominating the soil landscape, on low and mid-slopes under degraded forest and crops/fallow. This is followed by sedimentary rocks at moderate altitudes under forest/degraded forest and crop/fallow land. The difference in the number and characteristics of soil landscapes between zones is related to the geological formations found there.

However, difficulties may be encountered in this methodology (codification). This does not guarantee reliable (100%) prediction of results. The first difficulty concerns the choice of factors. The large number of criteria involved in soil landscape modelling makes prediction difficult. This was noted by Jourda (2005) in their study of fissured aquifers in West Africa [15]. According to this study, the coding method does not guarantee 100% results. Also, the accuracy of the results is influenced by the hydrological and hydrogeological regimes that condition erosive dynamics and landform configuration. For this reason, it is need to integrate a comprehensive harmonization methodology into digital soil mapping, in which it is essential to involve expert soil scientists and cartographers [22].

The second difficulty concerns the choice of rating scales ranging from 1 to 9, with their corresponding reciprocal weighting of criteria, as noted by Belton (1986) [23]. Indeed, the difficulty lies in the comparison of criteria, *i.e.*, which criteria are the most important and the most discriminating according to the scales.

Finally, the last difficulty lies in taking into account the different aspects for the orientation of decisions. Multicriteria analysis alone is incapable of taking into account all aspects of spatially referenced decision problems. For this reason, Kêdowidé (2010) and Ouédraogo and *et al.* (2012) suggest coupling it with GIS to obtain better results [24] [25].

5. Conclusion

At the end of this study, based on the application of the multicriteria analysis method using coding coupled with GIS, the analyses highlighted soil landscape units in forest (Daloa) and pre-forest (M'Bahiakro) zones. Twenty-seven soil landscapes were identified in the M'Bahiakro degree square. Acidic rocks are the most dominant in combination with different types of land use (savannah, degraded forest and crops/fallow). The Daloa area, on the other hand, has forty-one soil landscapes identified throughout the zone. Mafic rocks predominate on a moderate relief under different land uses (forest/degraded forest, water and crops/fallow). These results can be used as a guide for pedological prospecting.

Acknowledgements

The authors would like to express their gratitude to the "Conseil du Café et du Cacao" - CCC (project owner) and the "Fonds Interprofessionnel pour la Recherche et le Conseil Agricole" - FIRCA (delegated project owner) for funding the "Génération de Technologies pour l'amélioration de la productivité des vergers de cacacaoyers et de caféiers (2QC)" project, the Laboratory of Soil, Water and Geomaterials Sciences (LS2EG) of the Training and Research Unit of Earth Sciences and Mining Resources (UFR STRM) of the Félix Houphouët-Boigny University of Cocody-Abidjan and other partners for their support and backing for this study.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Koudou, A., Adiaffi, F., Assoma, T.V., Somba, A.P., Amani, E.M.E. and Biemi, J. (2013) Conception d'un outil d'aide à la décision pour la prospection des eaux souterraines en zone de socle du sud-est de la Côte d'Ivoire. *Revue internationale de géologie, de géographie et d'écologie tropicales*, **37**, 211-226.

[2] Koffi, K.M., Yao, K.T., Mobio, A. And Oga, Y.M.S. (2016) Apport de l'analyse multicritère à la cartographie des zones favorables à l'implantation de forages dans la région de Gagnoa (Centre-ouest de la Côte d'Ivoire). *Revue internationale de géologie, de géographie et d'écologie tropicales*, **40**, 327-344.

[3] ICCO (2015) What Are the Effects of Intensive Commercial Production of Cocoa on the Environment? Westgate House W5 1YY, United Kingdom. Rapport Annuel ICCO. 25 p.

[4] ICCO (International Cocoa Organization) (2014) Quarterly Bulletin of Cocoa Statistics, No. 4.

[5] N'Guessan, K.G., Assi, K.J.L. and Kra, K.T. (2021) Vieillissement du verger café/cacao et mutation de l'économie de plantation dans le département de Vavoua en Côte d'Ivoire. *International Journal of Humanities and Social Science Invention* (*IJHSSI*), **10**, 11-21.

[6] Assiri, A.A., Deheuvels, O., Keli, Z.J., Kebe, B.I., Konan, A. and Koffi, N. (2016) Identification de caractéristiques agronomiques pour le diagnostic et la prise de décision de régénération des vergers de cacaoyers en Côte d'Ivoire. *African Crop Science Journal*, **24**, 223-234. https://doi.org/10.4314/acsj.v24i3.1

[7] M'Bo, A.A.K., Mahyao, G.A., Kouadio, K., Okou, A.K., Brunelle, R. and Cherif, M. (2023) Variabilité climatique et devenir de la cacaoculture en Côte d'Ivoire d'ici 2050: Note de synthèse à l'attention des décideurs et décideuses, WASCAL, 10 p.

[8] Kassin, K.E., Koko, L., N'goran, K.E., Yao-Kouame, A. and Yoro, G.R. (2012) Sols

favorables à la cacaoculture au centre-ouest de la Côte d'Ivoire dans un contexte d'assèchement climatique. *International Journal of Biological and Chemical Sciences*, **6**, 1148-1157. https://doi.org/10.4314/ijbcs.v6i3.20

[9] Joerin, F. (1995) Méthode multicritère d'aide à la décision et SIG pour la recherche d'un site. *Revue internationale de géomatique*, **1**, 37-51.

[10] Joerin, F. (1998) Décider sur le territoire. Proposition d'une approche par utilisation de SIG et de méthodes d'analyse multicritère. Thèse de Doctorat ès Sciences Techniques, Ecole Polytechnique Fédérale de Lausanne.

[11] Yao, D., Delor, C., Gadou, G., Kohou, P., Okou, A., Konaté, S. and Diaby, I. (1990) Notion explication de la carte géologique feuille de M'Bahiakro; Mémoire SODEMI, Abidjan (Côte d'Ivoire).

[12] Kouamé, K.R., Kangah, B.A. and Koli. B.Z. (2019) Variabilité climatique dans le Centre-Est de la Côte d'Ivoire: Indicateurs, scénario actuels et futurs. *Revue de Géographie Tropicale et d'Environnement*, **20**, 7-20.

[13] Daouda, Y.B. (1998) Lithostratigraphie et pétrographie des formations birimiennes de Toumodi-Fêtêkro (Côte d'Ivoire). Implication pour l'évolution crustale du paléoprotérozoique du craton Ouest-africain. Thèse de Doctorat de l'Université d'Orléans, France.

[14] Brou, Y.T. (2005) Climat, mutation socio-économiques et paysages en Côte d'Ivoire. Mémoire de synthèse des activités scientifiques, Institut de Géographie Tropicale, 226.

[15] Jourda, J.P. (2005) Méthodologie d'application des techniques de télédétection et des systèmes d'information géographique à l'étude des aquifères fissurés d'Afrique de l'ouest. Concept de l'Hydrotechnique spatiale: Cas des zones tests de la Côte d'Ivoire, Thèse de doctorat ès Sciences Naturelles, Université de Cocody-Abidjan, Côte d'Ivoire.

[16] Youan Ta, M. (2008) Contribution de la télédétection et des systèmes d'information géographique à la prospection hydrogéologique du socle précambrien d'Afrique de l'ouest: Cas de la région de bondoukou (nord-est de la côte d'ivoire). Thèse unique de doctorat, Université de Cocody (Côte d'Ivoire).

[17] Youan Ta, M., Lasm, T., Jourda, J.P., Saley, B.M., Adja, M.G., Kouamé, K. and Biémi, J. (2011) Cartographie des eaux souterraines en milieu fissuré par analyse multicritère Cas de Bondoukou (Côte d'Ivoire). *Revue internationale de géomatique*, **21**, 4371. https://doi.org/10.3166/rig.21.43-71

[18] Youan Ta, M., Yao, K.A.F., Bakar, D., De Lasm, Z.O., Lasm, T., Adja, M. G., Kouakou, S., Onétié, Z.O., Jourda, J.P.R. and Biémi, J. (2015) Cartographie des zones potentielles à l'implantation des forages à gros débits en milieu fissure par analyse multicritère cas du département d'Oumé (centre-ouest de la Côte d'Ivoire). *Larhyss Journal*, **23**, 155-181.

[19] Eimberck, M. and Joly, B. (2008) Numérisation d'études pédologiques à moyennes échelles: Méthodologie et estimation des coûts, Etude et Gestion des Sols. *Etude et Gestion des Sols*, **15**, 51-68.

[20] Fritsch, E., Valentin, C., Morel, B. and Leblond, P. (1990) La couverture pédologique: Interactions avec les roches, le modelé et les formes de dégradation superficielles. Structure et fonctionnement d'un petit bassin versant, 31-57.

[21] Jamet, R. (1975) Pédogenèse sur roches cristallophylliennes et argileuses en milieu équatorial Congolais. Service pédologique 1er Fascicule, ORSTOM, 38.

[22] Benoit, G. (2017) Eau, agriculture et changement climatique. Statu quo ou anticipation? Rapport CGAAER n°16072-Annexe 1 - Eau, agriculture, et changement climatique:

Un état de l'art, 60.

[23] Belton, V. (1986) A Comparison of the Analytic Hierarchy Process and a Simple Multiattribute Value Function. *European Journal Operational Research*, **26**, 228-230. https://www.researchgate.net/publication/32980101 https://doi.org/10.1016/0377-2217(86)90155-4

[24] Kêdowidé, M.G.C. (2010) Modélisation géomatique par évaluation multicritère pour la prospection de sites d'agriculture à Ouagadougou. *VertigO - La Revue en Sciences de l'Environnement*, **10**, 20. http://vertigo.revues.org/10368 https://doi.org/10.4000/vertigo.10368

[25] Ouédraogo, L., Kaboré, O., Yanogo, P.I., Ouédraogo, B., Zoungrana, T.P. and Bouzou, M.I. (2012) Changement climatique et modèle spatial de gestion de l'eau pluviale dans le bassin versant de Yakouta, Burkina Faso, Revue de Géographie de l'Université de Ouagadougou, 1-20.