

Land Evaluation for the Development of Agriculture in Northern Area on Manado City, North Sulawesi

Berry Joseph¹, M. Luthfi Rayes², Arief Rahmansyah³ and Sudarto²

¹Doctoral Student at the Faculty of Agriculture, Brawijaya University, Jl. Veteran 2, Malang 65145, Indonesia, and a Lecturer at the Faculty of Agriculture, Sam Ratulangi University, Jl. Kampus Kleak, Manado 95115, North Sulawesi, Indonesia.

²Faculty of Agriculture, Brawijaya University, Jl. Veteran 2, Malang 65145, Indonesia

³Faculty of Engineering, Brawijaya University, Jl. Veteran 2, Malang 65145, Indonesia

Abstract: Agriculture sectors have its potentiality to develop in the north part area of Manado City, North Sulawesi. Success of the agriculture development has been influenced by the knowledge of land potential, especially its characteristics and capability. The aims of the study are to classify agricultural lands in northern area of Manado City and its chemical and physical characters. Based on the slope and landform analysis, this study confirms that soils in north Manado city can be classified into twenty four lands unit. There are two soils order, namely Inceptisols and Entisols. The Inceptisols orders consist of Udept and Aquept sub-orders, while Entisol has one sub order namely Aquent. Udept sub order contain single group namely Humudept with four sub group (i.e. Typic Humudepts, Oxidic Humudepts, Litic Humudepts, Pachic Humudepts). Sub order Aquept has one great group namely Endoaquept with one sub group called Humic Endoaquept. The Aquent sub-order contains great group namely Psammaquent and one great group namely Humaqueptic Psammaquent. Physical characteristics of soils shows that slopes can be classified into 0 – 3 %, 3 – 8 %, 8 – 15 %, 15 – 30 % and 30 – 45 % classes. Soil depth can be classified into deep, moderates and shallow soils. Land capability consists of class capability I, II, III and IV.

Keywords: Lands conservation, agro-tourism, North Sulawesi

I. Introduction

Land management is crucial aspect in sustainable urban and rural development. It is particularly important due to the past intensive development and exploitation led to the numerous land degradation. Soils have special characters which are important in land management. Soil is one of the important resources which have numerous important functions in ecosystem. Soils are important substrates for plant to grows, habitat of numerous microbes and soils biota, and space for natural organic material recycle which are important to provide nutrient for plant and soil biotic organism. Soil is also important in global water cycle.

There are physical and chemical characteristics of soils which are contribute to the land productivity and its availability to support biodiversity. Physical characters consist of soils texture, soils structure, soil consistency, soils porosity, soil temperature and soil color. Chemical characters consist of soil pH, cation-exchange capacity or CEC, base saturation, organic and nutrient soil content [1]. Color, texture, structure, morphology and mineral content are the important parameters to describes and assess the quality and characteristics of soil [2].

Soil types with its characteristics is one of the important factor in plant grows [3]. Therefore, classifying soils is become important steps in farming system and management. Soil classification contributes significantly in: (1) understanding about soils which is contributes to economic consideration, (2) providing data related relationship between soil class and soil biotic population, (3) identify soil traits for practical aspect, (4) understanding relationship and principles of soils population (5) establishing soil group, sub-division or class for practical and application purposes in (a) assessing soil traits, (b) identify the best usage, (c) assessing productivity, and (d) identifying object or unit to study soil [4].

Soil classification provides simple tools to describes the variation of soils characters simply without detail explanation [5]. Soils classification divided into natural classification and technical classification [6]. Natural classification is the classification based on the soil characteristic. This classification system provides basic description of physical and chemical characters of soil as well as soil minerals from each class as a basic consideration for soil use and management.

Every region has its lands characteristics which is representation of its natural environment. Therefore, studies about land characteristics were required for the proper land management and development. Some lands has its potentially to developed as agricultural area, but many lands is critical lands which were require technological intervention to improve land quality [7].

Land quality is the capacity of land to support highest biological productivity, conserve environmental quality and increase land and animals health [8]. In such a case several indicator has been used to assess land quality. The common indicators are encompasses physical, chemical and biological indicators. Indicator for lands quality should be able to: (1) shows the process which are occurs in ecosystem, (2) integrate physical and chemical soils characters with soil biology, (3) accepted by user and able to use in numerous field condition, (4) sensitive to numerous land management practices and climate changes (5) provide component of soil data [8].

North Sulawesi is one of the important areas for biodiversity conservation and sustainable development. Manado as a capital city of North Sulawesi has been grew significantly in the past decades. Tourism and agriculture sector contribute significantly in economic development. Land management in Manado city is therefore crucial to meet sustainable development agenda. Manado City covers an area about 15.727 Ha. It was dominated by farmland and orchards (ca. 11.267,35 Ha) and settlement and industrial area (ca. 3.329,60 Ha) [9]. Most of the northern area of Manado city was less developed. In order to maximize the potential resources of such lands, it is important to identify the land characteristics and its capability for agriculture activity. The aims of the study to classify agricultural lands in northern area of Manado City, soil's chemical and physical characters and lands suitability for agricultural practices

II. Materials and methods

This research was done in the northern area of Manado City, North Sulawesi. Material for the research consists of soils which were collected from twenty four land unit sites in research area. The profiles of the twenty four land unit were given in Table 1. The location of land unit area and its slopes attributes were identified using GPS (Garmin CSX76), altimeter (Vaude Gischar) and clinometer (Pm-5 Spc Opti Klinometer, Suunto). Soils analyses were performed through profiling methods. It was done by making soils holes by 2 m (length) x 1 m (width) x 1.5 m (depth) in size. In every soil sections, soils color, soils texture, soil structure, soil consistency, soil pore and roots performance were observed systematically [10].

Table 1. Land unit area in study sites

Land unit	Geology	Slope (%)	Landform
1	Limestone coral reefs	0 - 3	Coast
2	Quaternary volcanic rock	15 - 30	Alluvial Slopes
3	Quaternary volcanic rock	15 - 30	Alluvial Slopes
4	Quaternary volcanic rock	15 - 30	Vulkan Slope Central
5	Quaternary volcanic rock	30 - 45	Paralitic cone
6	Quaternary volcanic rock	8 - 15	Paralitic cone
7	Quaternary volcanic rock	8 - 15	River Flood Plain Not Meander
8	Quaternary volcanic rock	8 - 15	Volcanic plains
9	Quaternary volcanic rock	8 - 15	Coluvial Slopes
10	Tertiary Volcano rocks	0 - 3	Coluvial Slopes
11	Tertiary Volcano rocks	0 - 3	Lower Terrace
12	Tertiary Volcano rocks	0 - 3	Middle Terrace
13	Tertiary Volcano rocks	0 - 3	Volcanic plains
14	Tertiary Volcano rocks	0 - 3	Higher Terrace
15	Tertiary Volcano rocks	15 - 30	Volcanic plains
16	Tertiary Volcano rocks	15 - 30	Old Volcanic plains
17	Tertiary Volcano rocks	3 - 8	Volcanic plains
18	Tertiary Volcano rocks	3 - 8	Volcanic plains
19	Tertiary Volcano rocks	8 - 15	River Flood Plain Not Meander
20	Tertiary Volcano rocks	8 - 15	Volcanic plains
21	Tertiary Volcano rocks	8 - 15	Old Volcanic plains
22	Tertiary Volcano rocks	8 - 15	Old Volcanic plains
23	Tertiary Volcano rocks	8 - 15	Volcanic plains
24	Tertiary Volcano rocks	8 - 15	Volcanic plains

In order to describes soil physical and chemical characters, soil sample were collected from soil layers at 0-30 cm in depth and 30-100 cm in depth at twenty four point observation. Soils sample were analyzed in Soil Laboratory, Faculty of Agriculture Brawijaya University.

A. Sample preparation.

About 1 kg soil sample were collected from each soil layer 0 - 30 and soils layer 30 - 100 cm in depth. Such collection was done in all land unit area. Sample were dried about 6 - 10 days and strained to collect soil sample with 0,5 mm in size for further analysis.

B. Soil physical and chemical analysis.

Chemical analysis of soil were performed to identity Nitrogen (N) amount using Kjeldahl methods [11], C-Organic using Walkley-Black methods [12, 13], Phosphorus (P) using Bray-1 methods [14, 15, 16, 17,18] and Potassium (K) as well as CEC using NH₄OAc buffer pH 7.0 [18]. Soil classification was done following “Keys to Soil Taxonomy” methods from United State Department of Agriculture (USDA) [14].

C. Land capability class.

The evaluation of land capability were perform through evaluation of land slopes, erosion potential hazard, soil depth, soil texture, soil permeability, drainage, gravel, and flooding potential hazards.

D. Land suitability class.

Based on the framework of land evaluation [2] land characteristics and quality used in land evaluation criteria indicated in the Table 2.

Table 2. Land Characteristics And Quality Used In Land Evaluation Criteria.

Land Characteristics	Land Quality
Temperatures	The mean temperature or elevation
Availability of water	Rainfall, humidity and dry month
The availability of oxygen	Drainage
Rooting Depth	Drainage, texture, rough material, soil depth
Nutrient retention	CEC Clay, base saturation, pH H ₂ O and C-organic
Erosion hazard	Slopes and erosion danger
Flooding hazard	Pool
Land preparation	Outcrop rock surface and rock

III. Results and discussions

A. Soils classification.

Based on morphology properties and the laboratory analysis, soils consist of two order namely Inceptisols and Entisols. The inceptisols orders consist of Udept and Aquept sub-orders, while Entisol has one sub order namely Aquent. Udept sub order contain single group namely Humudept with four great group (i.e. Typic Humudepts, Oxic Humudepts, Lithic Humudepts, Pachic Humudepts). Sub order Aquept has one group namely Endoaquept with one group called Humic Endoaquept. The Aquent sub-order contains single group namely Psammaquent and one great group namely Humaqueptic Psammaquent. The classification was given in Table 3.

Table 3. Soils classification at North area of Manado City

Order	Great Group	Land Unit	Area (Ha)
Inceptisol	Typic Humudepts	1, 3, 4, 5, 6, 11, 13, 14, 17, 19, 21 dan 23	1819.56
	Oxic Humudepts	2, 7, 16, 18, 20 dan 22	1434.57
	Lithic Humudepts	8, 9 dan 15	314.17
	Pachic Humudepts	10	119.21
	Humic Endoaquept	12	133.10
Entisol	Humaqueptic Psammaquent	24	167.20

Inceptisols order has characteristics epipedon Umbrik with Kambik at lower horizon. This character similar with Inceptisols order criteria stated in “Keys to Soil Taxonomy”. Epipedon Umbrik has layer thickness about ≥ 18 cm, soil color was dark (value and chroma ≤ 3 (wet)), soil development stage were moderate, base saturation value < 50 % and N-Total < 0.7. The lower horizon of Kambik has sandy loam structure to clay. The identified Entisols order has some characteristics: found and distributes at 135 cm in depth, having epipedon okrik. This carracter not similar with the Entisols criteria which stated in “Keys to Soil Taxonomy” manuals. The characters of epipedon okrik found at horizon Ap, with less croma color, layer thickness about 15 cm and C-organic content was very low (0.09 %).

The identified Udepts sub orders has epipedon Umbrik and lower horizon Kambik, with dark color (value and chroma ≤ 3 (wet)), pH < 6.0 with temperature regime was Isohipertermik and land humidity was Udik. This character is similar with the sub ordo Udepts criteria in “Keys to Soil Taxonomy” as a soil characters references. Aquept Sub order found at soils at 50 cm in depth in aquic condition; color was chroma 2. These characters similar with Aquept sub order criteria as a stated in “Keys to Soil Taxonomy”. The identified Aquent Sub order has characterized aquic condition and sulfidik material in 50 cm in depth. This character is similar with the sub ordo Aquent criteria in “Keys to Soil Taxonomy”.

The existence of Humudepts group was characterized by epipedon Umbrik. This character is similar with Humudepts group criteria which were stated in “Keys to Soil Taxonomy”. The indentified Endoaquept

group was characterized by epipedon Umbrik and lower horizon Kambik, with soil color was dark (Value dan Chroma ≤ 3 (wet)), pH < 6.0 , soils temperature was Isohipertermic and soil humidity was Udik. This character is similar with the Endoaquept group as stated in "Keys to Soil Taxonomy". The identified Psammaquent group was characterized by loamy fine sand to rough at all layer of soils. This character is similar with reference keys in "Keys to Soil Taxonomy".

The identified Typic Humudepts Great group was found at soils at > 90 cm in depth, having epipedon Umbrik and lower horizons Kambik, soil color was dark (Value and Chroma ≤ 3 (wet)), pH < 6.0 , base saturation $< 50\%$, soil temperature was Isohipertermic and soil humidity was Udik. This characteristics was similar with Typic Humudepts great group which was characterized in "Keys to Soil Taxonomy". Oxic Humudepts Great group was identified in soil at > 90 cm in depth. This character is similar with the soil character in the "Keys to Soil Taxonomy". The identified Litic Humudepts Great group with litic was found at soil at < 50 cm in depth. This characteristic was similar with Litic Humudepts great group at the "Keys to Soil Taxonomy" manuals. The identified Pachic Humudepts Great group has characters epipedon Umbrik at > 50 cm. This character is similar with Pachic Humudepts great group at "Keys to Soil Taxonomy" manual. The identified Humic Endoaquept Great group has dark soil color and Chroma ≤ 3 (wet) with base saturation about $< 50\%$. The identified Humaqueptic Psammaquent Great group has color or less and has base saturation less than 50% . These criteria of Humaqueptic Psammaquent great group same with the characteristics in "Keys to Soil Taxonomy".

B. Land characteristics.

Land characters in northern area of Manado city was characterized by physical and chemical aspect. Physical characters encompasses slope, soil depth, soils texture, drainage, permeability, stone on soil surface, erosion and flooding hazards. The chemical characters consist of pH, nutrient content, CEC and base saturation [10].

Result of the physical characteristics shows that land in northern Manado has numerous slope category, namely : 0–3 %, 3–8 %, 8–15 %, 15–30 % and 30–45 %. The highest percentage of slopes were category 8–15 % (33.77 %) and slope category 15–30 % (21.91 %). Soil depth consists of deep, moderates and shallow. Deep soil category was dominant (> 90 cm). This category was found at 18 land unit observation. Soils texture was identified ranging from smooth, slight smooth, slight rough to rough. Soil drainage was good. Soils permeability ranging from low, slight low and moderate. The majority of soil permeability was slight slow. It was found at 17 land unit area. There are no stone under diameter < 25 cm in soil surface. There are no exposed the rocks exposed group were found, or less. Erosion hazard in the study area was ranging from several category namely without erosion hazard, low hazard, and moderate. The majority of area was dominated by land without erosion potential hazard to low potential hazard. It was found at 16 land unit area. According the local dweller, there are no flooding incidents.

Chemical evaluation of the soil confirms that soil in northern Manado has pH < 6 . It was found in all soil layers. This data shows that the soil in northern Manado is acid and the ability to accumulate nutrient was low. Moreover, soil with pH < 6 little bit poisonous to many soil organism. The C-organic content of the soils at 0 – 100 cm in depth were very low, low and moderates. This C-content data shows that basically soils has insufficient nutrient to support plant to grow with high productivity. N content at 0 – 100 cm in depth ranging from very low, low to moderate. Phosphor content in soil at 0 – 100 cm in depth in all land unit $< 10 \text{ Kg}^{-1}$, and it is classified as low category. Potassium (K) content at soils at 0 – 100 cm in depth was ranging from low, moderate to high. CEC value in soil at 0 – 30 cm in depth were ranging from low, moderate to high, while in 30 – 100 cm in depth it were ranging from low to moderate. The value of soil base saturation at 0 – 30 cm in depth were low to medium; while at 30 – 100 cm in depth consist of two category, namely moderate to high. Overall, the nutrient content was insufficient to support plant grows in optimum condition. In order to increase land capability to support agriculture practices, the application of fertilizer were recommended. It is especially important to increase chemical properties of soils.

C. Land Capability.

Based on the land suitability evaluation, the land in northern Manado can be classified into four classes, namely land capability class I, II, III and IV. Land capability class I covers an area about 709.91 Ha or 17.80 % of the total research area. This class was suitable for numerous agricultural practices, animals grazing area, and forest conservation. The uses of such land, however, require proper land management. Increasing crop productivity can be done through organic fertilizer applications, crops rotation, and the uses of mulch. This class was characterized by: (a) ranges of slope about 0 – 3 %, or flat (b) there are no erosion potential hazard (c) soil thickness was moderate to depth (d) good drainage and (e) safe from flooding.

Land capability class II covers an area about 547.10 Ha or 13.72 % of the total research area. This land can be used as agricultural farm through terrace management, rotation and mulch application. This class

characterized by: (a) range of slope about 3 – 8 % or sloping, (b) less erosion potential hazards, (c) soils depth was deep, (d) soils texture were slightly rough, (e) soil permeability was low, (f) drainage was good, (g) gravel < 25 cm; and there are no gravel > 25 cm soils surface, and (h) safe from flooding.

Land capability class III covers an area about 1346.76 Ha or 33.77 % of the total research area. It is able to use to cultivate annual crops, animals grazing, forest production, protected forest and wildlife sanctuary. This class characterized by slope about 8 – 15 % or slightly sloping.

Land capability class IV covers an area about 1384.04 Ha or 34.71 % of the total research area. There still possibility for agriculture practices by practicing terrace, rotation system and using mulch. This class characterized by slope about 15 – 30 % and 30 – 45 % or slightly sloping and slightly steep.

D. Land Suitability Evaluation.

Land evaluation is needed to determine the suitability class Goroho Banana plants (*Musa acuminata* sp), Gapi Banana (*Musa paradisiaca* sp), Papaya (*Carica papaya* L), Kuini Mango (*Mangifera odorata* sp), Rambutan Takupas (*Nephelium lappaceum* L) and Mangosteen (*Garcinia mangostana* L) of each of land units. Land suitability classes physically demonstrate the suitability of land physically by seeing the biggest limiting factor in each land unit. The main divider used in the evaluation of this land is the temperature, availability of water, availability of oxygen, nutrient retention and erosion [6].

Limiting factor in plant growth when comparing the suitability class object plant agrotourism with the actual land suitability class is the elevation (e), the state of rooting (rc), the availability of nutrients (nr) and erosion (eh). The actual land suitability classes with an inhibiting factor for crop agro objects presented in Table 4.

Table 4. Sub Class Land Suitability.

Land Unit	Goroho Banana	Gapi Banana	Papaya	Kuini Mango	Rambutan Takupas	Mangosteen
1	S1	S1	S1	S1	S1	S1
2	S2e,rc,nr,eh	S2e,rc,nr,eh	S2rc,nr,eh	S2rc,nr,eh	S2rc,nr,eh	S2rc,nr,eh
3	S1	S1	S1	S1	S1	S1
4	S1	S1	S1	S1	S1	S2rc,nr,eh
5	S1	S1	S1	S1	S1	S1
6	S1	S1	S1	S1	S1	S1
7	S2e,rc,nr,eh	S2e,rc,nr,eh	S2rc,nr,eh	S2rc,nr,eh	S2rc,nr,eh	S2rc,nr,eh
8	S3e,rc,nr,eh	S3e,rc,nr,eh	S3rc,nr,eh	S3rc,nr,eh	S3rc,nr,eh	S3rc,nr,eh
9	S3e,rc,nr,eh	S3e,rc,nr,eh	S3rc,nr,eh	S3rc,nr,eh	S3rc,nr,eh	S3rc,nr,eh
10	S1	S1	S1	S1	S1	S1
11	S1	S1	S1	S1	S1	S1
12	S2e,rc,nr,eh	S2e,rc,nr,eh	S2rc,nr,eh	S2rc,nr,eh	S2rc,nr,eh	S2rc,nr,eh
13	S1	S1	S1	S1	S1	S1
14	S1	S1	S1	S1	S1	S1
15	S1	S2e,rc,nr,eh	S1	S1	S1	S1
16	S1	S1	S1	S1	S1	S1
17	S1	S1	S2rc,nr,eh	S1	S1	S1
18	S1	S1	S1	S1	S1	S1
19	S1	S1	S1	S1	S1	S1
20	S2e,rc,nr,eh	S2e,rc,nr,eh	S2rc,nr,eh	S2rc,nr,eh	S2rc,nr,eh	S2rc,nr,eh
21	S1	S1	S1	S1	S1	S1
22	S1	S1	S1	S1	S1	S1
23	S1	S1	S1	S1	S1	S1
24	S1	S1	S1	S1	S1	S1

IV. Conclusion

There are about six soils great group, namely Typic Humudepts, Oxic Humudepts, Litic Humudepts, Pachic Humudepts, Humic Endoaquept and Humaqueptic Psammaquent. Physical characteristic of soils shows that slopes ranging from: 0-3 %, 3-8 %, 8-15 %, 15-30 % and 30-45 %. Soil deep are ranging from shallow, moderated to deep. Soil textures consist of Clay, Sandy Clay, Loam, Sandy Clay Loam, Sandy Loam and Sand. Soil has good drainage, and soils permeability was ranging from slow, slightly slow, and slightly rapid. Erosion hazards ranging from without potential hazards, less and moderate. There are no water accumulation and flooding potential hazard. Chemical analysis confirms that soils in study area have less C-organic and CEC. In order to increase farmland productivity, there are need organic fertilizer. Soil class suitability was classified into four classes, namely land suitability class I, IIe, IIIe and IVe. Compliance plant species evaluated very suitable (S1) for almost all existing land unit research area except 2, 7, 12 and 20 which includes S2 for all plants with the same barrier to the elevation (e), the state of rooting (rc), nutrient availability (nr) and erosion (eh). While other land units were classified as marginally suitable (S3) for all plants.

Acknowledgements

This research was supported by a scholarship research grant from the Indonesian Government. We grateful to the Rector of University of Brawijaya Malang and Rector of the University of Sam Ratulangi, Manado for permission on research and study in Brawijaya University.

References

- [1]. P. Buringh, Introduction to the Study of Soils in Tropical and Subtropical Regions (Center Agricultural Pub & Document, 1979).
- [2]. FAO, A Framework for Land Evaluation (Soil Resources Management and Conservation Service Land and Water Development Division, 1976).
- [3]. M.I. Darmawijaya, Klasifikasi Tanah: Dasar Teori Bagi Peneliti Tanah dan Pelaksana Pertanian di Indonesia (Gadja Mada University Press, Yogyakarta, 1997).
- [4]. S. Ritung, Wahyunto, F. Agus dan H. Hidayat. Panduan Evaluasi Kesesuaian Lahan Dengan Contoh Peta Arahan Penggunaan Lahan Kabupaten Aceh Barat (Penerbit Balai Penelitian Tanah Dan World Agroforestry, 2007).
- [5]. Pusat Penelitian dan Pengembangan Agroklimat. Jurnal Warta Penelitian dan Pengembangan Pertanian Vol. 24 No. 1. 2002
- [6]. D. Djaenudin H. Marwan, H. Subagy., A. Mulyani., N. Suharta. Kriteria Kesesuaian Lahan Untuk Komoditas Pertanian. (Penerbit Badan Penelitian Dan Pengembangan Pertanian Departemen Pertanian, Bogor, 2003).
- [7]. J.W. Doran and T.B. Parkin, Defining and Assessing Soil Quality, in J. W. Doran, D. C. Coleman, D. F. Bezdicek, and B. A. Stewart (Eds.) Defining Soil Quality for a Sustainable Environment. SSSA Special Publication 35. Washington DC, 1994, 1-21.
- [8]. D. L. Johnson, S. H. Ambrose, T. J. Bassett, M. L. Bowen, D. E. Crummey, J. S. Isaacson, D. N. Johnson, P. Lamb, M. Saul, and A. E. Winter-Nelson, Meanings of Environmental Terms, *J. Environ. Qual.*, 26, 581-589, 1997.
- [9]. BPS, Manado City in Figures 2009. (BPS Statistics of Manado City Manado, 2009).
- [10]. M. L. Rayes, Metode Inventarisasi Sumber Daya Lahan. (Penerbit Andi Yogyakarta., 2007).
- [11]. J. M. Bremner, Determination of nitrogen in soil by the Kjeldahl method, *The Journal of Agricultural Science*, 55, 11-33, 1960.
- [12]. F. Evrendilek, I. Celik, and S. Kilic, Changes in soil organic carbon and other physical soil properties along adjacent Mediterranean forest, grassland, and cropland ecosystems in Turkey, *Journal of Arid Environments*, 59, 743-752, 2004.
- [13]. A. Walkley and I. A. Black, An Examination of the Degtjareff Method for Determining Soil Organic Matter, and A Proposed Modification of the Chromic Acid Titration Method, *Soil Science*, 37, 29-38, 1934.
- [14]. I. Miralles, R. Ortega, G. Almendros, M. Sánchez-Marañón, and M. Soriano, Soil quality and organic carbon ratios in mountain agroecosystems of South-east Spain, *Geoderma*, 150, 120-128, 2009.
- [15]. S. Dragovic and A. Onjia, Classification of soil samples according to geographic origin using gamma-ray spectrometry and pattern recognition methods, *Applied Radiation and Isotopes*, 65, 218-224, 2007.
- [16]. S. R. Dickman and R. H. Bray, Colorimetric Determination of Phosphate, *Industrial & Engineering Chemistry Analytical Edition*, 12, 665-668, 1940.
- [17]. F. S. Watanabe and S. R. Olsen, "Test of an Ascorbic Acid Method for Determining Phosphorus in Water and NaHCO₃ Extracts from Soil," *Soil Sci. Soc. Am. J.*, vol. 29, pp. 677-678, 1965.
- [18]. D. H. Pote, T. C. Daniel, P. A. Moore, D. J. Nichols, A. N. Sharpley, and D. R. Edwards, "Relating Extractable Soil Phosphorus to Phosphorus Losses in Runoff," *Soil Sci. Soc. Am. J.*, vol. 60, pp. 855-859, 1996
- [19]. Soil Survey Staff, Keys to Soil Taxonomy, 11th ed. Washington, DC: USDA-Natural Resources Conservation Service, 2010.