technological process of their creation. It was proposed approach, which will create a modern soil GIS with the most adapted data set, easily to use, scalable and dynamically supplemented. Created GIS with minimal alterations can be integrated into the national geospatial data infrastructure and develop within it. It was highlighted the use of free open source software that is distributed free under the GNU GPL.

Keywords: *large-scale soil map, digital elevation models (DEM), geoinformation system (GIS), coordinate system, predictive soil mapping, multinomial logistic regression, GRASS GIS.*

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LAND SUITABILITY EVALUATION OF OGOCHIE RIVER WETLAND SOILS IN NGOR-OKPALA LOCAL GOVERNMENT AREA OF IMO STATE SOUTHEASTERN NIGERIA FOR RAIN FED RICE PRODUCTION.

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In a bid to contribute to food sufficiency and sustainability of rice production in Nigeria, we carried out the study on the land suitability evaluation of Ogochie river wetland soils in NgorOkpala Local Government Area of Imo State, South-eastern Nigeria. Three topounits were identified as footslope, midslope and summit and were connected by a transect using Global Positioning System (GPS). A profile pit was dug on each topounit. Both soil description and land suitability evaluation were carried out according to FAO guidelines. Soil samples were collected from each horizon, air dried and sieved for standard routine analysis. The soils were shallow in depth and imperfectly to poorly drained. Sand dominated the texture of the soils which was classified as sandy loam. Bulk density and porosity ranged between 0.82-1.68g/cm^3 and 36.6-69.2% respectively. All soils recorded acidic soil reaction (5.28-5.37). The fertility levels of all soils were low having organic matter (0.4-1.68 %), total exchangeable bases (2.68-3.18 cmol/kg), effective cation exchange capacity (3.38-4.11 cmol/kg) and available phosphorus (1.03-2.04 ppm). However, total exchangeable acidity was high (0.7-0.8 cmol/kg) depicting acidity of soils studied. Percentage base saturation was high (76.6-80.1%) but not sufficient for optimum rice production. The soils were non saline with electrical conductivity values less than 1dsm^{-1}.The soils of the study area were evaluated as being marginally suitable (S3) for rain fed rice production, with footslope having limitations in fertility, soil texture and depth. Midslope had limitations in fertility and soil texture while summit had limitations in fertility, soil texture and topography.

Keywords: *wetlands, soil, rice, land suitability evaluation, southeastern Nigeria.*

Introduction. Wetland soils are soils formed under conditions of saturation, flooding or ponding long enough during the growing season to develop anaerobic conditions on the soil surface. Wetlands have been neglected and underutilized in the past, thus have been reviled as disease ridden wastelands and actively drained. The rapid increase in population, urbanization and industrialization has led to the recognition of wetlands for agricultural production in Nigeria. Drained wetlands are among the most productive agricultural and forest soils, having relatively level topographic position, high organic matter content, high nutrient level and acting as both source and sink due to their role as transitional ecosystem between the aquatic and terrestrial ecosystems. The occurrence of wetland soils in Nigeria has been associated with three landforms namely; inland depressions, floodplains and coastal plains [1]. These soils are boom grounds for swamp rice [2] and can produce other crops such as banana, sugar cane, cocoa and coffee.

Rice is a staple food in many countries in Africa and is considered to have recorded a fastest growth in consumption in Nigeria. It has been reported that Nigeria loses N1bn daily to rice importation as the demand for rice in Nigeria is about 5 million tonnes yearly and the domestic production is less than 3 million tonnes which makes the importation of rice into the country more than 2 million tonnes.

Despite the good natural conditions for rice cultivation in Nigeria, the low level of its production is quite appalling. However, this triggered the study on the suitability evaluation of Ogochie river wetland soils for rice production in Nigeria.

Materials and Methods. Ogochie River is located at Ngor-Okpala Local Government Area of Imo State which lies between latitudes 5º20´N and longitude 7º8´E with an elevation of 52 m above sea level. The hydrology of Ogochie River is governed by Imo River and affected by tides, although seasonal influences which are related to the climatic regime are evident. The area lies within the humid tropics with a mean temperature range of 26-29 ºC. The climate of the area is characterized by distinct wet and dry seasons. The wet season begins in April and lasts till November, while the dry season begins in November till March. A short period of draught is usually experienced in July and August, while a period of harmattan characterized by cold dry winds and lower temperatures normally occurs between December and February [3, 4].

The relative humidity is high throughout the year especially in rainy season averaging 85 %. The mean annual rainfall ranges from 2500-3000 mm [5].The major parent material in the study area is the coastal plain sands and flood plains (Benin formation and Deltaic deposits) and marine deposits. The area has generally a lowland geomorphology, less than 80 m above sea level. They belong to the group of soils termed the acid sands in southern Nigeria [6].

A reconnaissance visit was carried out with the aid of a location map of the study area to identify the areas to be studied and the locations were georeferenced using a global positioning system (GPS) receiver (table 1). A combination of transect and random sampling techniques were used as a traverse was cut along the river bank in sampling.

Three topounits were identified namely footslope, midslope and summit and a profile pit was dug in each topounit and described using FAO (2006), (2006) procedures. Surface humidity was dry at the time of sample collection, which was in the dry season month of December 2012. Core samples were collected from each horizon. Samples were collected from the bottom to the top according to horizon differentiation in each profile pit and the maximum depth of soil examination differed for each pit. Soil samples were air-dried, gently crushed, sieved using 2-mm sieve and analysed in the laboratory.

Table 1. Location of pedons

Pedon number	*Coordinates*		*Elevation, m*	*Physiographic unit*
Pedon 1	Lat.$5^{0}20^{1}10.7^{11}$N,	Long. $7^{0}8^{1}48.1^{11}$E	45	Footslope
Pedon 2	Lat.$5^{0}20^{1}19.3^{11}$N,	Long. $7^{0}8^{1}47.2^{11}$E	46	Midslope
Pedon 3	Lat.$5^{0}20^{1}24.9^{11}$N,	Long. $7^{0}8^{1}47.2^{11}$E	46	Summit

Laboratory Analysis. Particle size distribution was determined by hydrometer method according to the procedure of [7]. Bulk Density was measured using core method as [8] recommended. Soil pH was determined in 1:2.5 soil liquid ratios in water and 0.1N KCl using pH meter [9].Organic carbon was determined using wet oxidation method described by [10, 11]. Available phosphorus was determined using Bray II solution method [12]. Electrical conductivity was measured in 1:2 saturation extract [13]. Exchangeable bases (magnesium, calcium, sodium and potassium). Exchangeable Na and K were extracted using 1*N* NH_4OAc using flame photometer [14], while Ca and Mg were determined using ethelenediaminetetracetic acid (EDTA) [15]. Total nitrogen was determined by Kjehdahl digestion method [14, 16]. Exchangeable acidity was determined titrimetrically [17]. Effective cation exchange capacity (ECEC) was calculated from the summation of all exchangeable bases and exchangeable acidity [18]. Percentage base saturation (% BS) was determined by calculation.

Land evaluation. The data collected on soils were used in comparing the land use with the land qualities and characteristics to determine which land unit is most suited for rain fed rice cultivation. The parameters used for the evaluation of soils were soil depth, texture, drainage, pH, available P, organic matter content, ECEC, base saturation and electrical conductivity while environmental factors were climate and topography. The suitability of each factor for respective soil unit was classified as highly suitable (S1), moderately suitable (S2), marginally suitable (S3) or not suitable (N).

Results and Discussion. Soil Properties. Although wetland soils in reduced state typically have dark, grey, mottled appearance with chroma colour of less than or equal to 2, the soils in the study site were characterised with strong brown, reddish brown, reddish yellow to yellowish red colour matrix of hues of 7.5 to 5 years and chroma values of 4-8 in all horizons. These colours indicate a relatively high amount of iron oxide, which may be due to the parent material. The structural development of the soils in the study site ranged from fine-weak to massive-strong sub-angular blocky peds. In moist state, the soils were friable and firm, soils were observed in dry consistence to be hard to extremely hard as depth increases. The main factor influencing the structure of floodplain soils is the hydrology/water table. Also, due to the concentration of Fe^{+} and Al^{+}, the soils harden to form nodules and concentrations. However, such hardened features, unless they have gradual or diffuse boundaries with surrounding matrix are indicative relict rather than contemporary saturation. The soils of the study site were imperfectly to poorly drained, therefore, base presence of roots decreased with depth in all pedons due to high water table.The textural characteristics of the soils studied showed that sand content were predominant having values above 800 g/kg (table 2). The soils were categorized under the sandy loam textural class. High bulk density and porosity were recorded in the study area which ranged between 0.82-1.68 g/cm^3 and 36.6-69.2 %. This is an indication of mineral soil dominance and high water absorption capacity. Bulk density increased down the profile, presence of organic matter was responsible for lower bulk density and high porosity recorded at the epipedon. Soils located at the footslope recorded the highest bulk density, followed by summit and midslope respectively.

Table 2. Some physical properties of soils studied

Physiographic unit	*Horizon*	*Depth, cm*	*Particles content, g/kg*			*Texture*	*MC, g/kg*	*BD, g/cm^3*	*Total porosity,%*
			Sand	*Silt*	*Clay*				
Footslope	Ap	0-14	804	0	196	LS	353	1.59	40.0
	Bt1	14-28	944	0	56	SL	492	1.62	38.9
	Bt2	28-43	824	20	156	SL	522	1.83	31.0
	Mean	**-**	***857***	***7***	***136***	***SL***	***456***	***1.68***	***36.6***
Midslope	Ap	0-14	844	40	116	LS	128	0.34	87.2
	Bt1	14-26	804	60	136	LS	139	0.55	79.3
	Bt2	26-67	824	20	156	SL	297	0.61	77.0
	Bt3	67-80	824	20	156	SL	324	1.22	54.0
	Btg	80-85	804	40	156	SL	478	1.36	48.7
	Mean	-	*820*	*36*	*144*	*SL*	*273*	*0.82*	*69.2*
Summit	Ap	0-14	844	20	136	LS	198	0.39	85.3
	Ab	14-27	744	40	216	SCL	202	0.77	71.0
	Bt1	27-66	787	20	196	SL	300	1.11	58.2
	Bt2	66-83	904	0	96	S	346	1.25	52.9
	Bt3	83-97	844	20	136	LS	441	1.44	45.7
	Mean	-	*824*	*20*	*156*	*SL*	*297*	*0.99*	*62.6*

Texture: S = Sand, LS = Loamy sand, SL = Sandy loam, SCL = Sandy clay loam

The pH of the study area were strongly to slightly acidic with footslope recording values of 5.37, followed by midslope 5.33 and summit 5.28 (table 3). This indicates the presence of Al^{+} and H^{+} ions in the soil exchange complex [19] and low organic matter levels.

Table 3. Some chemical properties of the soils studied

Physio-graphic unit	Depth, cm	pH H_2O	pH KCl	O.M., %	Al^{3+}	H^+	TEA	T.N, %	Ca^{++}	Mg^{++}	K^+	Na^+	TEB	ECEC	BS, %	AV.P, (ppm), %	Al %	EC, dSm^{-1}
					cmol/kg				cmol/kg									
Footslope	0-14	5.23	4.11	0.62	0.7	0.3	1	0.03	1.6	0.8	0.17	0.07	2.64	3.64	72.5	1	19.23	0.11
	14-28	5.18	4.28	0.17	0.2	0.1	0.3	0.01	1.2	0.8	0.27	0.06	2.33	2.63	88.5	1.1	7.6	0.10
	28-43	5.71	3.76	0.41	0.4	0.4	0.8	0.02	1.6	1.2	0.12	0.16	3.08	3.88	79.3	1.02	10.31	0.08
	Mean	5.37	4.05	0.4	0.4	0.3	0.7	0.02	1.5	0.9	0.19	0.10	2.68	3.38	80.1	1.04	12.38	0.1
Midslope	0.14	5.04	4.06	1.1	0.5	0.3	0.8	0.05	1.6	0.8	0.23	0.08	2.71	3.51	77.2	1.86	14.25	0.10
	14-26	4.96	3.89	0.96	0.5	0.2	0.7	0.04	1.6	1.2	0.26	0.13	3.19	3.89	82	0.85	12.85	0.10
	26-67	5.51	4.06	0.82	0.7	0.3	1	0.04	1.6	0.4	0.27	0.06	2.33	3.33	69.9	0.55	21.02	0.11
	67-80	6.43	3.94	1.27	1.1	0.1	1.2	0.06	2.4	1.2	0.22	0.09	3.91	5.11	76.5	0.47	21.53	0.13
	80-85	4.69	3.83	1.03	0.4	0.4	0.8	0.05	2	1.6	0.11	0.03	3.74	4.54	82.3	6.45	8.81	0.11
	Mean	5.33	3.96	1.04	0.6	0.3	0.9	0.05	1.8	1.0	0.22	0.08	3.18	4.08	77.6	2.04	15.69	0.11
Summit	0-14	5.05	3.9	2.03	0.8	0.2	1	0.1	3.2	1.2	0.25	0.11	4.76	5.76	82.6	0.60	13.89	0.11
	14-27	5.27	4.08	4.1	0.7	0.2	0.9	0.2	2.0	1.2	0.14	0.17	3.51	4.41	79.5	1.54	15.87	0.10
	27-66	5.74	3.86	0.68	0.9	0.2	1.1	0.03	1.6	0.8	0.21	0.08	2.69	3.79	70.9	0.36	23.75	0.12
	66-83	4.84	3.83	0.2	0.9	0.2	0.8	0.01	1.2	0.4	0.28	0.06	1.94	2.74	70.8	0.32	21.90	0.10
	83-97	5.19	3.9	1.37	0.6	0.2	0.8	0.06	1.6	1.2	0.17	0.07	3.04	3.84	79.1	2.31	15.63	0.10
	Mean	5.28	3.91	1.68	0.7	0.2	0.9	0.08	1.9	0.1	0.21	0.10	3.11	4.11	76.6	1.03	18.2	0.11

O.M. = Organic matter, Al= Aluminum, Ca= Calcium, Mg= Magnesium, P= Phosphorus, K= Potassium, Na= Sodium, TEA= Total exchangeable acidity, T.N= Total nitrogen, TEB= Total exchangeable bases, ECEC= Effective cation exchange capacity, BS= Base saturation, AV.P= Available phosphorus, EC= Electrical conductivity.

Footslope recorded the least organic matter content of 0.4 % compared to midslope 1.04 % and summit 1.68 %. Low organic matter is as a result of submergence of surface soil, causing anaerobic condition and inhibiting ripening environment. Total exchangeable acidity recorded high values, slightly below the critical toxicity value of 2.0 cmol/kg. This makes plant nutrients unavailable such as phosphorus, molybdenum as well as other basic cations, thus increases toxicity levels of Aluminium and Manganese.

Percentage base saturation ranged between 76.6-80.1 %, above 50 % the separating index between fertile and less fertile soils. M. Astera [20] noted that the strongest, healthiest and more nutritious crops are grown in soils having percentage base saturation of above 90 %. The ECEC values were low between 3.38-4.11 cmol/kg, this is as a result of high annual precipitation, low amount of basic cations, low activity clays and low buffering capacity to retain them against leaching. ECEC values <8-10 cmol/kg are stipulated as indicative minimum values in the top 30 cm for soils for satisfactory crop production in wet soils [21].

Available P content of the soils was low between 1.03-2.04 ppm. At low pH and solubility of Al and Fe hydroxyl, P is considered very low and this explains the reasons for high P fixation in wetland soils. High moisture level and sandy soil texture are also contributory factors. Electrical conductivity of the study site was less than 2 $dsm^{-1,}$ indicating non saline nature of the soils and fresh water status of the hydrology of the study area.

Land Suitability Evaluation. Results on the land suitability rating of the Ogochie river wetlands showed that the mean annual rainfall of the study area was above 1200 mm (Tables 4 and 5) and were rated as highly suitable (S1). The temperature of the study area was isohyperthermic (above 22 $^{\circ}C$) and rated as highly suitable (S1). On the basis of elevation, all topounits were below 50 m, thus were rated highly suitable (S1). Footslope and midslope recorded a rating of highly suitable (S1)having a slope gradient description of flat and level respectively while summit was moderately suitable (S2) having slope gradient description of nearly level. Sand dominated the texture of all soils studied and were rated as marginally suitable (S3), as the textural class of the soils were sandy loam. Footslope had a depth of 43 cm due to high water table and was rated as marginally suitable (S3) as crops may be lost in excess rainfall while midslope and summit had depths greater than 75cm, thus were rated as highly suitable (S1). Footslope was poorly drained, having a high suitability (S1) rating while midslope and summit were imperfectly drained and rated moderately suitable (S2). Stones and rock outcrops were not observed in all soils studied, therefore the soils were rated as high suitable (S1). The pH of all soils studied was acidic between 5.0-5.5 and rated as marginally suitable (S3). Organic matter contents of all soils were rated as being marginally suitable (S3). The Potassium content of the soils of the study site was moderately suitable (S2). The phosphorus content in all soils studied was less than 5ppm, thus rated as marginally suitable (S3). The footslope and midslope were rated as marginally suitable (S3) while summit was rated as moderately suitable (S2) in terms of calcium levels in the soils. The magnesium content of all soils studied was rated as marginally suitable (S3). Footslope and midslope recorded percentage base saturation suitability rating as moderately suitable (S2) while summit was highly suitable (S1) above 80 %. Total nitrogen in all soils was below 0.1 % and classified as marginally suitable (S3). The electrical conductivity of the soils were highly suitable (S1) as all soils recorded EC values less than 3 dms^{-1}, an indication that the soils are non-saline. The overall suitability of the soils studied showed that all topounits were marginally suitable (S3), with footslope having limitations in fertility, soil texture and depth, Midslope had limitations in fertility and soil texture with summit had limitations in fertility, soil texture and topography.

Table 4. Rating of land use requirement for rain-fed rice

Land qualities	*Factor suitability rating*			
	S1	*S2*	*S3*	*N*
Climate				
Rainfall (mm)	800-1200	700-800	600-700	<600
Temperature (ºC)	24-28	22-24	18-22	<18
Land/soil properties				
Elevation (m)	0-600	600-1200	1200-1800	>1800
Slope (%)	<1	1-2	2-4	>4
Soil texture	C, SiC, CL	SC, SiC, SiL	SL, L, SCL	S, LS
Soil depth (cm)	>75	50-75	25-50	<25
Drainage	Poorly drained	Moderately drained	Imperfectly drained	Well drained
Stones and rock outcrops (%)	nil	1-5	5-10	>10
pH	6.0-6.5	5.5-6.0	5.0-5.5	<5.0
Organic matter (%)	>3.5	2.5-3.5	<2.5	Any
Avail. P (ppm)	>15	6.15	<5	Any
K (cmol/kg)	>0.31	0.11-0.30	<0.11	Any
Ca (cmol/kg)	6-12	3-6	<3	Any
Mg (cmol/kg)	6-12	3-6	<3	Any
BS(%)	>80	40-80	20-40	<20
TN (%)	>0.2	0.1-0.2	0.05-0.1	<0.05
EC (dsm^{-1})	<3	3-5	5-7	>7

S1= Highly Suitable, S2= Moderately Suitable, S3= Marginally Suitable, N= Not Suitable
Culled from AkwaIbom State Ministry of Agriculture publication, Vol. II, 2003 and FAO 1983

Table 5. Suitability assessment of Ogochie river wetland soils for rain fed rice production

Land qualities	Factor suitability rating		
	Footslope	Midslope	Summit
Climate			
Rainfall (mm)	S1	S1	S1
Temperature (ºC)	S1	S1	S1
Land/soil properties			
Elevation	S1	S1	S1
Slope (%)	S1	S1	S2
Soil texture	S3	S3	S3
Soil depth (cm)	S3	S1	S1
Drainage	S1	S2	S2
Stones and rock outcrops (%)	S1	S1	S1
pH	S3	S3	S3
Organic matter (%)	S3	S3	S3
Avail. P (ppm)	S3	S3	S3
K (cmol/kg)	S2	S2	S2
Ca (cmol/kg)	S3	S3	S2
Mg (cmol/kg)	S3	S3	S3
BS (%)	S2	S2	S1
TN (%)	S3	S3	S3
EC (dsm^{-1})	S1	S1	S1
Overall suitability class	S3fsd	S3fs	S3fst

S3fsd= marginally suitable having limitations in fertility, soil texture and depth
S3fs= marginally suitable having limitations in fertility and soil texture
S3fst= marginally suitable having limitations in fertility, soil texture and topography

Conclusion. Ogochie river wetland soils were marginally suitable (S3) for optimum rice production as all topounits studied had fertility and soil texture as major limitations. The integrated use of organic and inorganic fertilizers and incorporation of plant residues such as rice straw would address the low nutrient status of the soils. Regarding the sandy nature of the soils, organic manure which acts as binding agents should be applied to check leaching of plant nutrients. Footslope recorded a limitation in depth due submergence of soils by water, adoption of improved agricultural practices should be employed to obtain optimum use of the land for rice production without loss through submergence. Making of checks will enhance water retention in the summit where topography was observed to be a limiting factor. Liming is also necessary to reduce the acidity and Aluminium and iron toxicity levels in the soils studied.

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ОЦЕНКА ПРИГОДНОСТИ ЗЕМЕЛЬ ЗАБОЛОЧЕННОГО БАССЕЙНА РЕКИ ОГОЧА (ШТАТ ИМО, ЮГО-ВОСТОЧНАЯ НИГЕРИЯ) ДЛЯ ПРОИЗВОДСТВА РИСА В УСЛОВИЯХ ДОЖДЕВОГО ОРОШЕНИЯ

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В стремлении повысить продовольственный достаток и стабилизировать производство риса в Нигерии, мы выполнили исследование по оценке пригодности земель заболоченной поймы реки Огоча, район Нгора-Окпэла, штат Имо, Юго-восточная Нигерия. Три топографические единицы, связанные трансектой посредством Системы глобального позиционирования (GPS), были идентифицированы как подножие склона, средняя часть склона и вершина, соответственно. На каждом из объектов был заложен полнопрофильный почвенный разрез. Описание почвы и оценка пригодности земли были выполнены согласно рекомендациям ФАО. Из каждого горизонта были отобраны пробы почвы, высушены на воздухе и просеяны для стандартной процедуры анализа. Почвы были мелкие и слабо дренированные. В грансоставе почв доминировал песок и они были классифицированы как песчаный суглинок. Плотность сложения и пористость составляли 0.82-1.68 г/см^3 и 36.6-69.2 %, соответственно.
Все почвы обладали кислой реакцией (5.28-5.37 pH). Уровень плодородия у всех почв был невысок: содержание органического вещества – 0.4-1.68 %, сумма обменных оснований – 2.68-3.18 cmol/kg, емкость обмена катионов – 3.38-4.11 cmol/kg, а содержание доступного фосфора – 1.03-2.04 ppm. В то же время, полная обменная кислотность была высока (0.7-0.8 cmol/kg), что отображало общую кислотность изученных почв. Процент насыщенности основаниями высокий (76.6-80.1 %), но недостаточен для оптимальных условий для производства риса. Почвы не были засоленными, а индекс их электрической проводимости составлял менее чем 1 dsm^{-1}. Почвы исследованной территории были оценены как слабо пригодные (S3) для производства риса с дождевым поливом, причем, почва у подножия склона имела ограничения в плодородии, грансоставе и мощности. В средней части склона ограничения касались плодородия и грансостава, в то время как на вершине были ограничения в плодородии, грансоставе и топографии.

***Ключевые слова**: заболоченные земли, почва, рис, оценка пригодности земель, юго-восточная Нигерия.*

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БАЗИ ДАНИХ ГРУНТІВ БОЛГАРІЇ, МОЛДОВИ, РУМУНІЇ Й УКРАЇНИ ТА ЇХ УЧАСТЬ У РОЗВИТКУ ЄВРОПЕЙСЬКОГО ГРУНТОВОГО ІНФОРМАЦІЙНОГО ПРОСТОРУ*

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У статті представлено національні підходи до структури грунтових баз даних у чотирьох країнах Південно-східної Європи – Болгарії, Молдові, Румунії й Україні. Показано способи збирання і систематизування даних та перелічено основні джерела інформації. Продемонстровано можливості і приклади застосування даних у наукових дослідженнях та оцінюванні стану грунтових і земельних ресурсів. Особливої уваги надано аналізу прийнятності національних баз даних для інтегрування та гармонізації їх у міжнародному інформаційному просторі.

***Ключові слова**: база даних, грунт, класифікація грунтів, властивості, карта.*

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