

Identification of Land Suitability for Agricultural Use by Applying Morphometric and Risk Parameters Based on GIS Spatial Analysis

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Abstract

Agricultural land is one of the main resources for the development of rural communities and the peripheries of urban centres. An area of 936 km², belonging to Intercommunity Association for Development Alba-Iulia, Transylvania region, Romania, was analysed in order to identify suitable land for agricultural use. This approach represents the stage preceding the identification of crops favourability for agricultural land, thus reducing the time and resources needed for the proper land evaluation mark. The extension of suitable surfaces for agricultural crops was realized using a GIS model based on spatial analysis, taking into account morphometric parameters (slope, altitude, slope orientation, the density of fragmentation) and the risk factors (probability of landslides, flooding, temperature and rainfall). The outcome of the case study was an agricultural land suitability map of the investigated area, which provides valuable information regarding areas suitable for crops. By applying this model, a better management of agricultural lands can be assured, representing an alternative to the classic method of evaluation marks. The proposed model was validated by comparing the results with the grades of crop suitability, method achieved through the land evaluation mark.

Keywords: agricultural land, database, favourable crops, GIS model, maps

Introduction

Agricultural land, as a support for the economic development of rural areas and the peripheries of urban major centres, represents even today a major interest for an efficient management of cultivable land, in terms of implemented crops. Sustainable agriculture relies on the use of land parcels, taking into account the specifics and their own production capacity (FAO, 1983). In the centre of Romania, Transylvania region, Intercommunity Association for Development Alba-Iulia (IADA) includes mainly rural areas, where the major activity is linked to land use. The economic profile of rural areas delimited by IADA is based on agricultural activities of land

cultivation, having as main sales market the polarizing urban centres.

The GIS model shown in the present article was intended to facilitate the agricultural land evaluation mark; the main purpose of was to reduce the time provided for the identification of favourability for some agricultural crops by imposing restrictiveness among the territory involved in the research. Using GIS technology with the purpose of identifying these territories has provided remarkable results for land evaluation mark (Dumitru *et al.*, 2010; Bhandari *et al.*, 2013; Halder, 2013; Roșca *et al.*, 2015).

Achieving the spatial analysis model relies on the morphometric and risk parameters of the studied territory, parameters that have the greatest influence on land suitability and on the arrangement of different types of crops.

Materials and Methods

Studied area

Intercommunity Association for Development Alba Iulia has 11 territorial administrative units (Fig. 1), spread over 936 km², which corresponds to 14.9% of the total area of Alba County, Romania (IADA, 2009).

Land use of the terrain within the analysed area is mainly agricultural, of which agricultural land occupies a share of 31% from the total surface, followed by pastures (Moldovan et al., 2015).

Agricultural production and crop type applied to different territories are under the direct influence of the environment and in recent years under the influence of anthropogenic factors, that may mitigate or exacerbate the restrictive nature or favourability of a territory. Thereby, the territory was identified by the main morphometric and morphographic characteristics related to the major relief units from the analysed area, with direct and indirect influence on favourability and restrictive aspects of the analysed area for different use of land, as a result of the conditions imposed by altitude, slope, fragmentation depth, fragmentation density, slope exposure etc.

Theoretical aspects

The parameters taken into account (slope, altitude, slope orientation, fragmentation depth, fragmentation density, temperature, rainfalls, probability of landslides) were analysed in

terms of their favourability influence on the following crops: potato, wheat, vegetables, lucerne, peas, barley, corn, clover, based on the methodology for land evaluation mark for agricultural lands (Teaci et al., 1972, 1989; Cernescu et al., 1986, 1989; Munteanu et al., 2000; Țărău, 2003; Păcurar and Buta, 2007; Roşca, 2014). Previous studies highlighted superior results obtained in terms of spatial distribution of land suitability for certain crops based on GIS modelling, if the chosen factors involved in the modelling are consistent with the land (Van Diepen et al., 1991).

Slope

Slope is a characteristic parameter of the relief which has an influence on production capacity of the agricultural land and also on the technological classification of the analysed territory. The influence of this parameter is reflected on the agricultural land both in terms of land degradation (Moţoc, 1983), mainly because of the erosion processes on surfaces with high slope and accumulation of material eroded on surfaces with sudden change of slope, and also in terms of mechanization of these lands, because plowing and cultivating on steep slopes is difficult for mechanized systems.

In terms of regional spatial distribution of areas with different degrees of inclination of the land, on IADA territory stands out moderate level of inclined slopes with a share of 30.40% of the total. Territorial areas characterized by slopes from 0.01% to 10% included in horizontal to slightly inclined categories, represented 38% of the total (Table 1).

Categories high, very high and steep slope, assigned to a variation greater than 25% represented approximately 31% of the total territory analysed. Based on the surface analysis of slope groups, stands out the large share of groups classified as suitable slopes to agricultural use, which highlights the agricultural suitability in terms of the slope of the analysed territory. Identifying the categories of territorial spatial gradient highlights the engratment of slopes suitable for agricultural use on lower area of Mureş corridor and on mollify slopes of lower hills (Fig. 2). Surfaces with high slope, very high and steep are located mostly at the contact between mountain area, located at the Northwest border of the analysed area, as well at the contact area between the large meadow of Mureş and the foothills (Fig. 2). This final aspect introduces restrictiveness on agricultural land suitability both in terms of agricultural crops and mechanized work.

Altitude

Levelling the relief on altitudinal steps has an indirect influence on the surface arrangement of agricultural lands, inducing restrictiveness through the components. The main two components that need to be analysed consistent with relief in terms of restrictiveness which they impose for the identification and spatial disposition of agricultural lands are temperature and

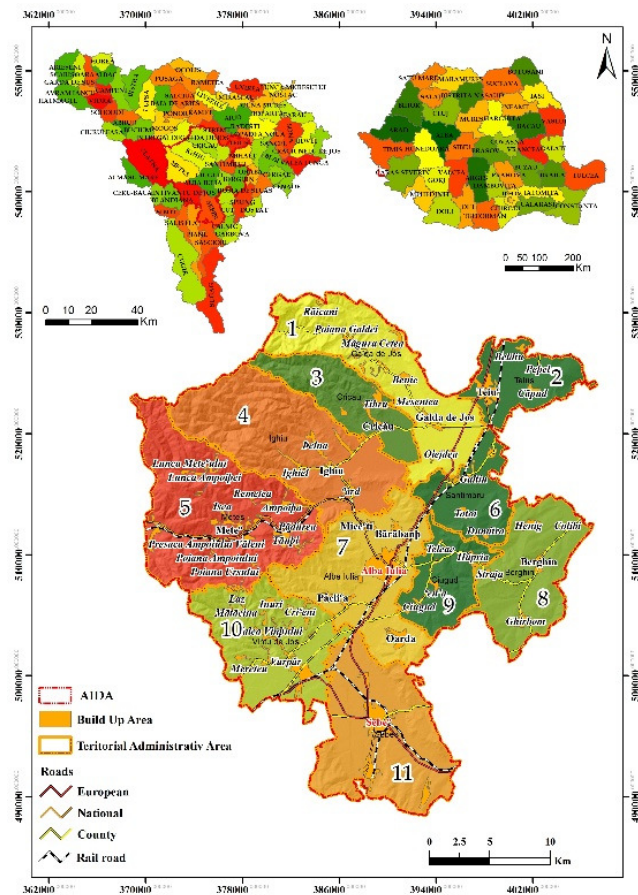


Fig. 1. Geographical position of the analysed territory

Table 1. The distribution of slope classes for the studied area

Slope groups (%)	Type	Surface	
		(Km ²)	%
≤2	Horizontal	85.90	9.66
2.1-5	Very low	157.21	17.68
5.1-10	Low	108.66	12.22
10.1-25	Moderate	270.38	30.40
25.1-50	High	220.32	24.77
50.1-100	Very high	46.77	5.26
>100	Steep	0.13	0.01

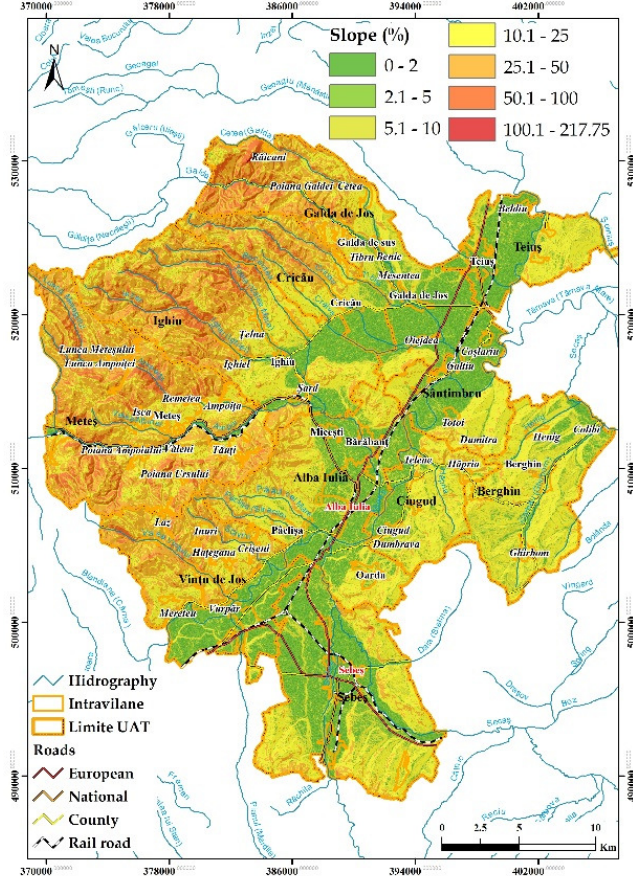


Fig. 2. Slope map

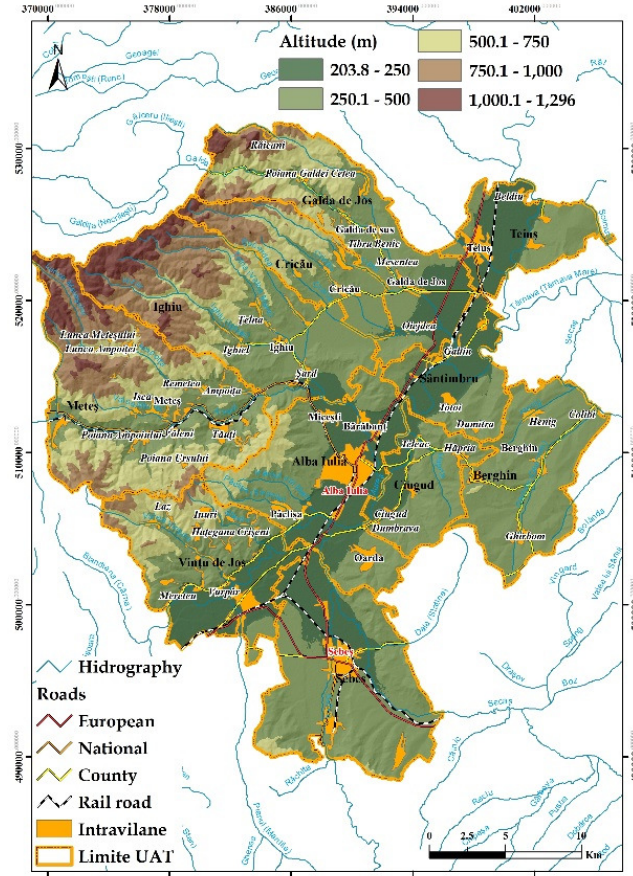


Fig. 3. Hypsometric map

rainfall, regarded as elements of risk because of their unpredictability manifestation on relief units. The altitudinal difference that fall within the analysed territory was 1,085 m, from an altitude of 1,250 m on the Eastern versant of Bedeleu Peak, to 165 m on the Mureş river meadow. This high altitudinal difference revealed the complexity of the analysed territory, given not only by the altitude of the relief, but also by the complexity of the hydro-climatic factors, lithological and pedological characteristics.

In terms of territorial extension, stand out the surfaces with altitudes up to 500 m in proportion of 70.61% of the analysed surface, which highlight a relatively high suitability of lands reported at altitudes (Fig. 3). The favourability for agricultural crops and the rural/urban development and ways of communications was represented for Mureş Valley in the analysed territory by Abrud (North sector) corridor and Vinţu corridor, where the altitudes of the intervals 201-250 m and 251-500 m (Table 2) represented low hills and extended meadows that provide the necessary conditions for the development of the region.

Table 2. The distribution of altitudinal classes for the studied area

Altitudinal classes (m)	Characteristic landforms	Surface	
		(Km ²)	%
165-200	Terraces, meadows	180.17	20.26
201-500	Low and medium hills	447.81	50.35
501-750	High hills	133.83	15.05
751-1000	Very high hills	93.88	10.56
1001-1250	Mountains with low altitude	33.69	3.79

Slope orientation

Slope orientation, as a parameter used in land evaluation mark, provides information related to the exposure to the sun and wind, probably wet areas and areas with lack of humidity. The analysis of orientation provides indirect information on hydric and thermal regime of micro-regions; thus Southern slopes have higher temperatures, therefore are characterized by moderate humidity, while Northern slopes have lower temperatures and are shady, resulting in a higher humidity. Also, thermic oscillations are higher on Southern slopes compared to those in the North. By the direct action of thermic difference, humidity and specialized studies, versants with Southern and Northern exposure are highly affected by erosion processes (Moţoc, 1983). Their share was 12.86% for versants with Southern orientation and 9.80% for those with Western orientation, standing out in terms of percentage of sunny slopes (33%) and half sunny (23%) (Fig. 4, Table 3).

Table 3. The distribution of slope exposure classes for the studied area

Slope exposure	Exposure	Surface	
		Km ²	%
N	Shady	110.12	12.39
NE		131.29	14.76
E	Half-shady	127.83	14.37
NW		93.37	10.49
S	Sunny	114.45	12.86
SW		99.70	11.21
W	Half-sunny	87.16	9.80
SE		123.73	13.91

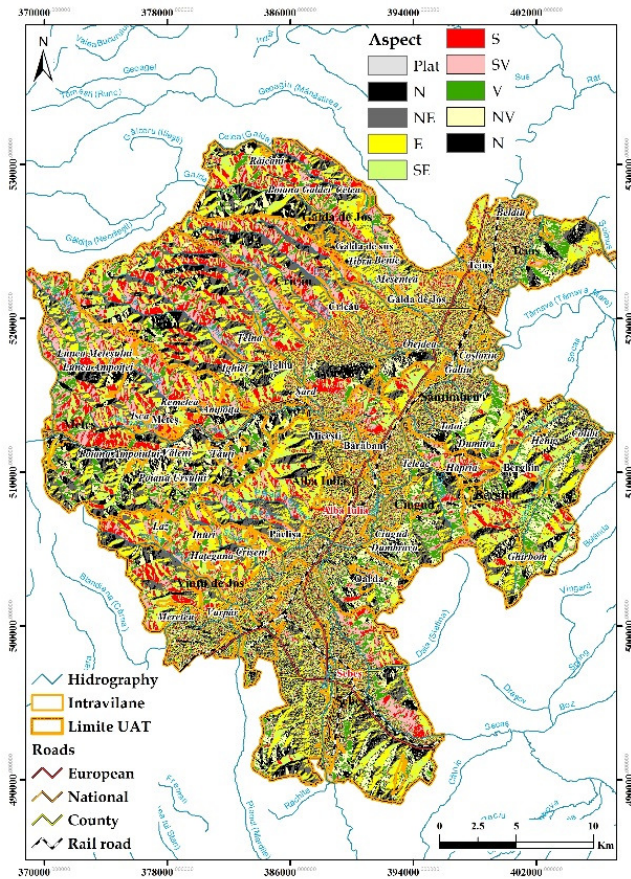


Fig. 4. Slope orientation map

Due to the high degree of sunlight, the versants with Southern and South-eastern exposure, lead to a more rapid melting of the snow during March-April. These are preponderant developed in right sub-basins and, in a lesser extent, in left sub-basins.

Thus, this characteristic can be managed locally by adapting forest and agricultural arrangements, but also by correct location and proper management of the operation and construction of communication lines.

Fragmentation depth

Fragmentation depth represents the depth of local basins of erosion (Grigore, 1973), providing useful preliminary information in the current study about the morphological potential and favourability or restrictiveness of transport infrastructure development. Values of this indicator ranged between 4.43 and 511.6 m/km², with an average at basin level of 147 m/km². Values higher than 300 m/km² correspond to steep slopes from the mountain area, occupying 33% of the territory, the difference of 50 up to 300 m/km² being found in the interfluvial areas, with higher altitudes, occupying 20% of the territory (Table 4). These territories need a special attention both for cultivation and achieving works, as well as for transport. Territories with low values of relief energy are favourable for crops, promoting mechanization and easy access to the parcels, establishing large parts in the category of territories favourable for agricultural land use (Fig 5). Analysing the spatial representation of this indicator, there can be noticed a pronounced character of right asymmetry: the Western sector of the analysed territory featuring values that can reach up to 500

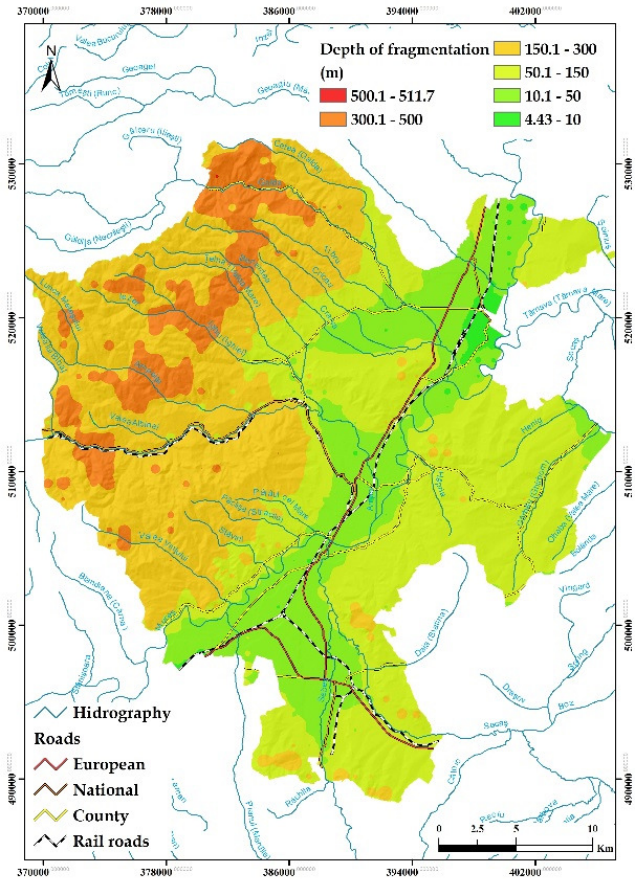


Fig. 5. Fragmentation depth map

Table 4. The distribution on fragmentation depth classes for studied area

Relief energy (m)	Surface	
	km ²	%
<10	83.65	8.92
10.1 - 50	341.76	36.47
50.1 - 150	188.26	20.09
150.1 - 300	0.03	0.003
300.1 - 500	314.01	33.51
500.1 - 511.7	9.21	0.98

m/km² in comparison with the Eastern sector which has high values only in the South-Eastern sector, that corresponds with interfluves surfaces. This regionalization derives from the structural and neotectonic conditions on river erosion that is to be found in the analysis of drainage density.

Drainage density

The drainage density, calculated as the ratio between permanent and temporary hydrological network length (km) to surface analysed territory (km²), indicated an average value of 0.82 km/km², with variations between 0 and 6.2 km/km². The interval of 0-0.5, with a share of 29.35% of the territory correspond to the superior sectors of mountainsides, followed, in percentage terms, by the intervals 0.5-1 and 1.1-2 with approximately equal weightings (of 34%), characterizing the principal tributaries meadows of Mures and the middle section of low hills (Fig 6, Table 5). The values of this parameter will produce valuable information on the drainage capacity of the territory, along with the slope, permeability and groundwater depth.

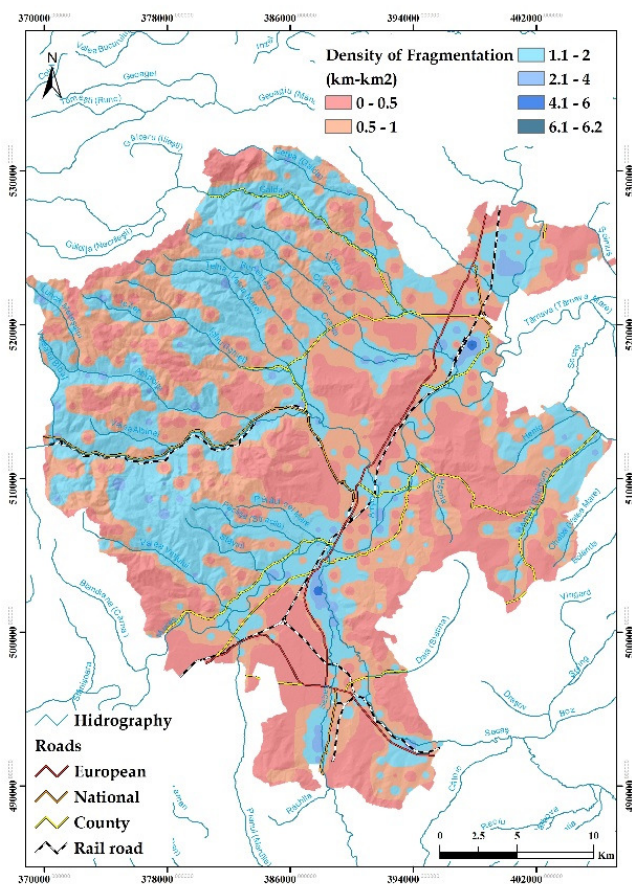


Fig. 6. Fragmentation density map

Table 5. The distribution on drainage density classes for analysed territory

Drainage density	Surface	
	Km ²	%
0-0.5	275.08	29.35
0.5-1	321.80	34.34
1.1-2	319.85	34.13
2.1-4	19.83	2.12
4.1-6	0.58	0.06
6.1-6.2	0.02	0.00

Temperature

The peculiarities of relief by altitude, orientation and fragmentation, give the variation of hydro-climatic parameters. Given the integrated nature of the present study, in order to identify the correct distribution of rainfall and average temperatures, databases were obtained on average annual temperatures and multiannual average rainfall, throughout statistical spatial analysis of measured point values.

In order to obtain the value of average rainfall of the studied territory, the Digital Elevation Model (DEM) was used as well as the average amount of rainfall (Bilaşco, 2010) from the weather stations. The results of specialized studies conducted in Romania allowed framing the analysed territory according to classes of average annual temperatures (Table 5). The analysed results

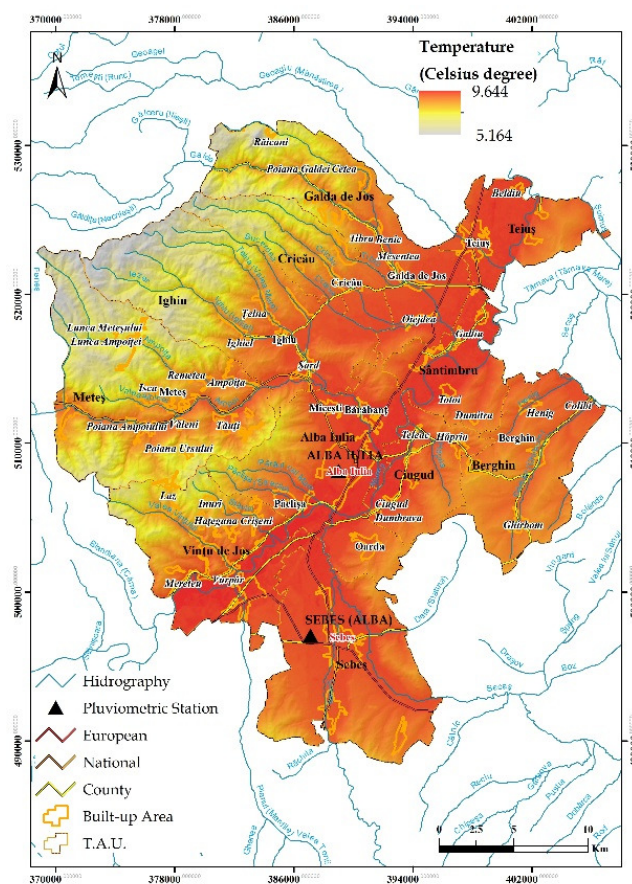


Fig. 7. The distribution of the annual average temperature

Table 6. The distribution of annual average temperature classes for the studied area

Annual average temperature (° Celsius)	Temperature classes	Surface	
		(km ²)	%
5.6-6	Below average	19.5	2.03
6.1-7	Medium	207	22.03
7.1-8			
8.1-9	High	711	75.93
9.1-9.64			

clearly highlighted the temperature variation with altitude, the highest temperatures representing areas of Mures corridor, part of the submontane hills and low hills (Fig. 7).

Rainfall

The rainfall parameter directly affects the agricultural crop arrangement specific for agricultural land due to variation in the quantity of water in a certain range. Water reserve is closely related to temperature and tightly correlated with the amount of water precipitated in a period of time. The influence of rainfall stands out by their natural setting on altitude, sub medium values for modeled precipitation in the low area of corridor and medium amounts of precipitation for the foothills and mountain area related to IADA (Fig. 8). The largest area of rainfall in

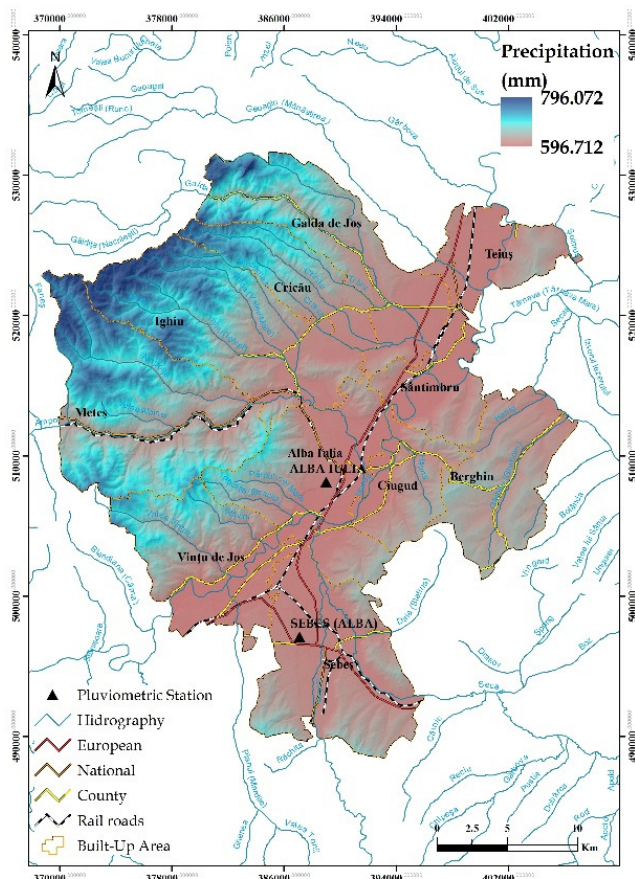


Fig. 8. The distribution of annual average rainfall

Table 7. The distribution of the annual rainfall classes

Average precipitation (mm)	Precipitation classes	Surface	
		(km ²)	%
596-600	Below medium	0.12	0.013
601-700	Medium	933.88	99.98
701-796			

proportion of 99.98% falls in the middle category, regarding favorability (Table 7). This highlights a good favorability in terms of agricultural crops category because there is a good reserve of water for most of the territory. Areas with deficient rainfall and thus little water reserve from precipitations ensure water reserve from the phreatic water near the surface of Mures meadow.

Landslides

The analysed territory, located predominantly in Western Transylvania Depression as a result of geographical and geological characteristics, have a high potential for landslides occurrence (Petrea *et al.*, 2015), and strong dynamic and accelerating trend of sliding because of cumulative rainfall triggering landslides (Roşca *et al.*, 2015).

After applying the bivariate statistical analysis model, the probability of occurrence of landslides was obtained based on the analysis of causative and triggering factors from the administrative territorial units of IADA (Moldovan *et al.*, 2015) (Fig. 9). Most landslides occur in areas with geology dominated

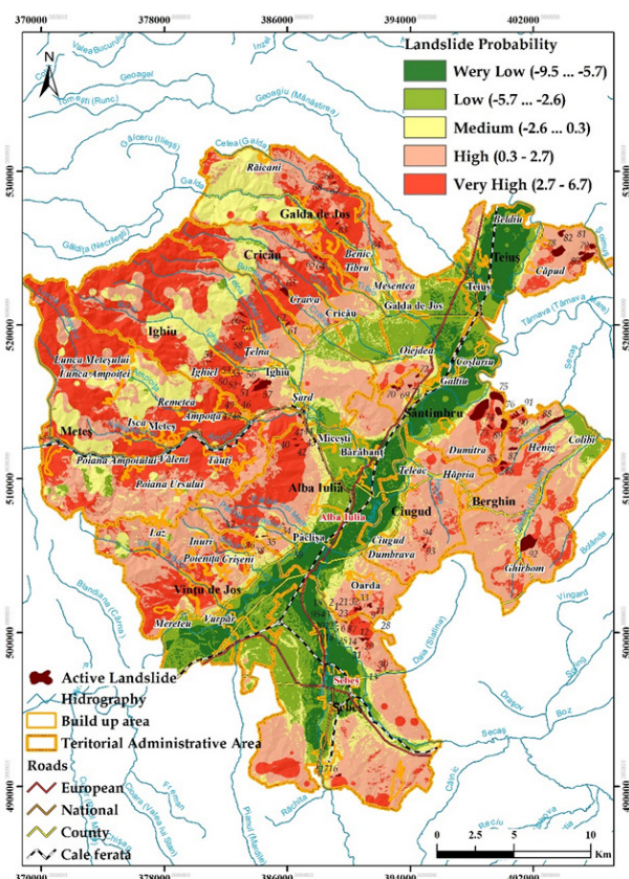


Fig. 9. Probability of landslides occurrence map

Table 8. The distribution of probability classes for landslide occurrence

Landslide probability	Surface	
	(km ²)	%
Very Low (-9.5 ... -5.7)	96.1236	10
Low (-5.7 ... -2.6)	116.0904	12
Medium (-2.6 ... 0.3)	147.4788	16
High (0.3 - 2.7)	333.7196	36
Very High (2.7 - 6.7)	242.14	26

by gravels, sands, clays, coal, sandy marl, conglomerates, sandstones, clays and purple striped marl. In the category of morphometric characteristics there was a high density of landslides on moderately inclined slope class (10.1-25.0%) on the territories characterized by an energy relief within 50.1-150 and 150.1-300 m and a fragmentation density between 0.5-1, with West and North-West orientation (Table 8). Landslides through areas with different degrees of vulnerability are one of the main restrictiveness factors of land cultivation. Major restrictions are induced on surfaces included in high and very high vulnerability due to the instability of the respective areas.

Flooding

Flooding classes identified in the analysed territory lead to its inclusion in two classes: unflooded and rarely flooded (Fig. 10). The two classes have been obtained by identifying the corresponding maximum flow of flood levels with the probability of occurrence of 1%, whose correspondent level has been transposed on transverse profiles (Roşca *et al.*, 2014b;

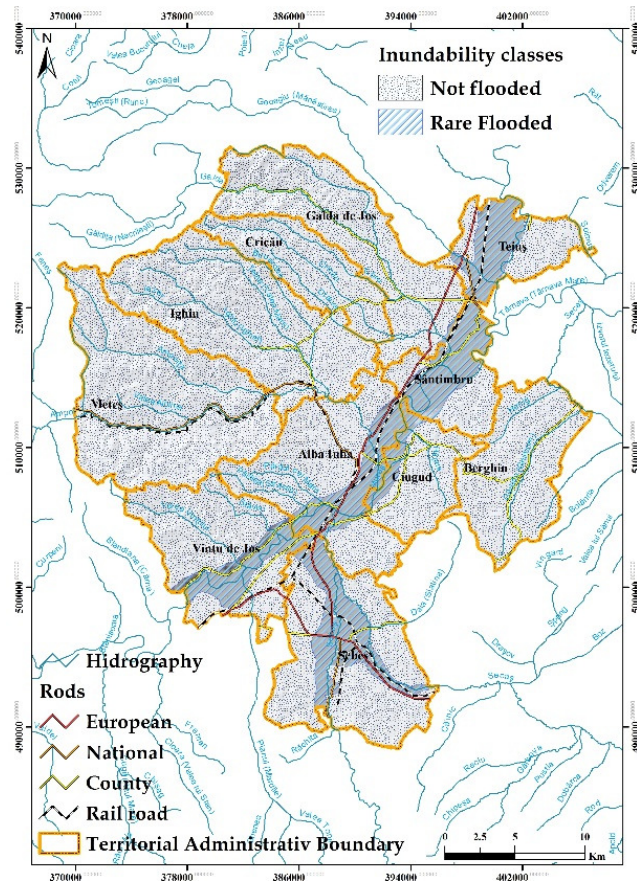


Fig. 10. Map of flooding classes

Table 9. The distribution of flooding classes

Flooding	Surface	
	(km ²)	(%)
Flooded	127	13.5
Unflooded	810	86.5

Bilaşco and Băţinaş, 2009). Most of the territory (810 km²) is represented by the unflooded territories, while the rest of 127 km² being represented by territories that present a probability of flood occurrence associated with a return period of once in a hundred years (Table 9). Inundability is one of the restrictive factors in terms of identifying areas suitable to any type of crops. Areas included into the flooding category have very high restrictiveness, going up to smaller restrictiveness or even zero where territories are not included in any flooding category.

Table 10. Database structure

Nr.	Database	Structure type	Source/resolution	Database type
1.	DEM	Raster (grid)	20 m	primary
2.	Hydrography	Vector	Topographical Maps	primary
3.	Inundability	Raster (grid)	1% modelled flood stripes	modelled
4.	Slope	Raster (grid)	degrees	derived
5.	Orientation	Raster (grid)	Derived from DEM	derived
6.	Drainage density	Raster (grid)	m/km ²	modelled
7.	Depth	Raster (grid)	m	modelled
8.	Precipitation data	Raster (grid)	Interpolation with a statistical model	modelled
9.	Temperature data	Raster (grid)	Interpolation with a statistical model	modelled
10.	Landslide areas	Raster (grid)	BSA model	modelled
11.	Suitability	Raster (grid)	20 m	modelled

GIS model for land suitability to agricultural crops

Agricultural crop land modelling suitability was based on the analysis of the parameters presented above, parameters embedded in a logic model of integrated spatial analysis. The pattern was defined in such a way that it could capture the influence of each analysed factor (7 factors), the final result revealing the areas suitable for agricultural crops.

The suitability model was developed on specific databases for each parameter included in the spatial analysis methodology based on their integration equations.

Database and methodology

Each of the indicators mentioned above were integrated into a database that contains primary, derived and modelled layers with their distribution in the analysed hydrographic basin (Table 10).

Each element of the database was included in the spatial analysis model, focusing on identifying areas suitable for agricultural crops for each parameter (Roşca et al., 2015). Using information extracted from the analysis stage of morphometric parameters, there were identified quantitative values that define areas suitable for each parameter (Table 11), values used in the spatial analysis.

Spatial analysis for identifying areas suitable for agricultural crops is based on overlay technique of identifying unique areas, which requires integrated analysis of the technical parameters included in the model based on equations of spatial analysis (Roşca et al., 2015), for highlighting any areas that meet both conditions (Fig. 11).

The spatial analysis was divided into three distinct methodological steps, each playing an important role in the final output. The first step was achieving specific databases which were derived from pre-existing databases, raster database (slope, altitude, aspect). Sub models are present in the model due to the fact that it is necessary to correct temperature and rainfall that were performed as secondary model through exploitation of raster modelled databases (temperature and rainfall), the primary (DEM) and derivatives (slope, orientation). In order to obtain density and fragmentation depth parameters of relief, the overlay technique was used on raster vector structures (surfaces of 1 km² and DEM) and vector structures (surfaces of 1 km² and the hydrographic network as primary data vector).

The second stage consisted in analysing the databases representing the input parameters in the model to spatial identify each influence and thus the areas suitable for crops. Also, in this stage, the minimum and maximal quantity limits have been set on variation of suitability for each parameter, as well as the identifier used.

Table 11. Parameters used in modelling

Nr.	Parameters	Values	Very high suitability (1)	High suitability (0,9)	Observations
1.	Slope	$\geq 0\%$ and $\leq 25\%$	Potato, wheat, vegetables, lucerne, peas, barley, maize, clover	-	- areas with slopes less than 25% are facile in terms of preparation, cultivation and harvesting of crops due to the low restrictions which they impose - allows mechanized work - are included in the first category of favourability for potato, wheat, vegetables and lucerne - in correlation with rainfall and temperature, areas found below 750 m altitude are the most suitable for crops
2.	Altitude	≤ 750 m	Wheat, vegetables, lucerne, peas, barley	Maize, potato, clover	- wheat, lucerne, peas and barley are included in the first category for favourability, while maize, potato and clover in class number 2 for favourability - give to the territory suitability according to the which use is carried out analysis - all types of orientations are suitable for agricultural use because agricultural crops can be independent from some orientations, depending on their specific - the type of orientations analysed for each parameter emphasize the good and very good suitability for potato, wheat, vegetables, lucerne, peas, barley, maize and clover - land area with high altitudinal difference impose restrictiveness regarding facilitated preparatory work, culture, maintenance and harvesting of mechanized production system - are identified cultures from the first class for wheat, vegetables, barley, on surfaces with low horizontal fragmentation (under 50 m), territories identified with less high surfaces - potato, lucerne and clover crops are identified on surfaces that have a fragmentation depth between 50-150 m, spatially grafted on submountain and mountain units with low temperatures and large amount of rainfall, which give favourability for the mentioned crops
3.	Orientation	N,NW,NE... ≥ -1 and ≤ 360	Potato, wheat, vegetables, lucerne, peas, barley, maize, clover		- low density of relief fragmentation highlights large areas with homogeneous surfaces used for agricultural crops - low fragmentation of territory reveals the continuity of parcels and the possibility of working in mechanized system - high fragmentation give the major restrictiveness regarding the continuity of parcels and spatial expending of them - is a restrictive parameter
4.	Fragmentation depth	≤ 150	Wheat, vegetable, peas, barley, maize	Potato, lucerne, clover	- limits the period of commencement of agricultural operations, growing, ripening and harvesting - potato, clover, vegetables, barley, peas and beans fit in the first favourability class for temperatures between 6 and 9.6 degree, situated in lower areas of low hills - barley, maize, potato and clover fit in second favourability class, towards the lower limit of temperature - is a restrictive parameter
5.	Fragmentation density	≤ 2	Potato, wheat, vegetables, lucerne, peas, barley, maize, clover		- they are closely correlated with the disposition of the relief altitude intervals - heavy rainfall specific to high altitudes are less favourable for clover and vegetable crops, fitting in the middle category in terms of favourability - lower amount of rainfall, that fit, in term of favourability, for the submedium category, the correlation with relatively average temperatures to lower temperatures reveal areas suitable for barley, wheat, maize and lucerne crops - is a restrictive parameter
6.	Annual average temperature (° Celsius)	≥ 6.1 and ≤ 9.6	Potato, clover, vegetables, barley, peas, beans	Barley, maize, potato, clover	- lucerne and clover, included in the first category for favourability (category one), have a role of stabilization and reduction of the erosion effect, being considered as pioneer agricultural crops for landslides - is a restrictive parameter
7.	Annual average rainfall (mm)	≥ 596 and ≤ 769	Potato, clover, vegetables	Barley, wheat, maize, lucerne, potato	- the lack of flooding areas reveals their favourability - flooding areas emphasize the retroactivity for all crops
8.	Landslides	≥ -9.5 and ≤ 0.3	Lucerne, clover	Potato, wheat, vegetables, barley, maize	
9.	Flooding	$= 0$	Lucerne, clover, potato, wheat, vegetables, barley, maize		

The final step was to finalize and implement spatial analysis equation, equation that integrated all database structures and identifiers of spatial analysis defined in previous stage, with the main purpose of illustrating the suitable areas in terms of crops.

Due to specific values of suitability for each parameter, a spatial analysis equation was defined, each parameter having equal proportion in the final result. Using the function "Raster Calculator" of a geoinformatic program, the following equation was obtained:

("Average annual temperature" ≥ 6.1) & ("Average annual temperature" ≤ 9.6) & ("Average annual rainfall" ≥ 596) & ("Average annual rainfall" ≤ 769) & ("slope" ≤ 25) & ("flooding" $= 0$) & ("Landslide Probability" ≥ -9.5) &

("Landslide Probability" ≤ 0.3) & ("Altitudinal scale (m)" ≤ 750) & ("Relief energy" ≤ 150) & ("Fragmentation density" ≤ 2)

Where: Average annual temperature, ... etc. - input parameter in the equation

& - logical identifier

\geq , \leq , $=$ - mathematic identifier

6.1, 596... etc. - coefficients of parameters

The equation result (Fig. 11) was materialized in a database raster with numeric attributes 0 ("False", all surfaces that do not meet conditions) and 1 ("True", all areas that meet conditions) (Bilaşco et al., 2013), in this case surfaces with zero suitability for agricultural crops and land suitable for them.

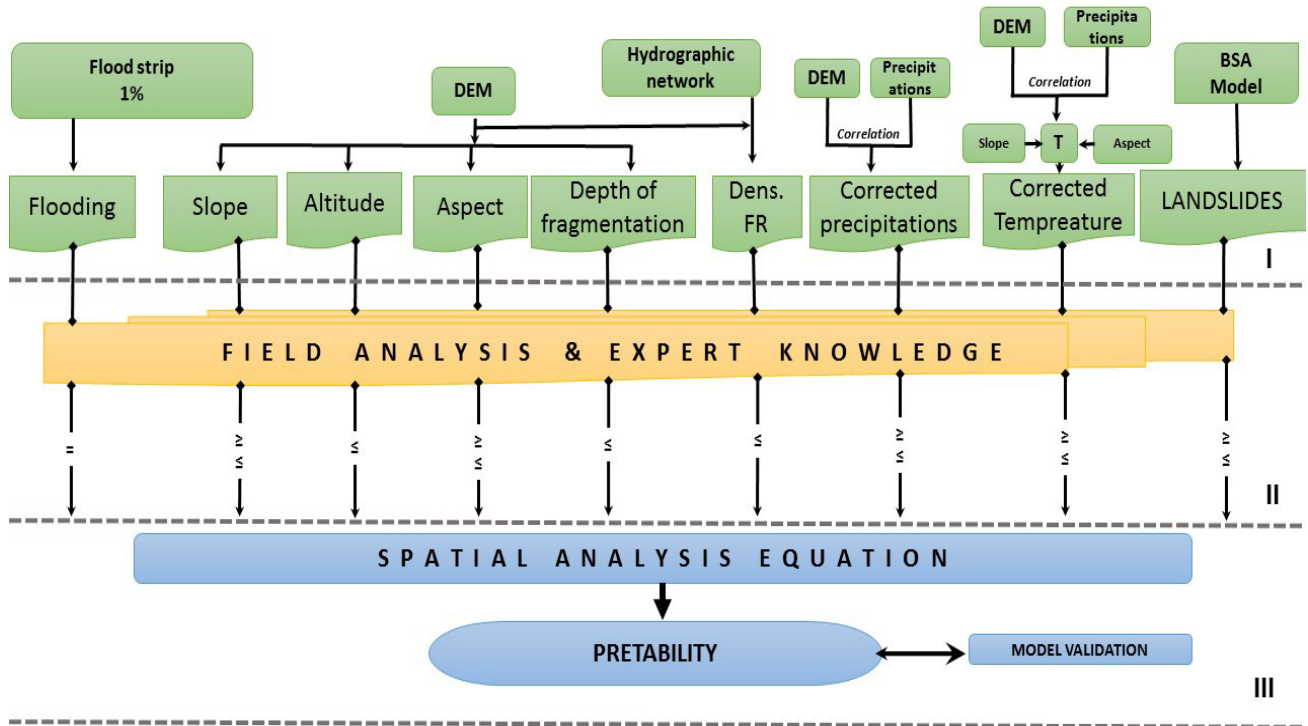


Fig. 11. Conceptual scheme of applied model

Results

Analysis of the obtained database after finalizing the model of spatial analysis, highlights the low extension of areas suitable for crops (%). Suitable areas have territorial extension mainly in Mureş corridor, some lower plateaus and the meadows.

Based on administrative units, the following ones stands out: Gârda de Jos, Alba Iulia and Sebeş, which offers high suitability for agricultural crops on areas larger then 18-20 km², which correspond to the proportion of over 20% from the surface of these units. The largest areas with restrictiveness for crops, due to the influence of parameters that are negatively influencing land cultivation and maintenance are: Meteş (99% of the territory), Sântimbru (93%) and Ighiu (87% of its adjacent area) (Table 12).

Model validation was performed using the method of comparison between the final result with the results achieved by the traditional method, the land evaluation mark for wheat and vegetable crops. This kind of validation of the results obtained by applying a model based on expert knowledge with the reality on the ground, gives an insight into the predictability of results

(Chung and Fabbri, 2008). To achieve validation, two surfaces were randomly selected and the results were compared with those areas considered suitable for respective crops. The first area as a test area is located South of the village Gâlda de Jos and the second one is West of the village Şard. After comparing the four results (Fig. 13), stands out the heavily overlapping modelled areas, considered suitable with favourable surfaces for crops, in this case wheat, which indicates the accuracy of the outcome.

Discussions

Morphometric and risk parameters represent the major factors of restrictiveness or favourability regarding the identification of suitable land for agricultural crops due to their complexity as way of manifestation and influence in landscape (Halder, 2013).

Individual analysis of the factors presented in this report highlights not only the complexity of the morphometric and risk parameters that were analysed, but also the major influence that each and every one of them has on

Table 12. Classification of administrative territorial units on suitability classes

Nr.	Administrative territorial areas	Non suitable areas		Suitable areas	
		km ²	%	km ²	%
1	Galda de Jos	68.43	71.71	26.99	28.29
2	Teius	35.32	84.61	6.42	15.39
3	Cricau	41.46	83.60	8.14	16.40
4	Ighiu	105.43	87.06	15.66	12.94
5	Metes	137.16	99.77	0.31	0.23
6	Santimbru	39.23	93.74	2.62	6.26
7	Alba Iulia	73.15	75.29	24.01	24.71
8	Berghin	60.28	84.97	10.66	15.03
9	Ciugud	36.00	86.77	5.49	13.23
10	Vinţu de Jos	65.72	78.01	18.53	21.99
11	Sebeş	79.61	75.01	26.52	24.99

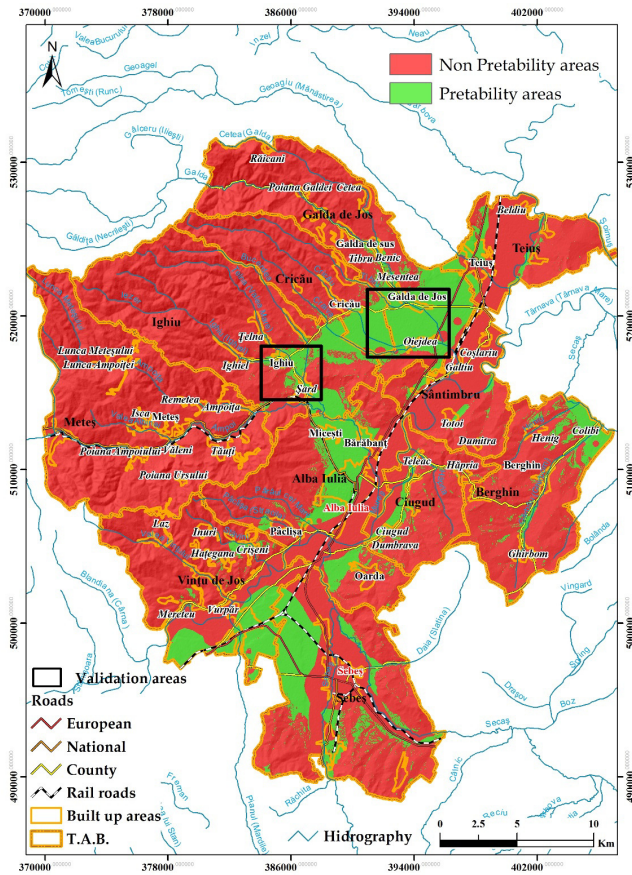


Fig. 12. Suitability map for agricultural crops

establishing and delimiting surfaces suitable for agricultural crops (Bhandari *et al.*, 2013). Thus, noticing the altitude zoning for respective crops and their correlation with vertical natural setting of the temperature (suitability of agricultural crops on surfaces with temperatures relatively medium and low altitudes), it lead to identifying suitable areas in Mureş corridor, sub-mountain hills and lowland areas. Rainfall, as a defining parameter in determining suitability, exerts its influence on relief surfaces characterized by high altitudes and low temperatures with average slopes, which only highlights suitability for specific and acclimatized crops (potato, clover etc.). The analysis of rainfall as suitability parameter cannot be made only closely related to groundwater, which in areas of Mureş corridor it is close to the surface and compensates the supply of precipitation water, favouring thus the suitability of areas for agricultural land.

Risk-inducing elements, landslides and flooding due to territorial expansion of areas with different areas of vulnerability (average and high vulnerability to very high for landslides and areas for flooding) are major limiting factors in terms of suitability in identifying agricultural areas (Borrelli *et al.*, 2014; Göransson *et al.*, 2014; Kundzewicz *et al.*, 2014). The areas identified as flood plains induce restrictiveness for 100 % regarding suitability, and areas identified as vulnerable areas, from average-high to very high, for landslides induce partial restrictiveness, depending on the degree of vulnerability.

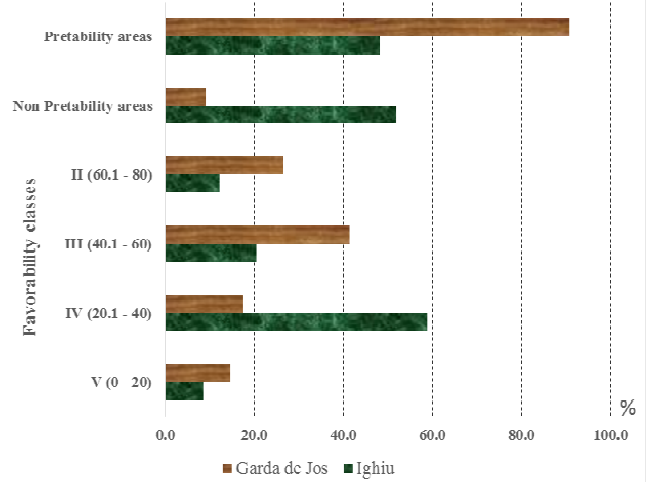


Fig. 13. Comparative analysis of suitability classes and the correspondence of suitability classes for crops

The spatial analysis model proposed in the present study was structured on three main stages: first stage represented the correct definition and implementation of databases with different structures (vector, raster) and ways of obtaining (derivation, modelling) intermediate and final results with a high degree of accuracy and territorial validation; the second stage was represented by the analysis of databases based on field study, bibliographic information and expert knowledge, aimed mainly to identify the logic and mathematic used in the equation of spatial analysis; the third stage represented the base of spatial equation model, by means of two main steps (spatial analysis equation and validation) (Roşca *et al.*, 2015).

Integrated analysis of all parameters considered for the identification of the agricultural land suitability was achieved by incorporating into the spatial analysis equation the quantitative values of variation of the suitability through the logical and mathematical identifiers established based on the quantifiable information obtained in the analysis from the second stage. By applying the spatial analysis equation on specific databases, the spatial extension of territories was obtained for areas suitable for agricultural crops. The model of spatial analysis cannot be applied as long as the result validation step is not completed (Van Diepen *et al.*, 1991). The authors validated the model by comparing the results with the favourability of a crop, wheat respectively, randomly selected, on two indiscriminately selected areas, the result being one included in the very good category, with a validation rate of 88.9% at comparing areas and 90.8% in comparing as regards to the spatial extension surface of the administrative unit.

Conclusions

The integration of the results of the analysis of individual parameters of a conceptual model, integrated into a model of GIS spatial analysis, complex in terms of techniques and methods of achieving, makes identifying areas suitable for agricultural land a necessity, given the current trend regarding the integrated land management. The proposed model can represent a preliminary stage of the land evaluation mark for establishing suitability. Tightening the territorial areas of surfaces suitable for some

general type of use would make the time for land evaluation mark shorter. The identification model of suitable agricultural crops proposed in the current study can be applied to almost all surfaces of meadow, hill and mountain areas with low altitudes because the quantitative and quantifiable values extracted for each parameter, presented in this study and included in the spatial analysis equation, fall into the range of values used within the current methodologies of land evaluation mark suitability.

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