Land Use Favourability Assessment Based on Soil Characteristics and Anthropic Pollution. Case Study Somesul Mic Valley Corridor, Romania

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Abstract: The Somes Corridor, located in the central Transylvanian region of Romania, is a territory characterised by favourable conditions for habitation and land use with agricultural purposes, offering suitable premises for the development of the settlements and the economic activities taking place in the area. This study aims to identify the parcels of land from outside the built-up area, which can be used as arable land, this particular use being pursued due to the favourability induced by the pedological resources, the morphometrical characteristics of the Somes floodplain and, last but not least, the climatic conditions. GIS technology has been used, enabling the management of the databases representing soil, topography and climatic factors, and thus obtaining the classification of all land parcels using favourability classes for agricultural land use. In order to perform a correct favourability classification, the degree of soil pollution and groundwater pollution have been analysed, using chemical tests of water and soil profiles taken in the area of former abandoned industrial platforms, which are intended to be reintroduced in the local economic use. The highest degree of soil pollution with ammonium and sulphates has been identified in the industrial park from Dej city, on the territory of the former industrial platform of the paper factory, this pollution modifying the quality scores of arable land use, despite the fulfilment of favourable climatic and topographic conditions.

Keywords: land use favourability; crops; GIS modelling; soil pollution

1. Introduction

The capitalisation of agricultural terrains is included in the category of the objectives from the national strategic framework of Romania for the sustainable development of the agri-food sector. This strategic document mentions the fact that, in order to attain this objective, thorough research of the natural potential of the territory is necessary to fully capitalise on the areas with high potential. This would provide the necessary agricultural products for the internal use of the community, by efficiently applying an economic capitalisation on the territory, by preserving a sustainable...
ecological balance and, as much as possible, by preserving an acceptable degree of conservation of pedological resources.

At this moment in Romania, in order to classify a specific territory according to its favourability for agricultural usage, one uses the methodology I, II and III of writing pedological studies, which regulates the required database as well as the intervals of each factor included in the analysis, that one may attribute the soil quality score for each crop and agricultural use.

The main purpose of the present study is to identify the land surfaces with high favourability for agricultural use, in an area with a long history of implementing plant cultivation. This tradition is mainly due to topographic factors (elevation, slope angle and slope direction), climatic factors (favourable climate with a high amount of precipitation and relatively high average temperature), natural water input (groundwater close to the surface) and the possibility to perform technical works to implement irrigation due to the presence of a permanent hydrographic network (the Someșul Mic river and its tributaries). Last, but not least, it is due to the facile access of all the categories of agricultural types of machinery used in the process of ploughing, amending and harvesting the products that are cultivated on the agricultural terrains.

The current reduction of non-agricultural economical activities from the vicinity of large urban centres was determined by the disbanding of the vast industrial platforms which had been active between 1970 and 1990. During that period of industrial development, there was a reduction of the agricultural surfaces from the development areas, as the land use was changed from agricultural land to industrial buildings. At present, the development of agriculture materialises through a politics of sustainable development of the former industrial areas and aims at reintroducing the lands occupied by industrial platforms in the agricultural circuit, as well as employing the former industrial workforce in agricultural activities.

Reintroducing industrial surfaces in the agricultural circuit is a long-term process and can be achieved only after doing research aimed at identifying the degree of contamination of the soil and of the groundwater with heavy metals [1–3]. These are left behind by the anthropic activities from the industrial units that are closed, and are still left contaminated in the study area.

The second main aim of the present study is to do such research which would identify the degree of contamination with dangerous substances of the industrial areas from the analysed territory, of the soil and the groundwater. This is absolutely necessary for amending the quality scores of the areas selected for being reintroduced in the agricultural use.

Achieving the two main objectives of the study leads to a specific, up-to-date image of the potential of agricultural capitalization on the lands from the study area. This image can be used as a basis for the measures that are necessary to develop the study area, but also in the studies required for providing subventions to the local farmers and investors. On the other hand, the results can be used to identify new lands which would be favourable for agricultural activities, by reintroducing former industrial lands in the agricultural circuit.

The current paper addresses the potential of GIS applications in order to radically improve the management of land parcels across the study area and agriculture in general. The databases incorporate environmental and topographic factors specific to the Someș corridor area in order to materialise favourability maps for eight popular type of crops in terms of local and sustainable agriculture. It also presents a procedure for incorporating the present degree of soil pollution and groundwater pollution towards a viable and correct favourability classification. The desideratum besides the scientific and research purpose is to offer assistance and guidance to local farmers and specialised institutions from the five studied administrative-territorial units. The established model highlights the optimal choice of crops and is fully integrable in numerous disadvantaged or previously contaminated areas in order to regenerate the economic aspect [4].
Study Area

The study area is represented by the valley corridor of the Someșul Mic river (the Cluj-Napoca-Dej sector), the sector that has a surface of 563 km² and is situated in the northwestern part of Romania, in the Cluj county. From a morphological point of view, this sector lies within an elevation range between 219 and 622 m, with a slope angle that ranges between 0.1 and 35.86 degrees. From an administrative point of view, there are seven administrative-territorial units in this area (five settlements and two cities: Gherla and Dej) (Figure 1).

![Figure 1. Geographical position of the Someș Valley Corridor.](image)

The agricultural land has been developed considerably in the analysed area due to the heavy demand for farming products coming from the large cities (Cluj-Napoca, Gherla, Dej, Romania) but also because of the favourable topographic, soil and climatic conditions. Therefore, surveying the administrative-territorial units reveals that there are 9778 land parcels with various usage at the moment, according to official data (Supplementary File 1).

In this respect, the land parcels used as arable land prevail (2132 land parcels, which represent 48% of the total number of parcels in the study area), followed by the land parcels used as permanent pastures (18.33%) and those covered by forest vegetation (for 13%).

The analysis of the data in connection with the actual use of the land in the discussed territory shows a strong agricultural feature, especially for the floodplain sector and the terrace sector of the
Somesul Mic river, while the territories situated in the adjacent hilly sector are mostly used as pastures, orchards, vineyards etc. [5].

From a pedological point of view, the analysed area is occupied by Chernosem soils on most of the surface (20,247 hectares that represent 35.95% of the analysed territory), on 8436 hectares there are Eutric Cambisol (14.98%), Anthrosol (on 20.69%) and Luvisol (on a surface of 5159 hectares that represent 16.6% of the study area), and on the rest of the territory there are types of soil that belong to Vertisol and Gleysol classes according to FAO (Food and Agriculture Organization) soil classification [6] (Supplementary Files 2 and 3).

The industrial activity sustained in the analysed territory and its stopping by disbanding the big industrial platforms after the 1990s highlights the existence of vast surfaces with contaminated lands that constitute sites that are included in a national inventory. The contamination has mostly taken place in the soil and the groundwater supplies.

According to official data, there are 1393 contaminated sites in the analysed territory [7,8] and potentially contaminated ones (on a total surface of 792.64 hectares in the study area which represents 16.01% of the total territories affected landslides within Cluj County), sites that can be reintroduced in the agricultural circuit through projects and decontamination work. Thus, they would be able to add to the economic value of the lands and the administrative-territorial units where they are located [8].

In this context, The National Strategy and the National Plan for the Administration of the Contaminated Sites in Romania establish the necessity of identifying the affected areas due to anthropic activities in the area of industrial sites and they present the necessary measures to eliminate the potential risks for the people’s health and the environment, as a result of the contamination of soil and water.

Two technological sites were identified for the study area that present these types of environmental problem: The Cellulose and Paper Plant and the Artificial Fibers Enterprise that closed beginning with 1990. These are included on the list of contaminated sites thanks to the identification of historical pollution with heavy metals, muck and solid waste that resulted from the technological process of making cellulose and paper on a surface of 10,000 m².

The sites are situated at a distance of just 2 km from the Someș river bed and from the Somesul Mic, which can lead to the possibility of polluting the water these rivers carry.

In addition to this, the industrial platforms are situated on the administrative territory of Dej town, so the introduction of its lands into the agricultural circuit could lead to the development of agriculture that could provide the necessary fresh vegetables and agricultural products the inhabitants of this town need. Nevertheless, it could contribute to a lasting development of the surfaces by implementing ecological crops based on improving the land with natural fertiliser and on the technique of crop rotation, in order to efficiently exploit the quality of the soils.

During the communist period, there was an Artificial Fiber Enterprise AFE where activities of producing celofiber were executed by approximately 1500 employees. It had a maximum capacity of 30,000 t/year, and after 1995, the used capacity diminished to maximum 15,000 t/year.

The fibre production is part of the category of those with high consumption of raw materials, so for 1 kg of fibre, 3–3.5 kg of raw materials are consumed, which consists of: chemical wood cellulose (conifers, hardwood) stored into a warehouse of 400 t; sodium hydroxide—600–650 kg/t fibre (concentration 220–240 g/l) stored into two reservoirs of lye with a volume of 1000 mc each, made of noncorrosive material; carbon disulfide (CS₂)—about 3400 t/year with a recovery of 70–72% (about 100 kg/t fiber were used). This is a volatile, flammable liquid, explosive when exposed to air, which was being stored in a closed hall in metallic reservoirs that have a layer of water or azote. The reservoirs were placed in concrete underwater pools. The carbon disulphide deposit was formed of 10 reservoirs of 50 mc each. In addition to these, there were also: sulfuric acid (H₂SO₄) about 11,200 t/year (the consume norm being of 1000–1200 kg/t fibre) stored into two reservoirs with a capacity of 1000 mc each and another with a capacity of 500 mc, made of iron sheet; accelerant (about 60 t/year); zinc sulphate (Zn₂SO₄), consumed between 15–60 kg/t fibre that was stored in paper bags with polyethene; sodium sulphate (Na₂SO₄); demineralised technological water (about 8–10 mc
water/t fibre for the preparation of the viscose and between 5–20 m/t fibre for the demineralisation of fibre). For the treatment of water there were used aluminium sulphate $\text{Al}_2(\text{SO}_4)_3$, lime, sodium chloride (NaCl), hydrochloric acid (HCl) and caustic soda (NaOH); the aluminium sulphate $\text{Al}_2(\text{SO}_4)_3$ was delivered under the form of blocks and was stored in the section of the water treatment. For water treatment, they used lime, iron sulphate (FeSO₄) and hydrochloric acid (HCl).

The consequences of using these substances and the lack of measures for storing and decontaminating dangerous substances are still felt locally. This has led to the decision to do some detailed analysis of the concentration of these substances in the soil and groundwater.

2. Materials and Methods

The identification of favourable land parcels for the eight crops under analysis is based on a methodology developed according to the final aim of the study and it is supported by a theoretical database that regulates and offers quantifiable data about all the factors included in the complex process of assigning quality classes to the agricultural land. Taking this into consideration, to achieve the purpose of the research, a complex GIS model of spatial analysis was developed (based on qualitative and quantitative analysis), composed of secondary models developed for nine crops: barley, corn, potato, wheat, beetroot, soy, green peas, beans and sunflower. The model is based on a digital database formed by raster and vector structures that are managed through geoinformatic software [9–11]. The result is represented by raster and vector databases, which spatially identify the territorial areas with the best quality score for the development of agricultural land [12–15] or to identify favourable or restrictive conditions for different plant [16,17] or forest species [18,19].

2.1. G.I.S. Determination of Land Suitability for Arable Use

Implementing any spatial analysis model implies the development of a specific digital database that should correspond to its requirements. In order to create the model used to identify the territorial areas that are favourable to agricultural activities using qualitative scoring and the model used for reintroducing the polluted sites in the agricultural usage, a database with vector structures (soil types, agricultural parcels, flood-prone area, soil sampling points etc.) and raster structures (DEM, average annual temperature grid, precipitation grid, soil characteristics etc.) was created, each structure having a well-established role in the model (Supplementary file 4).

Very important is the analysis of the physical and chemical characteristics of the soils [20–22], the focus being also on the degree of pollution due to the negative effects involved [23–26] but also on the degree of soil erosion [27–29].

In order to classify the study area according to agricultural favourability, a GIS model was applied to classify the territory using nine crops (barley, corn, potato, wheat, beetroot, soy, green peas, beans and sunflower), their average value determining the classification of the territory for agricultural use.

It is necessary to create a detailed database that includes all the factors which determine the growth of these crops. This quantitative database must include the pedological and topographical characteristics, as well as the anthropic influence in the territory (Supplementary File 4).

The DEM, as a primary database used in the spatial analysis model, was generated using the vectorised contour lines from the military topographic maps with a scale of 1:25,000, to which data identified on the 1:5000 maps were added for the flood area of the Someşul Mic river (areas with small variations of the topography, which were not recorded on the military maps). Using the attributed data (elevation), which is attached to the vector structures representing the contour lines, the Digital Elevation Model of the area was derived, with a $10 \times 10$ m resolution. This resolution better highlights the elevation variation of the study area and fits in the distance range between the contour lines, thus generating minimal errors in the process of spatial representation and modelling of the raster structures which are based on the management of the DEM.

The DEM with a $10 \times 10$ m resolution was used to generate the slope angle parameter, expressed in %, as it is a necessary parameter in the model. A high value of the slope angle in the agricultural
A parcel represents a restrictive factor for the crops, determining both restrictions for the agricultural technology used and a high amount of fuel consumption.

The complexity of the spatial analysis model is highlighted by the complexity of the databases used for its development. For this particular model, spatial analysis submodels were used to create the databases in a raster format, representing the spatial variation of the climatic parameters. The distribution of this variation was spatially illustrated by implementing two spatial analysis submodels based on the statistical modelling of the alphanumerical databases that represent the average multiannual precipitation and the temperature values, punctually measured. Their results were implemented in a spatial analysis equation on a supporting database represented by the digital elevation model.

The GIS technology used for creating the digital database enabled the creation of the raster database with the climatic parameter used in the modelling process (the average multiannual temperature and precipitation amount). The correlation equation of these parameters with the elevation was obtained after processing the point data from the weather stations from the proximity of the study area (the stations from Cluj-Napoca, Dej, Bistrita Năsăud, Băișoara and Turda). The identification of the spatial correlation through a regression for the previously mentioned climatic parameters and the elevation, as well as the integration of the equation that defines the regression curve as a spatial analysis equation, were possible in a GIS environment \[30\], having the advantage of a spatial distribution of these parameters for the entire study area.

The average annual precipitation grid has the form:

\[ Y = 0.435 X + 533.51 \] (1)

where: \(Y\)—average annual precipitation amount (mm); \(X\)—relative elevation (m)

The average annual temperature grid has the form:

\[ Y = 0.395 X + 363.76 \] (2)

where: \(Y\)—average annual precipitation amount (mm); \(X\)—average annual temperature (degrees Celsius)

The soil characteristics, such as gleying, pseudogleying and the soil texture present pedological characteristics, which directly influence the water storage from the soil. These parameters were obtained by digitising on the soil maps available for the study area.

The databases of the ecological factors, soil reaction, edaphic volume, and the humus storage (t/ha) were generated by interpolating the point data from the Pedologic Cadastre of Romania using the interpolation method Inverse Distance Weighted, as the dispersion range of the point data is of only 16 × 16 km.

Due to the interdependence between the factors, a series of corrections were performed; thus, the average multiannual temperature is corrected according to the slope direction and the slope angle, and the average annual precipitation amount is corrected depending on the slope angle and the degree of soil permeability (obtained by using the texture characteristics of the soil) \[31\].

An important restrictive factor in the modelling of the suitability for agricultural use is represented by landslides \[32,33\]. As a spatial database, the landslides identify the spatial expansion of these processes in the study area. They were integrated in the spatial analysis model through polygonal vector structures generated by mapping landslides on satellite images and during repeated field campaigns in the study area. Thus, the areas that are not affected by active or stabilised landslides have attributed the value 1, without negatively influencing the suitability value, while the rest of the territory, where shallow active landslides are present or there are landslides with a potential for reactivation, is amended with up to 60% in the case of potato and beetroot crops (Supplementary File 4).

The flood-prone area of 1% was also used in a vector format to highlight the areas located in the flood risk area. In the case of these territories, the excess of water can lead to a 50% amendment of the suitability values for wheat and barley crops and up to 40% for the rest of the crops.
2.2. Methodology

The research is based on the qualitative scoring of spatial databases and their correlate analysis, which is implemented in a GIS environment as spatial analysis equations. The development of the spatial analysis model implies three stages, each with its specificity: the stage of acquiring the databases, the stage of their management and the stage of implementing the spatial modelling (Figure 2).

**Figure 2.** Conceptual schematics of the applied model.

The specificity of the spatial analysis model proposed in this study involves two main ways of acquiring databases that substantiate it: direct acquisition by vectorization (soil types, polluted areas, landslides, flood zones), and direct field identification and data acquisition based on the derivation of spatial analysis submodels (average amount of precipitation, average annual temperatures, soil pH, useful soil volume, etc.), their result materializing as primary databases for entry into the main model.

Because the spatial analysis model presented is based on quantitative information, generalised at country level and published in tabular form for each ecological factor and different databases as the structure (vector and raster) required the inclusion of a database management stage within the model, the stage in which the analysis of each factor was performed based on the correlation of the tabular information with the identified classes of favourability as well as the uniformity from the point of view...
of the representation structure of the spatial databases (conversion of vector databases into raster with resolution equal to that of existing rasters).

The management of numerical and spatial databases allows for the transition to the next stage, the actual spatial analysis, providing quantitative information (obtained based on credit) that allows for obtaining basic structures dedicated to the same value scale useful in spatial analysis to identify favourability.

The spatial analysis itself is divided into four distinct stages, depending on the types of spatial analysis used to finalise the model.

The first stage, the one of obtaining the unitary spatial databases from the point of view of the numerical values of favourability, supposes the reclassification of the databases in raster format based on the quantitative information identified in the previous stage for each crop under analysis.

The next two stages (II and III) represent the core of the spatial analysis model (Figure 2), developed based on the integration of spatial databases into spatial analysis equations for spatial identification of favourability for each culture analysed and identification based on these colours of favourability for arable use for each plot studied. The spatial analysis equations developed within these two stages are in accordance with the equations proposed by the current methodology in the field, used in Romania.

Considering the fact that, within the analysed territory, a series of areas with intense pollution are identified, it is necessary to include in the analysis also these areas in order to diminish the value of favourability for all the impact surfaces. Consequently, within the spatial analysis stage, in order to obtain results with increased applicability, another stage was introduced (stage IV), which involves the development of a spatial analysis submodel developed based on the spatial analysis equation for the integration of databases that allowed obtaining the final database in raster format representing the favourability for arable use taking into account also the restrictive influence of soil and water pollution.

Depending on the influence of each ecological factor considered, quality scores were attributed with values from 0 to 1 for all the twelve factors included in the modelling process (Supplementary File 5), the most favourable being close or equal to 1 and the most restrictive having values closer to 0. These quality scores have represented the foundation for creating the suitability raster databases for all the 96 rasters that were necessary for determining the suitability of the eight crops included in the analysis.

The classification of the study area according to its suitability to agricultural use is performed after the suitability rasters are generated by using the numerical thresholds recommended in the methodology of land quality scoring for each crop separately.

All these indicators will be encoded with the help of the quality scores presented in Supplementary File 5 and will be integrated in the spatial analysis model. The spatial distribution of the quality scores for each factor of the eight different crops that are analysed will be achieved with the geoinformatic software Arc Map, by using the Raster Calculator extension and the following spatial analysis equation:

\[
(F_1 \cdot F_2 \cdot F_3 \cdot F_4 \cdot F_5 \cdot F_6 \cdot F_7 \cdot F_8 \cdot F_9 \cdot F_{10} \cdot F_{11} \cdot F_{12}) \cdot 100 \tag{3}
\]

where: “F1 . . . F12”—the raster database representing the encoded ecological factors.

The raster database generated as a result of implementing the spatial analysis equation will spatially highlight values between 1 and 100, the maximum values indicating that the factors of climate, soil and topography are all favourable to the analysed crop.

The favourability of agricultural use is obtained as an average of the specific favourabilities for the eight analysed crops.

In order to classify the territory according to its suitability for agricultural use, the following formula was applied in GIS environment:

\[
(NB_{barley} + NB_{corn} + NB_{potato} + NB_{wheat} + NB_{beetroot} + NB_{soy} + NB_{green peas} + NB_{sunflower})/8 \tag{4}
\]

where: “NBApple . . . ”—raster databases that represent the quality scores for the crops.
The integration of spatial databases, within the spatial analysis models, in order to obtain results that highlight the spatial characteristics of the final result is done based on the spatial analysis equations. Based on the spatial analysis equations, the digital databases are integrated within the correlative, comparative, statistical or deterministic analysis, in accordance with the requirements of the methodology followed in the development process of the implemented spatial analysis model.

The spatial analysis equations were developed in close connection with the methodology followed, based on bibliographic references and taking into account the stage of the model in which they were applied. Thus, two main equations of spatial analysis have been developed: the first spatial analysis equation utilises the mathematical operator “·” for the integration of spatial databases being implemented in the third stage within the proper spatial analysis; the second equation was developed based on the mathematical operators “+” and “/” being implemented in the third stage of the spatial analysis having as the main goal the integration of the spatial databases, in raster format, in order to identify the favourability for arable lands.

The result of the equation will materialise as a raster database with numerical attributes ranging between 1 and 100, these values being eventually reclassified according to the suitability classes: very high (80–100), high (60–80), medium (40–60), low (20–40) and very low (0–20 quality score) [34].

The study area is characterised by a high density of the population and by very scattered industrial activities that impose an amendment of the suitability scores according to the pollution degree determined by anthropic activities, as various pollution sources determine major restrictions [35–37] and different techniques for decontamination and reintroducing the land surfaces in the general agricultural use. Thus, according to the pollution degree identified in the field, by analysing the samples obtained by drilling and from the surface of flowing water, the amending rate will be established for the analysed areas.

2.3. The Identification of Contaminated Sites

In order to identify the rate of pollution, water samples have been taken from different locations, both from the industrial platforms and from the stream of the Someșul Mic. The chemical characteristics of these samples were determined both at the sampling site and as laboratory tests. Other tests were performed after collecting 42 soil samples and 5 groundwater samples.

The number of samples was determined by taking into account the area of the potentially polluted surfaces, the land stratification and the financial cost of the tests. Their position was determined to have a dispersion of the sampling points in all cardinal directions and by considering the possibility of the influence of several potentially polluting sources, so as to capture the possible negative influences affecting the activities from the vicinity of industrial sites [38].

In the case of soil drillings, it was necessary to ensure the access of the drilling rig by removing the rubble first, and in the case of concrete platforms, special drills were needed to drill through them. The drilling rig used for dry drilling is a Hydra Joy 3 machine (Supplementary File 6), which has a diesel engine of 100 horsepower and a force of push and pull of 3500 kg.

After taking the soil samples, specific chemical tests were performed both on the soil and the surface and groundwater samples.

In order to take the groundwater samples, a PVC pice was used (Ø = 70 mm), as well as PVC lids. The groundwater was taken with a sampling pipe (bailer) with a Dn = 40 mm diameter and V = 1 L volume, which enables the loading of a water column of 0.97 m, including the water film on the same surface of the water body. The groundwater samples were taken after pumping 3 times the volume of water from the drilling column. These drillings were performed down to the layer that is considered to be the bedrock, at approximately 7 m of depth from the elevation of the platform.

The pH was determined according to the ISO 10523: 2012 standards that imply an accuracy of ±0.2 and an uncertainty range of ±0.2.

In order to determine the sulphate content, the MSZ ISO 9280-2: 1998 standard was used. The content of sulphides was determined by applying the ISO 10530: 1992 standard, and (ICP-MS) EPA 6020B: 2014 was used for determining chemical elements: cadmium, lead, chromium, copper and zinc.
The soil sampling process required a considerable effort because it lasted for three days (26–29 November 2019) on the industrial platform from Dej North, using a ROLATEC RL46L equipment which enabled drilling in a continuous rotating system, in dry mode.

In a first stage on the field, the sites for the soil and groundwater sampling were determined depending on the representativity of the site and the drilling plan (Figure 3), which is dependent on accessibility, according to the SR EN 1997-2 and SR EN 1997-1 standards. The purpose was to identify and describe the lithological succession and to take soil samples for chemical testing in the laboratory.

Figure 3. Geographic position of the soil and water sampling sites (where: CC—land occupied by buildings, yards and industrial zones, CP—permanent crops, DR—land occupied by roads and railroads, HB—water surface, HN—unproductive lands with marsh vegetation, HR—lands occupied by running water, PA—lands occupied by forest vegetation, PN—mine tailings, landfills, PP—permanent pastures, TA—arable land, VI—land with vineyards, XX—areas where no photo interpretation was performed).
Thus, 11 drillings were performed where soil samples were taken from 5–10 m depth down to where the groundwater was reached, totalising 66 linear meters of drilling. For 5 of these drillings, drainage pipes were installed; the next day, water samples were taken for the chemical testing of the groundwater.

The drillings were located so as to capture in as much detail as possible all the aspects of interest for this study: drilling number 1 was performed in the area of the wastewater treatment plant and the thermal power station, drilling number 2 was made in the area of the treatment plant (mechanical stage), drilling number 3 in the area of the treatment plant (chemical stage), drilling number 4 in the area of chemical preparation (alkalising workshops, viscose, refrigerating installation with ammonium absorption, gas washing), drilling number 5 in the area of the carbon disulfide storage, the sulfur storage, the loading/unloading the railroads ramp in the south-east, drilling number 6 in the area of the carbon disulfide storage, the sulfur storage, the loading/unloading CF ramp in the south-west, drilling number 7 in the area of the adsorbing platform, the hall for recovering carbon disulfide, unit of distillation gas washing, chimney for gas dispersion and the oxidation basin, drilling number 9 in the area of the spin bath workshop, the chemical warehouse (between the section of chemical preparation, the spinning section and the water treatement station), drilling number 10 in the area of chemical preparation (alkalising workshops, viscose, refrigerating installation with ammonium absorption, gas washing) and drilling number 11 in the area of the treatment bath and of the spinning section (Figure 3).

3. Results

By applying the previously presented methodology, a series of results were obtained as GIS databases and were represented as thematic maps. There are also results related to the physical and chemical characteristics of the soils and of the groundwater, which will be presented in the following section.

3.1. Groundwater and Soil Pollution

As a result of the hydrogeological investigations, in the case of the paper factory from Dej it was determined that the groundwater is well distributed in the floodplain area of the Somes, up to its contact with more elevated landforms. In the present case study, the groundwater level was identified in the drillings performed on the site at a depth between 1.5 and 7 m.

This small depth of the phreatic surface is due to the presence of a clay layer (clayey silt or sand) with a thickness of 0.5–2.9 m, little permeability, which favours water stagnation on its surface, the variable groundwater discharge being directly dependent on the superficial flow, with a higher discharge in the periods with a high pluviometric regime or in the intervals with snow melting, in spring. This aquifer is located in the gravel layer with sand and boulders under layers of dark grey sandy clay with a thickness between 2.4 and 4.0 m.

The lithological succession is consistent and continuous in every drilling. The lithology types appear in each drilling without any layer thinning (Supplementary File 7). Thus, the vulnerability of the aquifer manifests itself in the areas with cracks or human interventions which have penetrated through the impermeable layers and allow possible pollutants to leak into the groundwater.

The drilling processes have enabled the analysis of the layer succession. Fillings were identified in the superior layer (of anthropic origin, formed of gravel, boulders, clay, concrete and brick elements, from a depth of 0.3 m, in drilling number 3, to a maximum depth of 4 m, in drilling number 7). A clayey layer of alluvial origin comes next, formed of clay, sandy clay and clayey sands and a coarse alluvial layer formed by the fluvioglacial deposits (gravel and sand) of the Somes.

A chemical analysis was also performed for the groundwater samples for six locations from the industrial platforms (Supplementary File 8), as well as for five locations from the Somes riverbed and for two samples from wells located in the Fundătura settlement (samples f11 and f12) (Supplementary File 9).
The analysis of the total hydrocarbon content (TPH-GC) from the soil samples (in relation to the dry substance, mg/kg) (Supplementary file 8) highlights the exceedance of the intervention thresholds in comparison to the limits established by the 756/1997 order.

The analyses indicate TPH contaminations with exceedances of the intervention threshold (2000 mg/kg), the maximum value being 3490 mg/kg (drilling number 10). One can notice that the majority of the analysed samples are under 100 mg/kg (11).

In the case of the drillings 4, 5, 6, 7, 10, and 11, TPH exceedances are identified (total hydrocarbon content) at a depth ranging between 0.5 and 1.7 m, the soil fill being present in all the analysed areas. One assumes that this pollution is due to some flawed handling of fuel and other petroleum products (fractions of heavy hydrocarbons) on the platform or directly from the filling material that was contaminated, taking into consideration the fact that the previously mentioned drillings are all in the production zone: chemical section, spinning section, carbon disulfide storage.

The TPH concentration could have been caused by flawed handling of petroleum products, the existence of some oil/district heating pipeline or by the contamination of the soil fill during the functioning stage of the plant, until the concrete platforms were executed.

For most of the drillings from the production area (5, 6, 7, 8, 9, 10 and 11), the samples have an alkaline pH down to a maximum depth of 5 m. In these areas, the alkaline substratum is formed of soil fill (building materials with sand, gravel and clay).

This contaminating element has been identified only in the soil test results and not in the water ones, as the identified samples with TPH contamination are located above the level of the groundwater. Thus, the distribution of the contaminant element was not made through the groundwater that has a relatively permanent flow regime, but through isolated contamination and local dispersion through the low infiltration of pluvial water.

The variability of the quantity of TPH is very high on vertical, in comparison to the frequency of the data in a horizontal plane (drillings at approximately 60 m–80 m); thus, it was modelled according to the distribution, inverse-distance weighting solid modelling. The total estimated volume of the contaminated soil fill with TPH is 11,700 m$^3$ (Supplementary File 10).

In the case of the drillings 1, 2, 3 and 4, which are located in the area of the treatment station, cooling towers/water pumps, the pH is only slightly alkaline, its decrease taking place with the increase in depth. The basic character of the soil at the surface could be caused by the handling/storage/accidental spill of some basic substances/materials/waste or by the natural fund (soil fill).

The in-depth contamination is due to prolonged infiltration from the surface area. The pH is not regulated by the Order 756/1997, but its value is directly correlated with the presence of some existent chemical substances, either naturally or as a result of an older activity, which have not been identified through tests until now.

For the other two indicators analysed, originating both from basic and acid substances used on the site, the intervention values regulated by the Order 756/1997 are not exceeded.

In the case of drilling number 4, at the depth of 1.7 m, the intervention threshold is exceeded, while, at the contact with the clay, the contamination decreases below the warning threshold. In this area, the soil fill made of concrete and gravel is present down to the depth of 1.6–1.7 m. One can assume that the layer of clay from the depth of 1.6 m down to 6 m has prevented the sinking of the pollutant.

For drilling number 5, the intervention threshold is exceeded only at the depth of 1.5 m, according to the Order 756/1997. The layers above this depth are not contaminated and neither are the ones below; thus, this contamination does not originate in the soil horizons above it, nor is it caused by the groundwater and its vertical variations. In this area, there is a deposit of carbon disulfide as well as the CF ramp for loading/unloading, the pollution originating at the ramp.

In the FM 6 drilling, the TPH intervention threshold is exceeded at a depth of 0.5 m, according to the Order 756/1997, while the inferior layers are not contaminated. Down to the depth of 0.5 m, there is concrete and soil fill, and from 0.5 to 4.5 m there is consistent sandy clay, which has blocked the
migration of the pollutant upstream. In this area, there is the deposit of carbon disulfide, as well as the CF ramp for loading/unloading, the pollution originating at the ramp.

In the FM 7 drilling, the TPH intervention threshold is exceeded at a depth of 0.5 m, according to the Order 756/1997, while the inferior layers are not contaminated. Down to the depth of 4 m, there is soil fill and building material with sand. The sampling point is located in the spinning section and the area of sulfur and carbon disulfide storage (CS$_2$).

In the FM 10 drilling, the TPH intervention threshold is exceeded at a depth of 1.0 m, according to the Order 756/1997. Below 1.0 m, there is no exceedance of the threshold due to the low permeability of the clay layer, the superior layer not being contaminated. The drilling is located between the spinning section and the section of chemical preparation.

In the FM 11 drilling, the TPH intervention threshold is exceeded at a depth of 1.5 m, according to the Order 756/1997. Below 1.9 m, there is no exceedance of the threshold due to the low permeability of the clay layer, the superior layer not being contaminated. The drilling is located in the middle of the spinning section.

By performing an organoleptic analysis, at drilling number 1 there was an unpleasant smell of sulphides (HS), while, in the case of drilling number 2, there was a strong sewer smell. The test results for the chemical analysis of groundwater indicate an exceedance of the maximum limits that are allowed by NTPA 001 for the ammonium indicator (NH$_4^+$). In the drilling number 1 from the area of the water treatment station, the CET power station and the administrative pavilion and in drilling number 4, between the section of chemical preparation and the spinning section, these exceeding values are 19.3 and 12.8, respectively. There are also exceeding values for sulphides in the case of drilling number 1 (Supplementary Files 10 and 11).

These exceeding values of the limits for the pollutant substances are further used in the process of amending the quality scores for the analysed crops and agricultural use.

One must notice the fact that the general flow direction of the aquifer is directed perpendicularly towards the Somes on the north-south direction. Thus, the agricultural parcels which are found in this direction are amended due to this negative influence. For the parcels that are located in the proximity of the industrial platform from Dej, in the intervals with a high pluviometric regime, the groundwater flow is stagnant, the site favouring this stagnation as a result of the reduced slope angle and the presence of an impermeable layer of clay which reduces infiltration. As a result, for short periods of time, the flow direction of the aquifer could stagnate as its flow speed is reduced.

3.2. The Modelling of the Parameters Required for the Classification of Agricultural Suitability

The functions of the GIS technology have made possible the implementation of equations that correlate the elevation with the climatic parameters used in this study. The grid of the average multiannual precipitation and the average annual temperature was generated based on the results of the modelling.

In the study area, the variation of the average annual temperature ranges between 7.48 and 9.58 °C, the temperatures below 8 °C being considered medium, while those above 8 °C are considered high, favourable to the crops which need higher temperature values for growth and ripening.

The only crop that does not receive its necessary temperature value is the sunflower. Because of this, the areas characterised by temperature values ranging between 8.01 and 9 °C have been encoded with the lowest quality score (0.3).

The average multiannual precipitation values vary in the study area between 630.5 and 804.5 mm, this reduced variation being due to the reduced variation of the elevation which is characteristic to a valley corridor. However, the areas where the annual precipitation exceeds 800 mm/year impose restrictions for the sunflower crop (that is why it has received a quality score of 0.3), while, for the potato these precipitation values determine a high suitability (therefore it has received the maximum quality score, 1).
The slope angle has been derived using the digital elevation model and for the study area, its values range between 0.1–89.7%. The floodplain area of the Someșul Mic is characterised by low slope angle values below 15%; therefore, it offers favourable conditions for agriculture and it was encoded with the value 1 or close to 1. At the same time, the slope sector is characterised by slope angle values above 35%, which have the strongest negative influence on the agricultural suitability (the quality score is below 0.2).

The gleying and pseudogleying characteristics of the soils from the study area do not impose any restrictions for the analysed crops, but a slight negative influence is present in the areas with higher humidity (for the barley crop).

The soil texture has been digitised from the soil maps of the study area and has been classified according to the texture classes, the soils with a sandy texture are present in the floodplain of the Someș (they received a low-quality score for all the crops). These soils provide the necessary amount of water for only a short period and are characterised by a low content of humus.

The humus reserve in t/hectare has been obtained as a raster database by using the point data obtained from the Soil Cadastre. In the study area, this indicator ranges between 146 and 462 t/hectare, which explains the maximum values of the quality scores, 0.9 and 1.

The main geomorphologic process from the study area that causes problems in the agricultural land is represented by landslides. Previous studies have had as their aim the identification of landslides, the analysis of their causing factors and the thresholds of cumulated precipitation which act as landslide triggers. There are 554 active landslides in the study area that are stabilised but have a potential for reactivation; therefore, the land on which these processes manifest themselves has received more reduced quality score values in the suitability analysis for beetroot and potato (0.4), corn, soy and sunflower (0.5).

3.3. Favourability for Crops of Barley, Corn, Potato, Wheat, Soy, Green Peas, Beetroot and Sunflower

By applying the GIS model that uses the environmental factors modelled for the Someș corridor area, several databases were generated, which materialise as suitability maps for the eight specific crops according to the scoring methodology for the agricultural lands from Romania.

The analysis of the results obtained in the case of the land favourability for barley crops reveals that the best conditions for this crop can be identified in the terrace area of the Someș and on the slopes with small slope angle from the watersheds of the tributary rivers (Figure 4a). Of course, the areas that offer the best conditions for this crop are territorially reduced, occupying only 3.6% of the study area (these areas are characterised by quality scores between 41 and 70).

Most of the study area (55.1%) is included in the very low suitability class (characterised by quality scores ranging between 0.08 and 20) and in the medium suitability class (characterised by quality scores ranging between 20.1 and 40). For these territories, other crops are recommended instead of barley. Barley is used both as human and animal food, with 70% of the barley production on the globe being used directly and indirectly for the feeding of animals [39]. Another important use for barley is the production of beer malt, but, in Romania, this usage has decreased especially after 1990, although the production per hectare has increased from 1.64 t/ha in 1961 to over 3.1 t/ha in the last years [40].

The land suitability for corn (Figure 4b) is similar to the previous situation presented, as on 61.1% of the study area the suitability is low. However, for 15.2% of the total area, the conditions are favourable. Furthermore, corn crops are well spread, especially in the case of subsistence farming [41].

The potato has medium conditions on 45.5% of the study area and good growth conditions on 28.3% of the territory, while 6.3% of the total area is characterised by high values of the quality score (ranging between 61–80) (Figure 4c). This vegetable has also been used both in the food industry and as animal fodder, its high suitability offering the possibility of obtaining high productivity, which makes it usable even for export [42].

Studying the classification of the territory according to the land suitability for wheat crops, an extended surface of 150.6 km² becomes highlighted (which represents 27% of the total study area), as it offers good conditions for wheat growth, and on another 9.1% of the area (50.8 km²) the suitability is
high (quality scores ranging between 61–70) (Figure 4d). In the case of this particular crop, the influence of the climatic factors is of capital importance [43], especially the air temperature that influences both the phenology and the quantity of wheat obtained per hectare [44].

The beetroot crop is also possible on 14.4% of the territory, which is characterised by quality scores above 60.1. These areas are found on 4.3 km² from the administrative-territorial unit of Mintiu Gherlii and on 4.4 km² from Apahida (Figure 5a). However, most of the study area (41.2%, which represents 229 km²) does not offer favourable conditions for beetroot, especially due to the water resource and the clayey texture of the soils.

![Figure 4.](a) Land favourability for barley. (b) Land favourability for corn. (c) Land favourability for potato. (d) Land favourability for wheat.)
Soy has recorded a decrease in the cultivated areas during the last years [45–47]. This crop has restrictive conditions on most of the territory (61.2%) and favourable conditions on 18.3% of the total study area (110 km$^2$) (Figure 5b).

Figure 5. (a) Land favourability for beetroot. (b) Land favourability for soy. (c) Land favourability for green peas. (d) Land favourability for sunflower.
Green peas have the best conditions on large areas (97 km² are characterised by suitability values ranging between 40.1 and 60 and 108.5 km² by suitability values ranging between 60.1 and 80) (Figure 5c).

An important national crop is sunflower. This cereal is used for extracting the oil used in the food industry, its waste being used as fodder for animal raising.

Nevertheless, for obtaining a significant production of sunflower, a high sum of the temperature values is required in the ripening period, as well as significant water resources [48]. Unfortunately, in the study area, the conditions for sunflower growth are not very good, only 3.2% of the territory offers medium conditions for this crop (Figure 5d).

4. Discussion

Using the GIS model for determining the suitability of the eight crops previously presented, their average was computed to determine the classification of all the land parcels depending on their agricultural use (Figure 6). We kept the analysis and the discussions related to all the parcels, irrespective of their present land use, because we want the results of the present study to be useful to farmers, landscapers and specialised institutions when the land use of the parcels is to be changed [49]. For the whole study area, the values of the arable land vary between 1.49 and 70.2 (Figure 6).

![Figure 6. Map of favourability to arable use for the land parcels from the administrative-territorial units located in the corridor of the Someșul Mic.](image)

For all the land parcels from the five administrative-territorial units, the restrictive factors are related to topographic characteristics, especially slope angle, and pedological characteristics (edaphic volume, soil texture etc.) or reduced water resources. Thus, 49.5% of the land parcels (representing
4565 parcels) present one or more restrictive factors and are characterised by quality scores ranging between 1.49 and 20. For 2469 land parcels, the modelled suitability values range between 21 and 40; however, they are affected by difficulties in applying specific agricultural technologies, as well as by low productivity. In total, 19.6% of the land parcels offer medium conditions for this type of land use, while 4.1% of the land parcels (374 land parcels) offer favourable conditions for arable land use. It is obviously important for these latter 374 land parcels to choose the crop for which the growth conditions are optimal in order to easily apply the specific technologies and reduce the production costs to a minimum.

For the results of the study to be more easily used by the representatives of the institutions that have as their field of activity the recommending of crops with the best suitability, according to the local specificities of topography, climate, soil and depending on the pollution degree, we will further present the suitability classification for the analysed crops at the level of each of the five administrative-territorial units from the study area (Figure 7).

Figure 7. Cont.
After classifying each administrative-territorial unit according to its suitability for the eight crops corresponding to arable land use, one can identify extended areas in the high suitability class for beetroot in the administrative-territorial units of Jucu, Bonțida, Gherla.

The high suitability class (61–80 scoring points) is present for the green peas crop inside the administrative-territorial units of Dej and Iclod, while sunflower for Mintiu Gherlii, Apahida and Bonțida.

The local farmers and the investors in agriculture can use the results of the study to establish new crops and access non-refundable agricultural money by expanding the land which is presently used as

Figure 7. Distribution of suitability classes on administrative-territorial units.
arable land for crops with favourable conditions. Thus, the risk of failure and the risk of obtaining an agricultural production below expectations will be diminished.

The analysis of the final result highlights the territorial areas that are favourable for the implementation of crops, especially in the terrace areas from the Someş and on the slopes with a small slope angle from the tributary watersheds, as well as on the land parcels from the close vicinity of the great urban centres. This aspect reveals the low cost necessary for the implementation of the agricultural activities (land preparation, land cultivation, harvesting), due to the easy access of the agricultural equipment (next to the European road and with an extended network of agricultural roads) and due to the configuration of the topography with low slope angles and a rather flat slope orientation.

The identification of large surfaces with high suitability for growing crops in the vicinity of large urban centres and the implementation of specific crops would have a major social impact. This would have effects both in the professional reorientation of the human resource towards agricultural activities or exploiting agricultural products, for the people who became unemployed as a result of the large industrial platforms being closed and in the lower cost of the disposal of agricultural products, due to a decrease in the transport costs, as their main market is in the large cities.

The studies carried out by the research institutes involved in the management and sustainable exploitation of the agricultural lands are carried out at a point level for the territorial surfaces that are an integral part of the experimental lands owned by them [50,51]. The proposed analysis, carried out at a regional level highlights the general characteristics in terms of favourability leading to recommendations for the development of functional agricultural areas for the local actors (territorial administrative units, large farmers, water basin administrations, economic agents etc.), and it also makes the economic value of agricultural production increase due to the correct management from the point of view of productivity of the lands on large areas as opposed to individual lands and small plots.

The establishment of inter-municipal associations for the exploitation of the natural potential of the lands would be one of the main proposals that are outlined as a result of the implementation of the results of the present research. From the point of view of the evaluation marks, several areas stand out very clearly (Figure 6), the Jucu-Bontida ATU area, Gherla-Mintiu Gherlii ATU where the high favourability class (60.1–70.2) occupies large, unitary surfaces that are outlined on natural limits (Somes River terrace area), areas that, following an integrated management, would bring added economic value to the respective lands as a result of the cultivation on large areas of crops with high suitability.

In order to identify the degree of soil pollution due to industrial activities, several soil drillings were performed together with chemical tests of the surface and groundwater. In order to increase the representativeness of the final results of the proposed rating model, it would be useful to introduce in the pollutants analysis the category of pollutants from non-compliant storage of municipal waste and individual farms, but this will be the objective of future studies.

The results highlight the degree of pollution for the study area, a very important aspect when we consider the general protection of human health and the identification of the possibility of practising efficient ecological agriculture, by respecting all the regulations from the field of environment and water management.

5. Conclusions

The present study uses a complex model of land analysis based on GIS spatial analysis using digital databases that represent the parameters for climate, soil and topography, which are taken into consideration for the identification of land suitability for agriculture. The complexity of the model raises a series of problems, which are mainly determined by the quality of the databases (the resolution of the DEM, different scales of representation for various factors included in the model, different structure of the databases etc.), the integration of various submodels that were obtained by implementing spatial analysis equations or spatial interpolation equations and, last but not least, by the management of the databases (approximately 110 different database structures) inside the model.
The implementation of the presented spatial analysis model raises a number of issues that vary from one implementation area to another. The main problems refer to the availability of spatial databases regarding the necessary ecological factors, the scale of their representation, and the resolution of the databases integrated in the analysis, which leads to the development of models with their own specificity for each analysed area.

The model can be implemented on large surfaces from different areas, surfaces for which there are databases available with the input parameters, the result being useful in the specialised application for the easy management of the land and the increase in the commercial value of the crops. This is done by using lands with a high suitability for them, thus increasing the rentability of crop exploitation.

Supplementary Materials: The following are available online at http://www.mdpi.com/2073-4395/10/9/1245/s1. Supplementary File 1: Distribution of land parcels in the study area using land use classes, Supplementary File 2: Distribution of soil classes and soil types in the study area, Supplementary File 3: Soil types in the Somes Valley Corridor, Supplementary File 4: The database used for the GIS model, Supplementary File 5: Quality scores awarded for each ecological factor, Supplementary File 6: A. The soil profiles were obtained with the help of ROLATEC RL46L equipment. B. Determination of the water pH at the sampling site. C. Water sampling from the Somes D. Mounting the pipes for water sampling from soil profiles E. Taking water samples from soil sampling drill, Supplementary File 7: The 3D geological structure of the site, Supplementary File 8: Chemical characteristics of the samples taken from industrial platforms, Supplementary File 9: Chemical characteristics of the samples taken from groundwater, Supplementary File 10: The distribution of the TPH contamination (over 2000 mg/kg) in relation to the geological structure, Supplementary File 11: Chemical characteristics of the samples taken from the Somes riverbed.

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