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OPTIMUM AGRICULTURAL LAND USE IN THE HILLY AREA OF EASTERN ROMANIA. CASE STUDY: PERESCHIV CATCHMENT

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Abstract: The Pereschiv catchment is a typical rural and poorly developed area from eastern Romania, where over 90% of active population has been involved only in the primary sector. The local subsistence agricultural pattern is based on crop production and defined by very low yields. Degradation of the land quality strongly connected with the improper human impact resulted in significant soil erosion and gulling rates. Under such background and using GIS techniques, the main objective of this study is to establish an appropriate methodology to identify the best land use pattern, based on the natural conditions, so that land planning and land treatment investments to be at minimum level. Thus, the expected outcome is to automatically create an optimum land use map by comparing the present land use map with the evaluation score calculated for each land use type. The obtained results show that the current land uses do not match the maximum favorability due to the natural conditions for over half of the study area. The geomorphologic and pedologic conditions indicate that forestland, pastures and meadows should have to extend against the arable land, which it is recommended to be halved. The pastures slightly extend from 21.6% to 28.3%, while the forestland should increase more than three times from 12.2% at present to 37.1%. Generally, in the Pereschiv upper basin, the people are recommended to shift towards large-scale livestock, an activity which currently supports only their domestic purposes. In the middle and lower catchment, livestock has to extend too, and alternate with crop farming on relatively large areas, but higher than today. In terms of sustained investments, vineyard and the orchard can achieve very good results.

Keywords: optimum land use pattern, land suitability, GIS

1. INTRODUCTION

The agricultural land represents one of the most important natural resources of Romania and the need to assess some significant patterns is of interest.

Usually, the "*field*" system includes, as morphological and functional components, the soil cover, landforms, climate and land use methods (Patriche, 2003). Under these circumstances, the land evaluation involves quantification of the land intrinsic features both by the ecological value of soil quality, landforms and climate characteristics (Lewandowski & Zumwinkle, 1999) and by the socio-economic value defined through location, accessibility, land assessment works, economic infrastructure, property system etc. (FAO, 1976; Rossiter, 1995).

By using six principles of land evaluation, the paper "*Framework for Land Evaluation*" (FAO, 1976, 2007) substantiates concepts, methods and procedures for a systematic biophysical and socio-economic assessment of the potentials for appropriate land use.

Some of the most important land evaluation systems were defined in *The Fertility Capability Classification* (Sanchez et al., 1982), *Land Evaluation and Site Assessment* (USDA, 1983), *Land evaluation and farming systems analysis* (Fresco et al., 1992), *The framework for evaluating sustainable land management* (Smyth et al., 1993).

Also, a series of land evaluation methodologies have been developed and applied on regional or local level (Johnson et al., 1994; Messing et al., 2003; McBride & Bober, 1993).

Since the '90, the development of modern geographical information system (GIS) techniques and methods has covered the need for fast and complex data processing and specializing. Consequently, a number of computerized land evaluation systems have emerged, namely: *The automated land evaluation system* (Rossiter & van Wambeke 1997), *MicroLEIS* (De la Rosa et al., 1992), *Intelligent System for Land Evaluation* (Tsoumakas & Vlahavas, 1999).

Based on a series of previous approaches recommended by Teaci (1980), an appropriate methodology for land assessment has been developed in 1987, in Romania by the National Research and Development Institute for Soil Science, Agrochemistry and Environment - ICPA (INCDPAPM – ICPA). Through a continuous background and taking advantage of GIS resources, highly complex databases have been developed and implemented (Munteanu et al., 1998; Vlad, 2003).

All these works generally aim to a qualitative and quantitative evaluation of land suitability, which is the match of a given land type for a defined use in its present condition, without major improvements or after improvements (FAO, 1976). Thus, the studies for land evaluation are more used to aid land use planning for achieving the ecological and economic goals. This approach touches either the theoretical level (Bouma, 1997; Grabum & Meyer, 1998; Herrman & Osinski, 1999) or the applied one (Chen et al., 2003; Gao et al., 2010; Huising et al., 1994; Johnson et al., 1994), and many of these studies are using GIS methods (Xiang, 1996; Baja et al., 2007; Allan & Peterson, 2002; Conine et al., 2004, Xu et al., 2011; Biali & Stătescu, 2013).

Under such background and using GIS techniques, the main objective of this study is to establish an appropriate methodology to identify the best land use pattern, based only on the geographical features of the land, so that the land planning and land treatment investments to be at minimum level. The socio-economic land value, defined through location, accessibility, land assessment works, economic infrastructure, property system etc., is not taken into account.

Thus, the expected outcome is to automatically create an optimum land use map by comparing the present land use map with the evaluation score calculated for each land use type.

2. THE STUDY AREA AND THE WORK METHOD

2.1. The study area

The Pereschiv catchment is located in the Tutova Rolling Hills, Southern Moldavian Plateau, Eastern Romania and covers 23,267 ha (Fig. 1).

The catchment is comprised mainly of sandy-clayey Miocene-Pliocene layers that show a gentle dipping of 7-8 m/km NW-SE (Jeanrenaud & Saraiman, 1995). The topography comprises firstly sculptural landforms typifying the entire area on almost 85% and secondly accumulative landforms that cover over 15%.

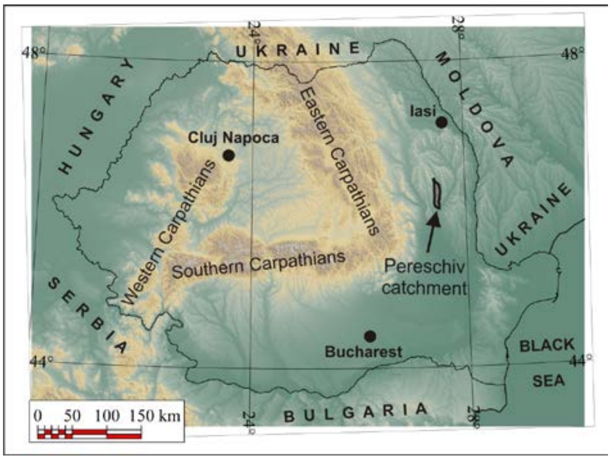

Figure 1. Location of the Pereschiv catchment in Romania

Stable slopes within the hill tops and plateaus are mantled by chernozems (21.9%), faeozems (18.7%) and forestry soils, such as entic luvosols (23.9%) and typic luvosols (1.2%). In addition, on degraded slopes, the azonal soils (e.g. regosols and anthropic sols) controlled by erosion amount 21.7% of the Pereschiv catchment (Niacșu, 2009).

The native vegetation cover was drastically changed over the last two centuries in the favor of agricultural terrains, and the percentage of forestland has continuously decreased from over 55.0% to only 12.2%. Therefore, the cropland has progressively become the most widespread land use type. Nowadays, the row spacing crops, such as corn (58.5%), sunflower (16.2%) are prevailing against close growing crops as winter wheat and rye (22.4%) (Niacșu, 2012b).

The improper human activity in the Moldavian Plateau unveiled by the up and down hill farming and inadequate road network has resulted in a significant development of soil erosion (Ioniță et al., 2006), gulling (Rădoane et al., 1995; Ioniță, 2000; Ioniță, 2006) and to a lesser extend of landslides (Pujină, 2008, Ioniță et al., 2014). The total erosion computed for the entire Pereschiv catchment exceeds 410,763 t yr^{-1}, and consequently the mean annual erosion rate amounts 17.7 t ha^{-1}, of which 44% is due to soil erosion and 56% to gully erosion (Niacșu, 2012b).

Generally, the hilly area of Eastern Romania is a typical rural area, poorly developed, where over 90% of active population work in the primary sector

(Tudora, 2012). Today, this area is facing with subsistence agriculture, described by very low yields, and the constant need for new agricultural land generates a high pressure especially on forestland.

2.2. The work method

In order to achieve the objective of this study, three steps methodology has been deployed (Fig. 2).

2.2.1. The achievement of the present land use map

Land use map was based on GIS-assisted interpretation of aerial photos. These images were delivered by the Romanian National Agency for Cadastre and Land Registration (NACLR, 2005) at scale 1:5,000 and 0.5m x 0.5m pixel resolution.

Complementary, for some land categories, such as the forest roads, the aerial photos are supplemented with the cadastral maps data. The land categories features and the nomenclature have been provided by the General Land Cadastre according to the provisions of the Act no.7/1996.

For outcomes, in better accordance to local conditions, some categories have been splited into subcategories. In our case study, due to the widespread degradation state of vineyards and orchards, each category has been customized in two subcategories: in good shape and degraded.

2.2.2. The achievement of the land suitability map for the main crops and land use types

Was done by using GIS software, where the geomorphological, pedological, climatological and hydrological maps have been integrated into the natural land favorability maps according to a renowned methodology (Niacșu, 2012a).

In our case study, the land evaluation data were calculated and spatial distributed by using TNTmips 7.3 software (MicroImages, Inc., 2008) for the most important land use types, namely: arable (as average of the main four crops: corn, sunflower, wheat, peas and beans), vine grapes, cherry and pasture. The Romanian methodology of land assessment was achieved within the framework of the Soil Studies Development Methodology – SSDM (INCDPAPM – ICPA, 1987). It takes into account 18 indicators of the environmental conditions. Of those, 12 indicators describe the soil conditions and refer to the occurrence and intensity of some pedogenetical processes such as *carbonatation* (the total $CaCO_3$ content in 0-50 cm range), *gleysation*, *surface-water gleysation*, *salinisation or alkalization.* The following soil physical properties have been taken into account: *texture in the top horizon* (or in 0-20 cm range), *total porosity*, *physiological useful volume*, *groundwater depth*. *The soil reaction within the top horizon* (or in 0-20 cm range), *humus storage* (in 0-50 cm range), *degree of base saturation* and the human influence on *pollution* are some of the chemical properties. Other factors having in view are: the landforms depicted by *slope* and *landslides*, the climate, described by adjusted values of *annual mean temperature* and *rainfall*, and the drainage through *the flooding* and *excess surface moisture*.

According to SSDM, each of those 18 indicators has a different assigned value (Land Evaluation Index - LEI) depending on the natural favorability to each particular crop or land use. It varies between "1" for total favorable to "0" for total unfavorable (Table 1). The LEI values have been based on long-term results obtained in the experimental research fields widespread all over Romania.

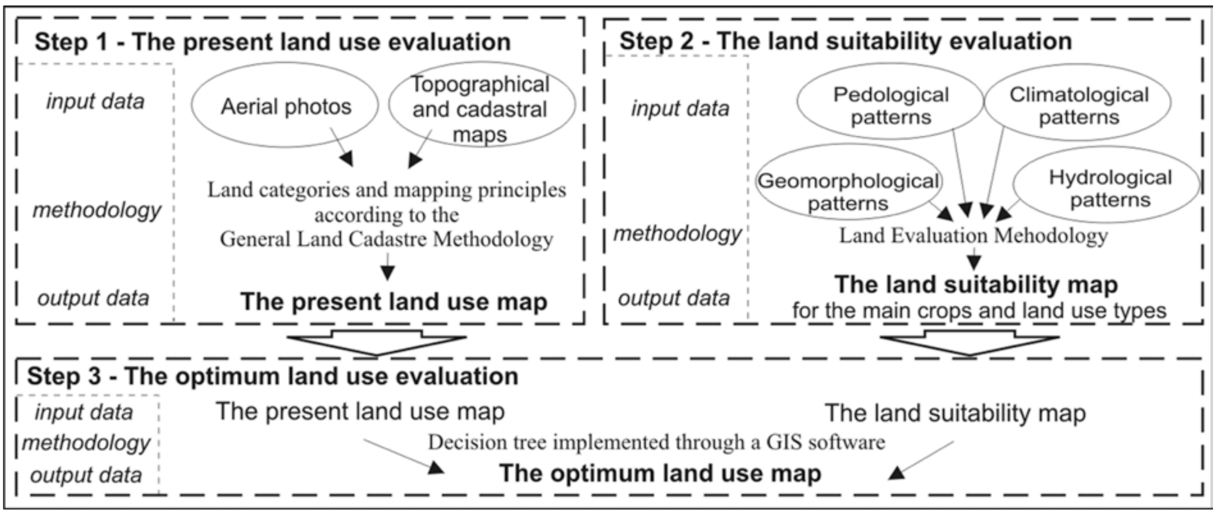

Figure 2. The methodological framework

Table 1. The favorability and restrictiveness classes estimated on land evaluation index (accord. SSDM, 1987)

Land evaluation index (LEI)	Favorability class	Restrictiveness class
1.00	total favorable	no restriction
0.99 – 0.81	very favorable	very low restrictions
0.80 – 0.61	favorable	low restrictions
0.60 – 0.41	medium favorability	medium restrictions
0.40 – 0.21	unfavorable	high restrictions
0.20 – 0.01	very unfavorable	very high restrictions
0.00	total unfavorable	entirely restrictive

Finally, the evaluation scores (LES), grouped in ten land suitability classes or five land suitability clusters, have been obtained by multiplying with 100 the multiplication results of all corresponding coefficients. The first class includes the LES values between 90 and 100 associated to the maximum suitability for a particular use, while the last class, the 10th, comprises the LES values below 10 to meet the minimum suitability. The land suitability clusters are easier used in this study (Table 2).

Table 2. Land suitability clusters estimated on land evaluation score (accord. SSDM, 1987)

Land evaluation score (LES)	Land suitability group
>81	A – very high
61-80	B - high
41-60	C - medium
21-40	D - low
<20	E – very low

As for the input data, the geomorphological ones have been obtained both by the field observations and the interpretation of aerial photos and topographical maps. In addition, some morphometric parameters, such as hypsometry and slope have been calculated (Hengl & Evans, 2008).

The soil maps, accompanied by an attribute database, have been obtained by integrating various soil surveys for nine territories delivered by the Pedology and Agrochemistry County Offices (PACO Bacău, 1985, 1992a, 1992b, 1993; PACO Galați, 1988; PACO Vaslui, 1997, 1998, 2004). The climatological and hydrological raw data have been delivered by the National Meteorological Administration and the "Prut" Water Department.

2.2.3. The achievement of optimum land use map.

Finally, we have tried to automatically create an optimum land use pattern by comparing the current land use pattern with the natural suitability conditions for each use. Drawing of the final map is based on a decision tree scheme applied to the input maps in raster format, depending on the present land use type and the computed evaluation marks. Under this approach, the SML (Spatial Manipulation Language) application implemented through the TNTmips 7.3 GIS software has been used (Fig. 3).

```
GetInputRaster(A)
GetInputRaster(B)
GetInputRaster(C)
GetInputRaster(D)
GetInputRaster(E)

GetOutputRaster(F,NumLins(A),NumCols(A),RastType(A))
SetScale(F,LinScale(A),ColScale(A))
CopySubobjects(A,F)

for each A begin
F=((A=1 and B<=40 and C<=60)*6\
        +(A=1 and B<=40 and C>60)*2\
        +(A=1 and B>40 and B<=60 and C<=60)*1\
        +(A=1 and B>40 and B<=60 and C>60)*2\
        +(A=1 and B>60)*1\
+(A=2 and C<=60 and B<=40)*6\
+(A=2 and C<=60 and B>40)*1\
+(A=2 and C>60 and B>40)*1\
+(A=2 and C>60 and B<=40)*2\
        +(A=41 and D<=40 and B<=50 and C<=60)*6\
        +(A=41 and D<=40 and B<=50 and C>60)*2\
        +(A=41 and D<=40 and B>50 and B<=60 and C>60)*2\
        +(A=41 and D<=40 and B>50 and B<=60 and C<=60)*1\
        +(A=41 and D<=40 and B>60)*1\
        +(A=41 and D>40 and D<=60 and B<=60)*41\
        +(A=41 and D>40 and D<=60 and B>60)*1\
        +(A=41 and D>60)*41\
+(A=42 and D<=60 and B<=50 and C<=60)*6\
+(A=42 and D<=60 and B<=50 and C>60)*2\
+(A=42 and D<=60 and B>50 and B<=60 and C>60)*2\
+(A=42 and D<=60 and B>50 and B<=60 and C<=60)*1\
+(A=42 and D<=60 and B>60)*1\
+(A=42 and D>60)*42\
        +(A=51 and E<=40 and B<=50 and C<=60)*6\
        +(A=51 and E<=40 and B<=50 and C>60)*2\
        +(A=51 and E<=40 and B>50 and B<=60 and C>60)*2\
        +(A=51 and E<=40 and B>50 and B<=60 and C<=60)*1\
        +(A=51 and E<=40 and B>60)*1\
        +(A=51 and E>40 and E<=60 and B<=60)*51\
        +(A=51 and E>40 and E<=60 and B>60)*1\
        +(A=51 and E>60)*51\
+(A=52 and E<=60 and B<=50 and C<=60)*6\
+(A=52 and E<=60 and B<=50 and C>60)*2\
+(A=52 and E<=60 and B>50 and B<=60 and C>60)*2\
+(A=52 and E<=60 and B>50 and B<=60 and C<=60)*1\
+(A=52 and E<=60 and B>60)*1\
+(A=52 and E>60)*52\
        +(A=6)*6\
        +(A=7)*7\
        +(A=8)*8\
        +(A=9)*9\
        +(A=10)*6\)
end.
```

Legend:

Input rasters:

Raster A = the land use map (where: 1 = arable lands, 2= pastures and meadows, 41 = vineyards, 42 = degraded vineyards, 51 = orchards, 52 = degraded orchards, 6 = forestlands, 7 = water lands, 8 = roads and railways, 9 = constructions. 10 = unproductive lands);

Raster B = the land evaluation marks for arable lands;

Raster C = the land evaluation marks for pastures and meadows;

Raster D = the land evaluation marks for vineyards (grape vine);

Raster E = the land evaluation marks for orchards (cherry);

Output raster:

Raster F = the optimum land use map;

Figure 3. Decision tree scheme implemented by the SML application through TNTmips 7.3 GIS software

Starting from the current pattern, the SML application analyses and chooses the optimum land use category for each pixel, considering the following principles:

- Wetland, roads, railways and constructions areas keep their land use category;

Present-day uses with high and very high land suitability (> 60 points of evaluation score) keep their land use pattern;

- Current uses with medium land suitability (40-60 points) change their land use pattern only for a higher suitability use. If there is more than one use type with higher land suitability, then vineyards, orchards, arable and pastures have priority, keeping to this ranking.
- Present-day uses with low and very low land suitability (< 40 points) comprise the land use pattern with the highest suitability. If there is more than one use type with higher land suitability, then the priority will be in the favor of vineyards, orchards, arable and pastures;
- If all the present crops and uses show a low and very low suitability (less 40 points), the land is suitable to be under forest;
- Unproductive land passes into the forestland.

3. RESULTS AND DISCUSSIONS

According to the above mentioned methodological framework, based both on the present land use map and the land suitability map for the main land use types, an optimum land use map at 1:10,000 scale and 5m x 5m pixel resolution was proposed for the Pereschiv catchment within the Moldavian Plateau of Eastern Romania.

3.1. The present land use map

Starting from the interpretation of the aerial photos at 1:5,000 scale, the resulted map was drawn at 1:10,000 scale and 5m x 5m pixel resolution. It includes a population of 10,885 polygons with an average area of 2.2 ha (Fig. 4).

The current land use pattern shows us that about 4/5 of the entire area represents agricultural land and only 1/5 non agricultural. The diagram presented in the figure 5 suggests a radical change of the native vegetal cover, especially of forest and grassland and their replacement with cropland.

Agricultural land covers 18,687 ha, where arable land averages 54.3% of total (12,628 ha), pastures and meadows 21.6% (5,014 ha) and 1,045 ha (4.5%) are under vineyards and orchards.

As for the non-agricultural land (4,579 ha), the forestland amounts 2,839 ha (12.2% of total area), the unproductive land 618 ha (2.7%), roads and railways 580 ha (2.5%), construction area 410 ha 1.8%) and

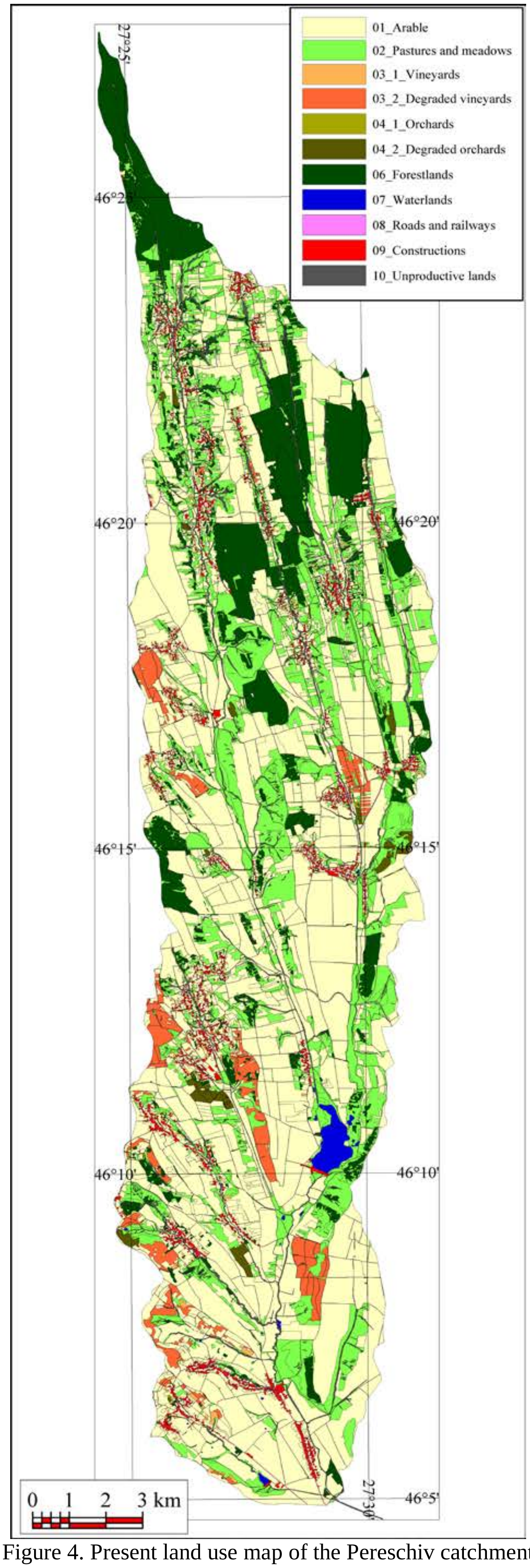

Figure 4. Present land use map of the Pereschiv catchment

(wetland with only 132 ha (0.6%).

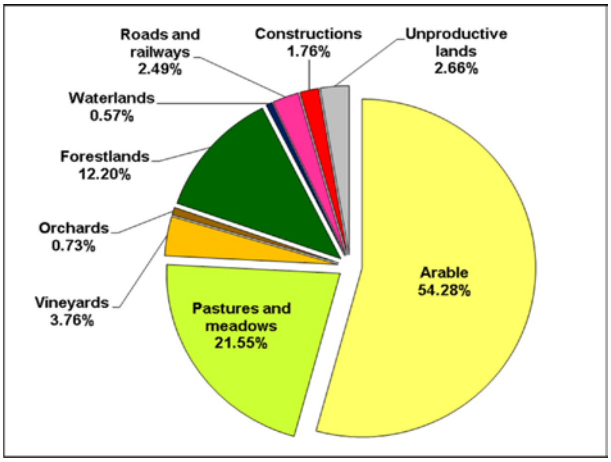

Figure 5. Present-day land use categories in the Pereschiv catchment

3.2. The land suitability map for the main land use types

For this approach, we have adopted the output maps of land suitability, drawn at the same 1:10,000 scale and 5m x 5m pixel resolution. These maps were delivered for each land use type and show us that the average LES value for main uses is 45.7, corresponding to the third suitability group (Fig. 6).

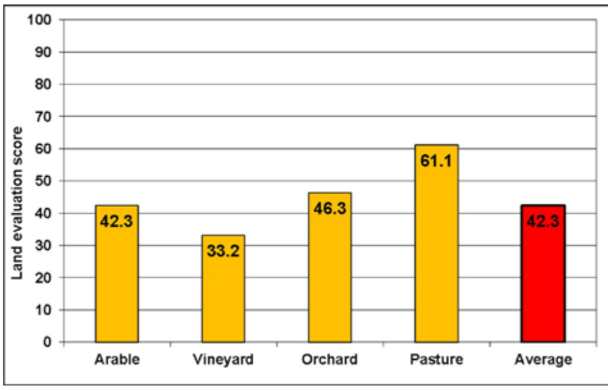

Figure 6. The mean land evaluation score for the main land uses

Among the land use categories, pastures and meadows have the highest average score showing high suitability (61.1 LES rating). The orchards and arable follow with a medium suitability (46.3 LES rating, respectively 42.3), and finally the vineyards with a low suitability of 33.2 LES rating.

The suitability map for the arable land shows that 45.2% of the catchment is under low and very low suitability, while 33.1% has medium suitability. Only 21.5% of the total reveals high suitability and 0.4% very high suitability (Fig. 7).

The traditional vineyards present a low suitability, with a 33.2 LES value. Despite the lowest average evaluation mark, the land has high and very high suitability for vineyards in the middle and lower Pereschiv catchment. The LES values exceeding 60 show a high and very high suitability and typify 16.9% of the study area. About 24.9% of the total area is depicted by medium suitability with 40-60 LES values. Low suitability fits for about 20% of the area and for 40% the natural conditions enter with extreme low suitability.

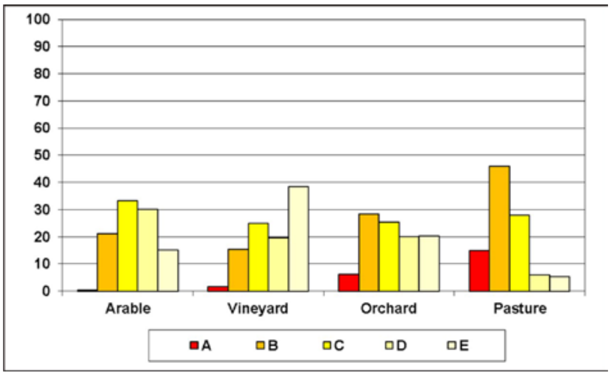

Figure 7. The share of land suitability groups for main land uses

Among the fruit trees, the cherry trees have been chosen because they encounter the best conditions if compared with apple or plum trees. The average evaluation mark of 46.3 for orchards in the entire basin represents a medium suitability. With LES values over 40, the suitability is at least medium in two thirds of the catchment. The high suitability includes more than one third of the catchment, whereas the very high suitability comprises 6.1%.

The pastures and orchards have gained the best average evaluation score of 61.1 among all the crops and land uses. About 60.8% of the area has obtained a high suitability, while 14.6% show very high suitability. Depicting a low and very low suitability, the evaluation scores less than 40 represent 11.2% of the total.

3.3. The optimum land use map

The final map drawn at 1:10,000 scale and 5m x 5m pixel resolution shows that the present-day land use pattern does not overlap with the maximum land suitability given by natural conditions for over half of the selected study area (Fig. 8).

The main finding refers to that the arable use is recommended to be halved, respectively to be maintained on 6,600 ha if compared with the current 12,600 ha (Fig. 9). Only 39% of the present arable land is under optimum conditions, while 43% of this current use category fits more appropriate to pastures and 18% to forestland. Therefore, the arable weight should be halved from 54.3% to only 28.7% within the entire Pereschiv catchment.

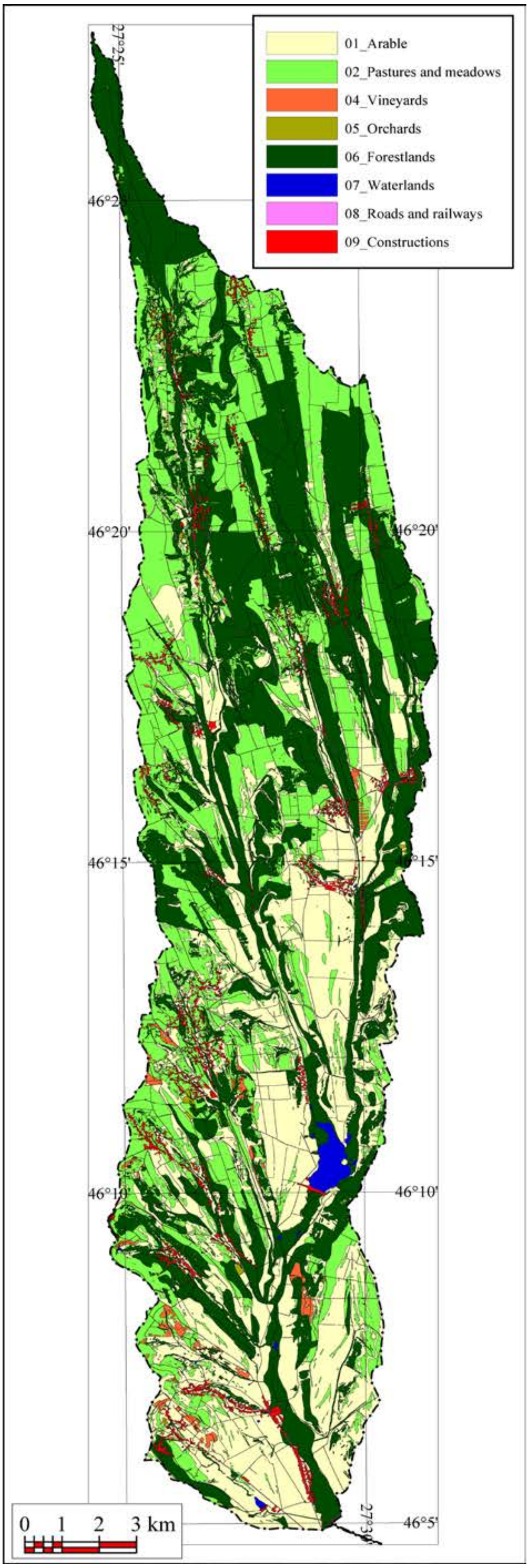

Figure 8. The optimum land use map of Pereschiv catchment

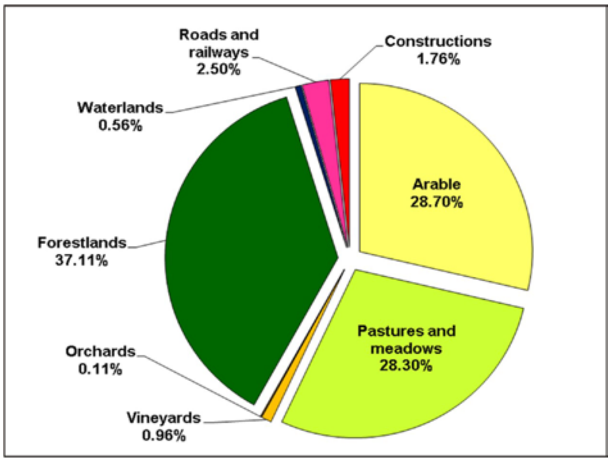

Figure 9. The proposed share of the optimum land use categories

As regards to the area of 5,000 ha (21.6%) under pastures and meadows, it is adequate to increase it by 1,600 ha, and thus to weight 28.3% of the total catchment, which is similar to arable. Today, only 770 ha (14%) under pastures and meadows could maintain their land use category, and the remaining will be turned into arable (30%) and especially to forestland (56%).

The forestland displays the most spectacular positive leap. Based on arable and pastures, this category weight should increase by three times from 2,800 ha (12.2% of total) to over 8,600 ha (37.1%).

In the case of vineyards, a sharp decrease of 74.5%, from 874 ha to 223 ha, is obviously. Only 31% of the present-day vineyards could maintain their use type, while the prevailing area should be converted as pastures (35%) or forestland (26%). Also, the orchards area should decrease from 170 ha to 25 ha. For both uses, only the present vineyards and orchards with high and very high suitability for such use category have been considered. Certainly, a lot of land under other current use types presents favorable conditions for these plantations. Since we prefer to establish an optimum land use pattern without major investments, such land fits better to use with higher suitability.

If possible, the area of 660 ha unproductive land is recommended to be forested.

4. CONCLUSIONS

The obtained results show that the present-day land use does not match maximum favorability given by the natural conditions within the Pereschiv catchment. The arable land is too extended and it is recommended to be halved from 54.3 % of the total area to only 28.7%. The pastures and orchards plantations should slightly be extended from 21.6% to 28.3%. Instead, the forestland is appropriate to increase more than three times, from current 12.2% to 37.1%.

This approach can provide a sustainable development pattern for local communities by delivering an optimum land use with minimum auxiliary investments. After choosing the most appropriate pattern the land use should be in full agreement with the soil conservation practices.

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