MORPHOLOGY ANALYSIS IN LAND SUITABILITY ASSESSMENT

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ABSTRACT: The paper presents the results of morphology analysis (AIDA technique) for land suitability assessment. The methodology has been applied to energy crops potential assessment for liquid biofuel production within a European Union research project. In the study, pan-European agroclimate maps are evaluated with crop requirements. The AIDA method is applied for generation of admissible elements from the decision areas represented as mapped environmental attributes (climate and soils parameters). The search for optimal solutions starts from the decomposition process where the elements of decision problem are distinguished (sets of areas and their elements) and evaluated by their importance and exclusions. The number of possible solutions is substantially reduced by illogical solution elimination and stop criterion--elimination of nonperspective branches during a decision trees generation. The solutions differentiate mapping units and present European land suitability assessment. The AIDA method demonstrated relative simplicity and high efficiency for creative spatial data mining.

Key words: geographical information systems, morphology analysis, AIDA, land suitability, agriculture.

1 INTRODUCTION

The presented methodology has been elaborated within EU founded research Project RENEW Renewable Fuel for Advanced Powertrains.

RENEW aims to develop, compare, (partially) demonstrate and train on a range of fuel production chains for motor vehicles. Ligno-cellulosic biomass sources will be used as feedstock to produce synthesis gas from which various vehicle fuels can be derived: Methanol/DME, ethanol (thermochemical and enzymatic pathway) and a novel biomass-to-liquid (BTL) fuel.

Beside strictly technological activities, the project includes the analysis of the biomass potential in Europe, the life cycle assessment from well to tank, technical and economic assessment of available production routes for BTL fuels from ligno-cellulosic biomass [4] .

The presented morphology analysis is a part of the work package: Biomass potential assessment, particularly focused on the energy crops potential assessment. Energy crops are a new alternative species, coming into the agricultural sector, dealing with the common in Europe food overproduction and the growing demand for the energy. This promising alternative for farmers and industry is more and more popular, however still on the research phase.

The basic need for the presented analysis was looking for the answer: Where and what species can be grown in terms of agro-climate conditions.

2 CONCEPTION

Climate and local soil properties are the most important constraints influencing the agricultural productivity within a specific region.

The target is the standardised evaluation of geographically assigned climate and soil conditions for specific energy crops. The environmental characteristics of the species are matched with the terrain conditions to derive the quantitative, spatial assessment in the form of digital maps. The analysis is performed within ArcGIS software enabling wide range of ready to use tools.

The pan-European spatial databases and Energy Crops Characteristics Catalogue are the key date sources for the described analysis.

The computational program designated on the base of analytical technique AIDA (Analysis of Interactive Decision Areas) is applied for analysis of properties from climate, soil and land use maps.

3 METHODOLOGY

Decomposition Process in AIDA Technique

The AIDA technique, elaborated by J. Luckam is one of the morphological methods, it is characterised by its relative simplicity and high efficiency [3] .

General morphological analysis is a method for identifying and investigating the total set of possible relationships or ‘configurations’ contained in a given problem complex [5] .

The technique is applied for generation of admissible solutions from the decision areas. For solution of a given problem there is provided the decomposition process where the elements of decision areas are distinguished and described by their weights and exclusions, then there are generated solutions – the possible combinations of the elements. The number of possible solutions is substantially reduced by the elimination of the illogical connections and the stop criterion.

The illogical solutions results from the exclusion relationships – defined illogical connections between particular elements of different decision area. The elements of each decision area are internally alternative, thus in every possible solution there is exactly one element from each area.

The stop criterion stops the process of a decision tree generation by elimination of non-perspective branches when the total weight of the possible solution is lower then the given criterion value. All decisions areas and their elements are sorted by their weight, thus each next generated solution has no-higher total weight.

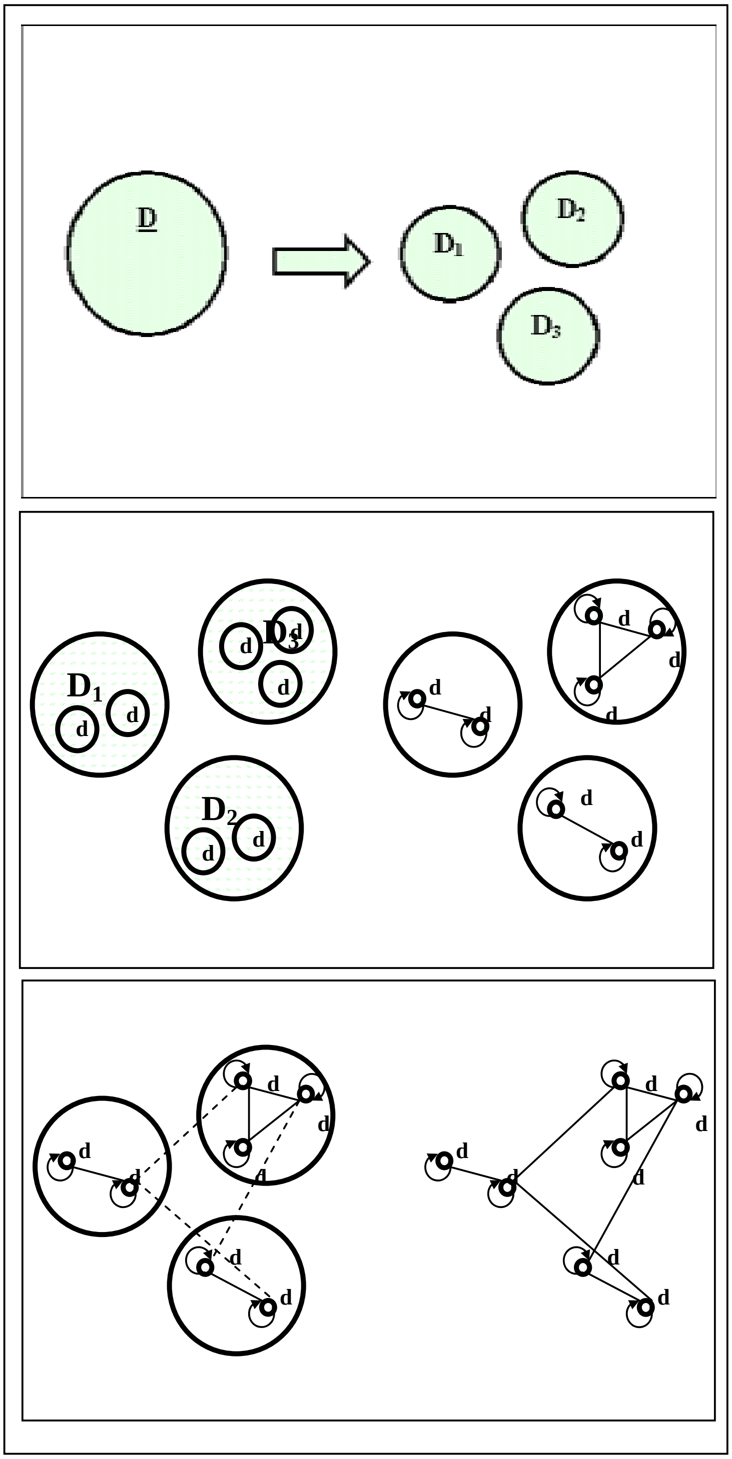

Figure 1 The process of formulation and decomposition of decision areas. From above: 1.Decision areas are separated; 2.The formulation sets are ready– the switch into the graph model;3. The interactive decisions are marked – the graph model is ready.

Calculation Module – AIDA Technique

The computer program has been designed, which realises the calculation technique AIDA.

The analysis consists of the following steps:

1. The decisive problem (area) is defined. The target and the scope of analysis are formulated. The decision criteria are known. The solution is the ranking of possible combinations of analysed elements.
2. The decision area is subdivided for smaller sub-areas (here: group of soil parameters create a sub-area e.g. area: soil chemical prosperities and sub-area: soil acidity).
3. Every sub-area is evaluated by its importance for the target of analysis expressed in a dimensionless coefficient (weighted value).
4. The created sub-areas contain elements (e.g. pH values or ranges). Each element is designated by an expert for a certain value –dimensionless coefficient.
5. The result of steps 4 and 5 is the parameterised and divided decision space. All elements have an individual value defined for a certain application (here – a given energy crop) including their sub-area (point 3) and ranking position within elements in a given sub-area (point 4).
6. The exclusions are defined. Exclusions represent impossible connections between pairs of elements from different sub-areas. Experts are defining the exclusions after a deeper quality analysis (morphology) of elements from different decision sub-areas.
7. The stop criterion is defined. The program is generating a set of values of the total solution.The program stops computation when the value is reaching the stop criterion value.
8. The computation starts. The generation process is based on the algorithm generating all possible solutions, what would give a huge number of solutions (product of sets' quantity).
9. The time consuming process is substantially reduced by:

- stop criterion (point 7):

  The implemented stop criterion: elements from the areas generating solutions are continuously put in order according to their individual or total dimensionless value.
- Exclusions (point 6):

  The exclusions are cutting 'non-perspective branches' in a generating decision tree of all theoretical combinations

The results are evaluated combinations, where the number of elements in a solution is equal to a number of analysed sub-areas (here the solution is reflecting the existing set of parameters in a mapping unit).

Figure 2 presents the steps of process based on the AIDA morphological approach.

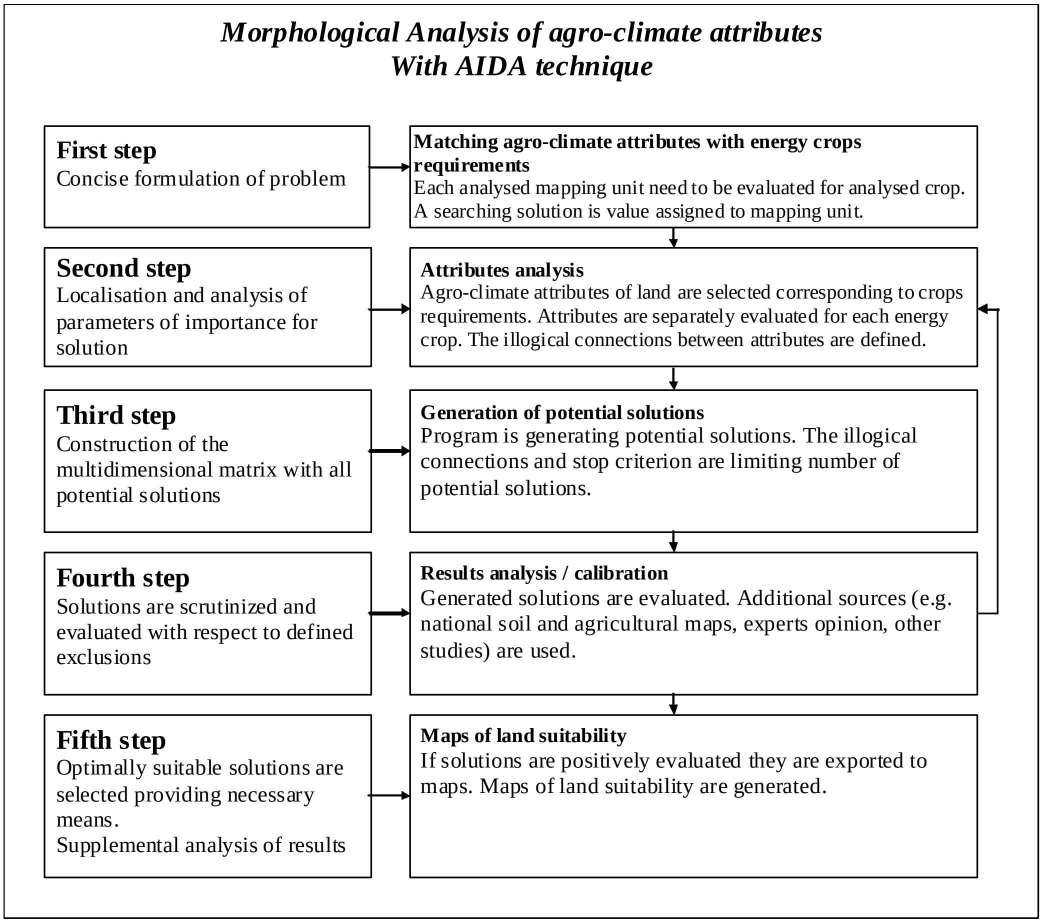

Figure 2 Agro-climate attributes morphological analysis with AIDA technique

Figure 3 presents the diagram for the analysis and spatial data:

- Land use spatial data from CORINE Land Cover (CLC) database;
- Soil data form Soil Geographical Database (SGDB) ;
- Climate data (e.g. annual rainfall, average extreme temperatures) from MARS project;
- Energy Crops Characteristics Catalogue.

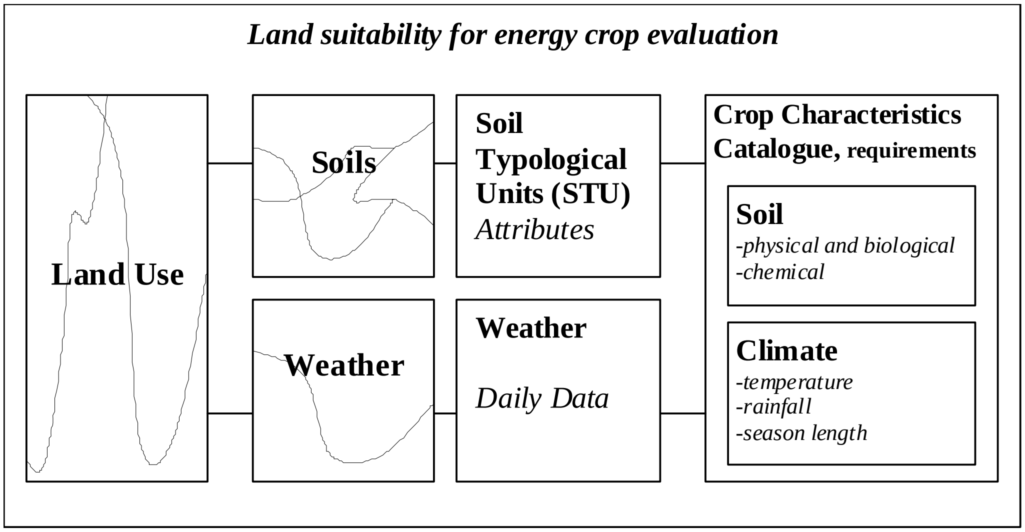

Figure 3 The elements of land suitability evaluation for Energy Crops Cultivations

Land use, soil and weather components are spatial databases with assigned attributes. Those data describe agro-climate conditions for each mapping unit with a certain spatial localisation. The attribute data are stored in relational databases and analysed in an external calculation AIDA model.. The model is matching and evaluating agro-climate attributes with certain crop requirements taken from the Energy crops catalogue.

Agro-climate and land use data are attributed to certain mapping units. Thus each mapping unit is assigned a set of information, stored in a GIS geo-database. The attributes of mapping units are exported to external programs for processing and analysis and afterwards imported as the result – land suitability for relevant energy crop. Figure 4 depicts the process of analysis.

The less accurate spatial –database (SGDB, 1:1.000.000) determinates the resulting map scale, which finally corresponds to average NUTS-2 level

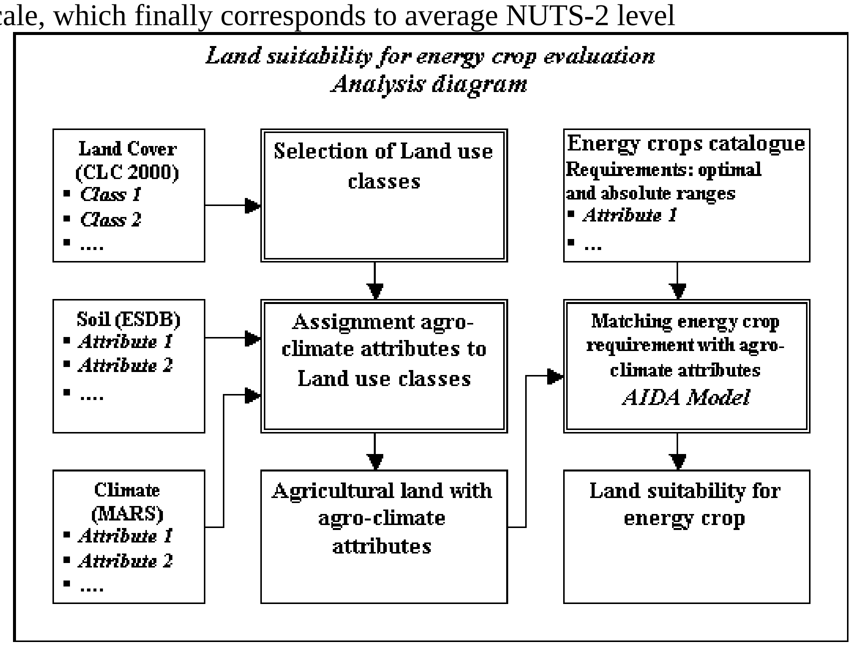

Figure 4 Diagram of analysis for land suitability assessment

Elements of Land Suitability Assessment

Land use

CORINE Land Cover, version 2000 (CLC) database is used.

CLC is a spatial pan-European database of land cover. Land cover is described by 44 land use classes. The information was derived through interpretation of satellite images obtained from the Landsat TM (Thematic Mapper) scanner and other remote-sensed data or cartographic data at the scale 1:100.000.

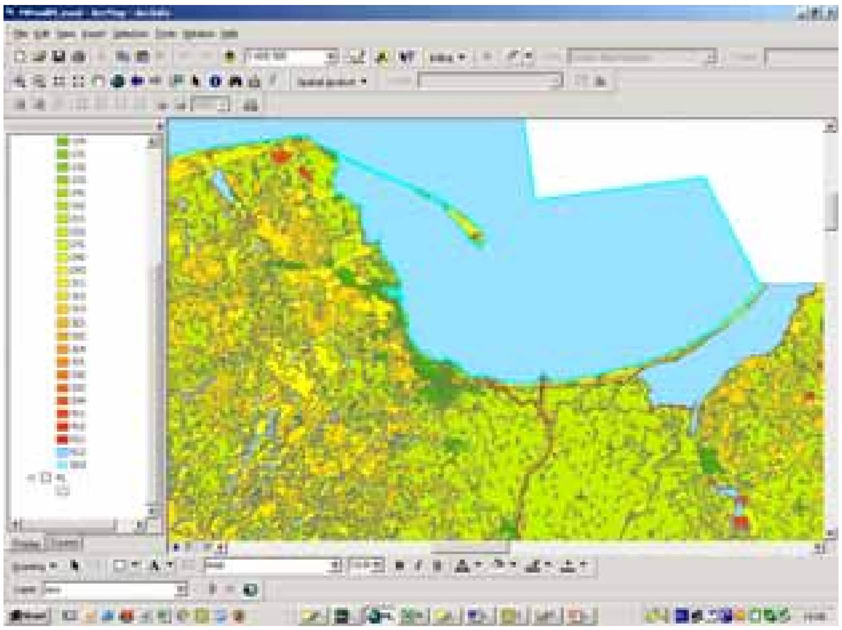

Figure 5 Sample of Corine Land Cover 2000 data.

Soil

Information about soil properties and quality is important in understanding the functionality of major agricultural systems. Soil properties play a major role in the distribution of plants, water and nutrients.

European Soil Database (ESDB)is used of reference scale 1:1.000.000. ESDB consists of:

- Soil Geographical Database of Europe;
- Soil Profile Analytical Database of Europe;
- Soil Pedotransfer Rules Database of Europe.

ESDB derives significant amount of soil conditions, off acceptable accuracy for the given analysis.

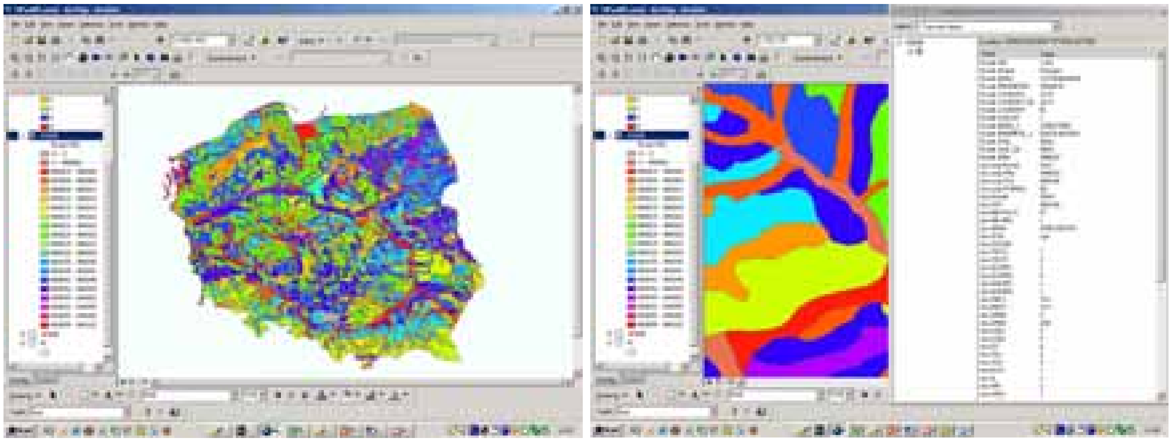

Figure 6 An sample from European Soil Database

Climate

Climate parameters are obtained from weather data. Daily data for a 10 years' period from the MARS project are used. Time-series data are completed in 50x50 km grid covering Europe.

MARS-STAT data, corresponding to NUTS-2 level are downloadable for research projects.

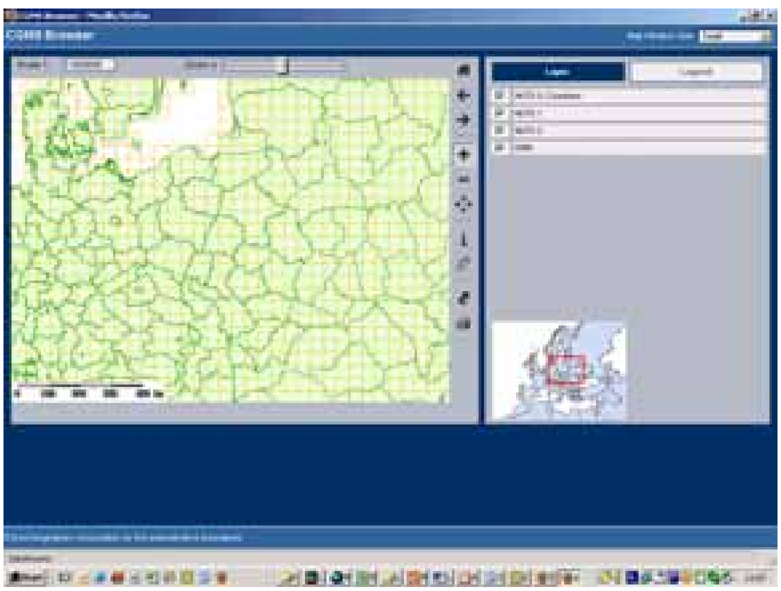

Figure 7 A sample of MARS weather data

Energy Crops Characteristics Catalogue

The Energy Crops Characteristics Catalogue (ECCC) is the standardized description of energy crops species. The catalogue includes description of each species for quantitative agro-climate conditions evaluation. Stress is put on the evaluation of environmental requirements for each species. Those parameters are corresponding with the spatial databases. The additional information such as general description, morphology, distribution or common names are of additional value.

The energy crops description is based on the FAO databases: ECOCROP [1] and ECOPORT [2] .

The main parameter describing energy plants based on FAO information databases [1] ,[2]

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Sorghum bicolor – SWEET SORGHUM

Fig. 1 Sorghum bicolor photo from www.ca.ecoport.org

FAMILY			
LIFE FORM	Grass		
COMMON NAMES			
STRUCTURE	**HABIT**	**PHYSIOLOGY**	**LIFE SPAN**
	erect	single stem	annual
YIELDS	Min.	Max.	
PLANT ATTRIBUTES	grown on large scale, grown on small scale		
CATEGORY	cereals & pseudocereals, forage/pasture, medicinals & aromatic		
FUEL CHARACTERISTICS			

HABITAT		Sweet sorghum has a wide adaptability range. It is drought resistance, waterlogging tolerance, and saline-alkali resistance.
MORPHOLOGY	**Roots**	It has fibrous, spreading roots. Prop roots may grow from culm nodes.
	Stems	It has an solid, erect, nodose culm or sometimes with spaces in pith, 0.6–5 m tall, depending on variety and growing conditions, 5 to over 30 mm in diameter.
	Leaves	The leaves are broad, dentate, rough-textured, ligulate and ribbed. Similar in shape to those of corn but shorter and wider. Blades glabrous and waxy; sheaths encircle culm and have overlapping margins.
	Flowers	The flowers are grouped in an apical panicle formed by up to 6,000 reddish spikelets. The panicles are erect, sometimes recurved, usually compact in most grain sorghums and more open in forage types.
	Fruits	The fruit consists of an oblong caryopsis. Seeds are white, yellow, red, or brown and covered by glumes that may or may not be removed by threshing. 25,000 to 61,740/kg for grain sorghum; 120,000 to 159,000/kg for grass sorghum.

ENVIRONMENT	**OPTIMAL**		**ABSOLUTE**	
	Min	***Max***	***Min***	***max***
Temp. requirement	**22**	**35**	**8**	**40**
Annual rainfall	**400**	**600**	**300**	**700**
Latitude	**10**	**30**	**0**	**45**
Altitude			**0**	**2500**
Killing temperature	*during rest: 0*		*early growth: 0*	
Light intensity	*very bright*	*very bright*	*clear skies*	*very bright*

SOIL	**pH**	**depth-m**	**Texture**	**Fertility**	**salinity-dS/m**	**drainage**
OPTIMAL	**5,5 – 7,5**	medium **0,5 – 1,5**	medium, light	moderate	low **<4**	well (dry spells)
ABSOLUTE	**5 – 8**	medium **0,5 – 1,5**	wide	low	medium **4-10**	well (dry spells), excessive (dry/moderate dry)

CLIMAT ZONE	tropical wet & dry (Aw), steppe or semiarid (Bs), subtropical dry summer (Cs)		
Photoperiod	short day (<12 hours)		
Abiotic toler.			
Introduction risk			
USES	Food and beverage (starch, seeds), fodder (stems and leaves), medicinal (flowers), fuels (stems)		
PRODUCTION SYS.	Cropping system: permanent rainfed, sub-system: mono - cropping		
CROP CYCLE	Min. **90**, max. **300**		

4 RESULTS

The results are transferred back to GIS software and presented as energy crops – land suitability maps. Land suitability is classified in a suitability scale. The scale can be transferred for a yield’s values or ranges for further analysis.

There are considered already excepted and widely applied soil classifications, e.g. Agro Ecological Zoning, or FAO suitability classes.

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