BeonNAT

Innovative value chains from tree & shrub species grown in marginal lands as a source of biomass for bio-based industries

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Results on characterizing the initial soil conditions in marginal sites (SQR)

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1 (Coordinator)	CIEMAT	Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas
2	CESEFOR	CESEFOR
3	REC	Renewal Energy Consortium for Research and Demostration
4	AIM	Instituto Tecnológico del Plástico
5	ATB	Leibniz Institute for Agricultural Engineering and Bioeconomy
6	BTU	Brandenburg University of Technology Cottbus-Senftenberg
7	USV	Universitatea Stefan el Mare, Suceava
8	IPB-CIMO	Centro de Investigação de Montanha / Instituto Politécnico de Bragança
9	CTA	Contáctica
10	IDS	IDOASIS 2002 S.L.
11	EJAR	El Jarpil
12	ENV	Envirohemp
13	NNFCC	The Bioeconomy Consultants NNFCC
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15	MAVERICK	Laboratorios Maverick
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Abstract:	In this task the initial degree of marginality of the selected case study sites in Spain, Romania and Germany will be investigated by assessing the soil quality. For characterizing the initial soil conditions of underutilized, marginal sites a soil assessment is carried out by BTU using the Soil Quality Rating tool (SQR). Regional partners in Spain and Romania delivered preliminary data on relevant site conditions.

1 Introduction

Selected underutilized, marginal sites in Spain, Germany and Romania are used in BeonNAT as test fields. Within Task 2.3 both the degree of marginality of these sites as well as reasons for their underutilization have to be characterized. Marginality of land can be defined in different ways (e.g., Campbell et al., 2008; Dauber et al., 2012). Often degraded or naturally poor soil conditions and other physico-chemical constraints are used as main indicators for explaining marginality of land (e.g., Cai et al., 2011; Feng et al., 2015; Gopalakrishna et al., 2011; JRC, 2014). In other cases, land marginality is also explained by specific socioeconomic conditions which make traditional land use unattractive (e.g., Baumann et al., 2011; Nalepa & Bauer, 2012).

For quantifying the marginality of the chosen BeonNAT test fields it was decided to assess soil quality of each test site. A well-suited instrument for this assessment is provided by the Soil Quality Rating tool (SQR) (Mueller et al., 2007). This tool assesses soil quality by means of a number of indicators representing potential constraints for agriculture. It was successfully introduced for assessing site marginality for the first time within the H2020 project SEEMLA (Gerwin et al., 2018). The SQR tool valuates a number of soil and general environmental site properties (both physical and chemical soil parameters and other site factors like topography) which can be easily assessed during field work and further refined by later laboratory analyses.

In the work plan of BeonNAT a visit of each test field site by a team from BTU was scheduled for spring/summer 2021. During these visits soil and site properties should be assessed, soil conditions classified and the SQR tool applied. However, this scheduled practical implementation was obstructed by the still ongoing COVID-19 pandemic situation. This situation did not allow for travelling to the selected case study sites by BTU staff as originally planned. Therefore, and according to the importance of classifying the selected sites, alternatively a preliminary assessment based on the indicators provided by the SQR tool has been carried out. The applied methodology is described below, data were provided by regional partners in Spain, Germany and Romania. Results of this preliminary assessment are shown in this report.

It is planned to perform the complete assessment at a later time when travelling throughout Europe is possible again without larger restrictions. It is assumed that the general soil conditions as the basis for this marginality assessment will not change within a short time of one or even a few years. Thus, it will be possible to carry out this survey later on without distorting its outcomes. An updated report on the soil conditions of each case study site and its marginality will be provided after visiting the sites and regularly applying the SQR methodology – probably in spring or autumn 2022.

2 Location of case study sites

BeonNAT study sites are located in Northern and Southern Spain, Northeastern part of Romania, and Eastern Germany (Fig 1). Details are given below.

2.1 Spain

Two test sites have been selected in Spain representing different climatic and edaphic situations. In the south of Spain close to Almeria the site “Velefique” is available for BeonNAT field experiments (Fig. 2). This site represents marginal former agricultural land under Mediterranean climate conditions. In Northern Spain a test field is established on fields owned by CEDER-CIEMAT at Lubia (Soria) (Fig. 3). This site represents underutilized marginal forest land and is covered by grasslands with sparse woody vegetation.

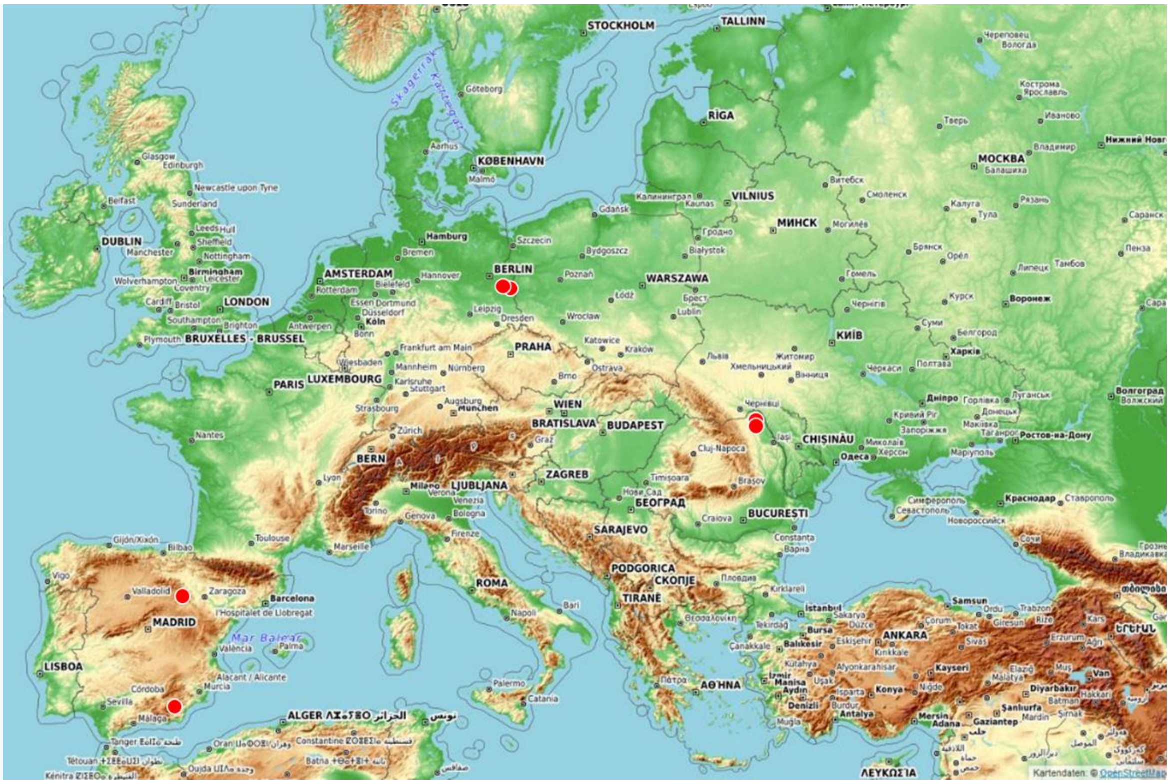

Fig. 1: Location of BeonNAT test fields (red dots) in Spain, Germany and Romania (map: opentopomap.org)

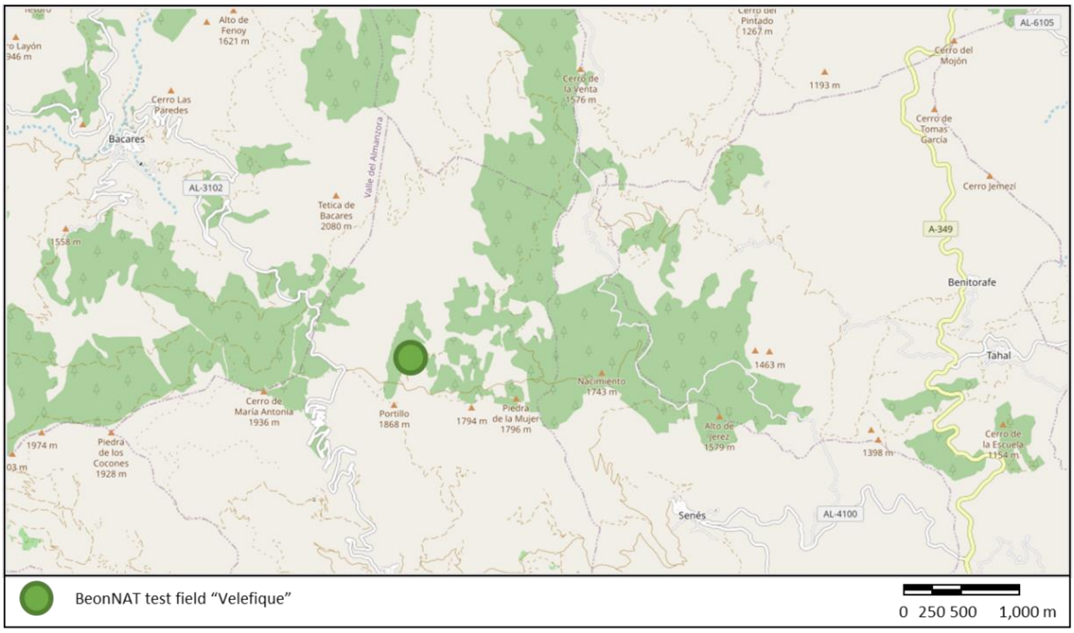

Fig. 2: Location of test site “Velefique” (Spain) (map: OpenStreetMap)

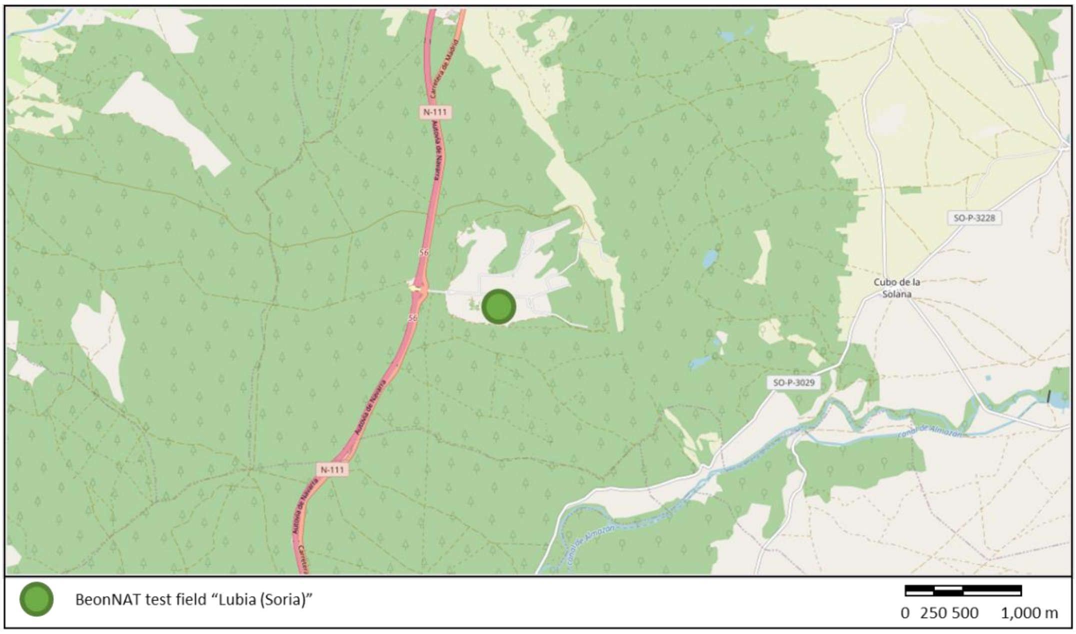

Fig. 3: Location of test field “Lubia (Soria)” (Spain) (map: OpenStreetMap)

2.2 Germany

The two German test sites are located in the southern part of the State of Brandenburg (“Welzow-South”) and in the northeastern part of the State of Saxony (“Kromlau”), respectively, both in Eastern Germany. The “Welzow-South” site is part of the recent post-mining landscapes of this region within the reclaimed part of the lignite open-cast mine Welzow-Süd (Welzow-South) (Fig. 4). Site “Kromlau” represents marginal forest site conditions (Fig. 5) in a region also affected by mining activities in the past.

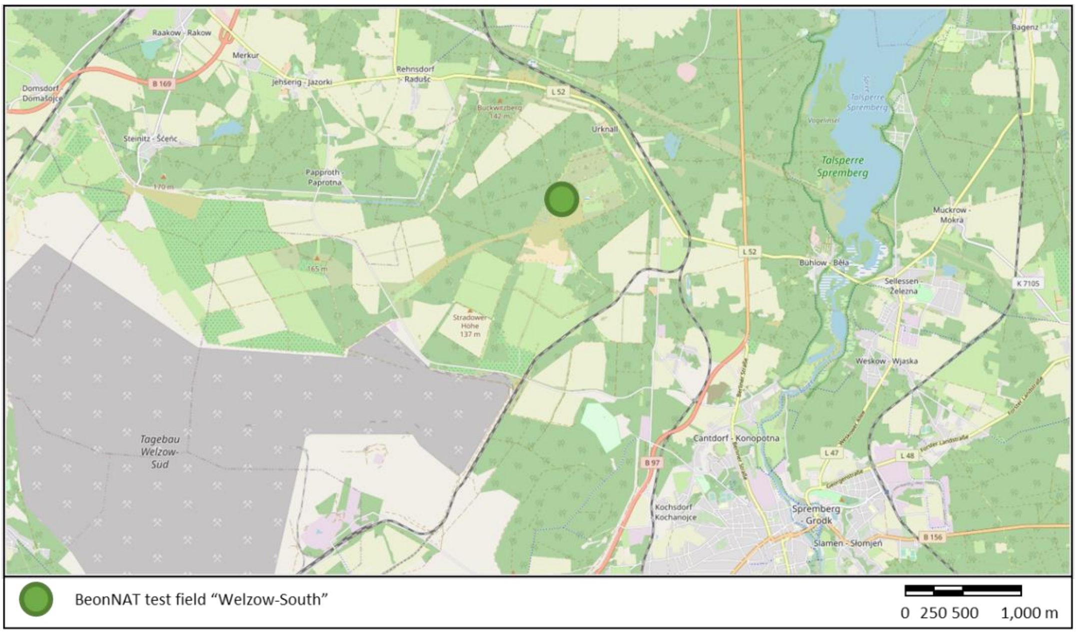

Fig. 4: Location of test field “Welzow-South” (Germany) (map: OpenStreetMap)

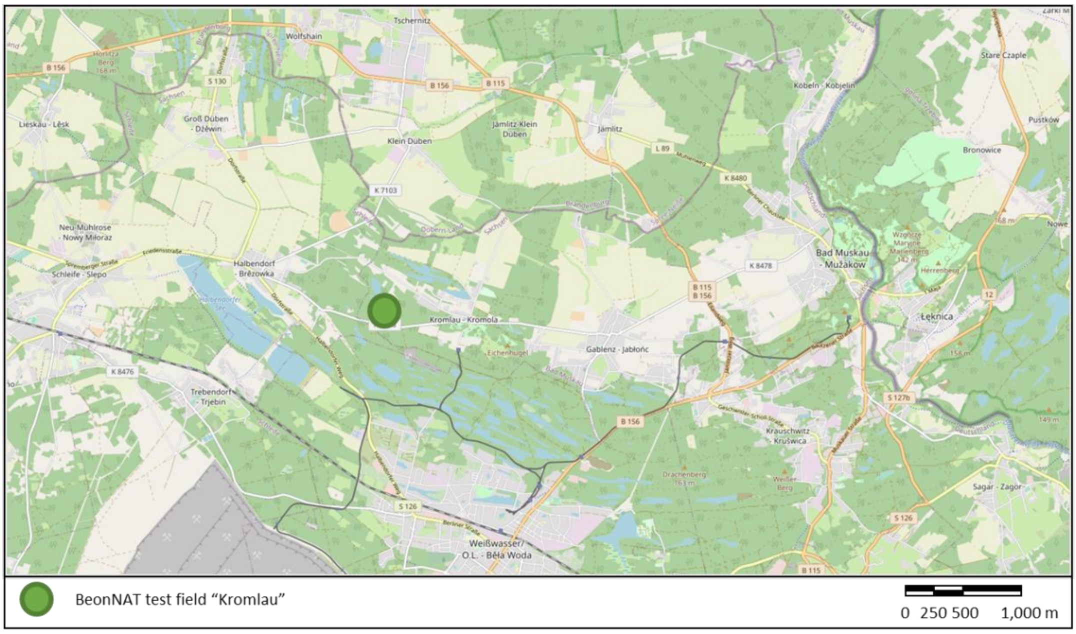

Fig. 5: Location of test field “Kromlau” (Germany) (map: OpenStreetMap)

2.3 Romania

Two test fields are available for BeonNAT experiments in the vicinity of Suceava in the northeastern part of Romania. Both, “Zamostea” and “Moara”, are located on former agricultural land. The “Zamostea” site is situated in the floodplain of River Siret (Fig. 6), whereas the “Moara” site is lain close to the City of Suceava (Fig. 7).

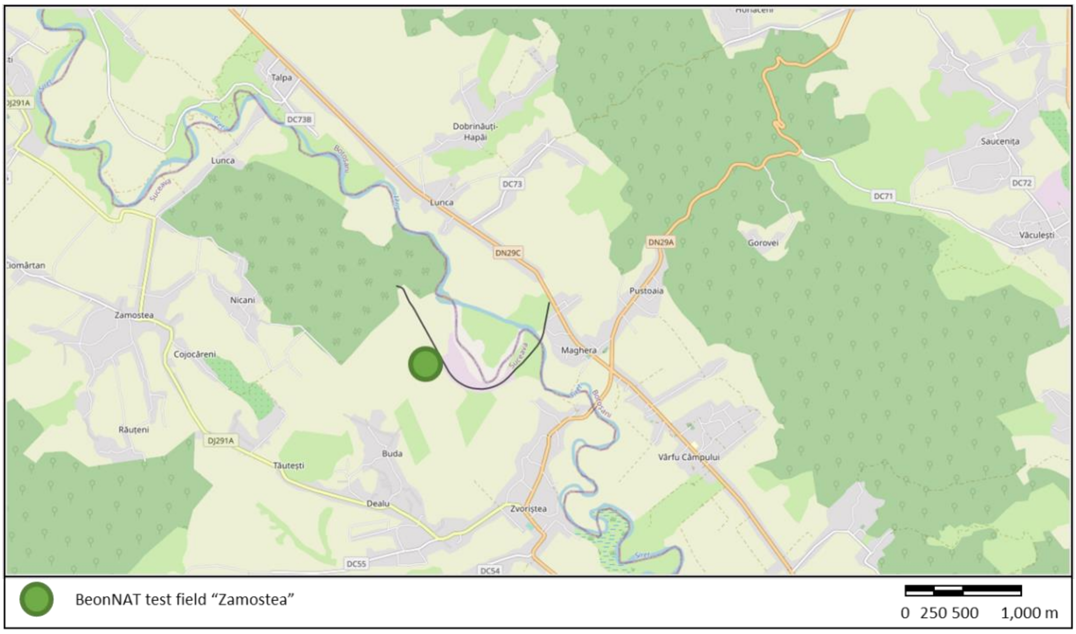

Fig. 6: Location of test site “Zamostea” (Romania) (map: OpenStreetMap)

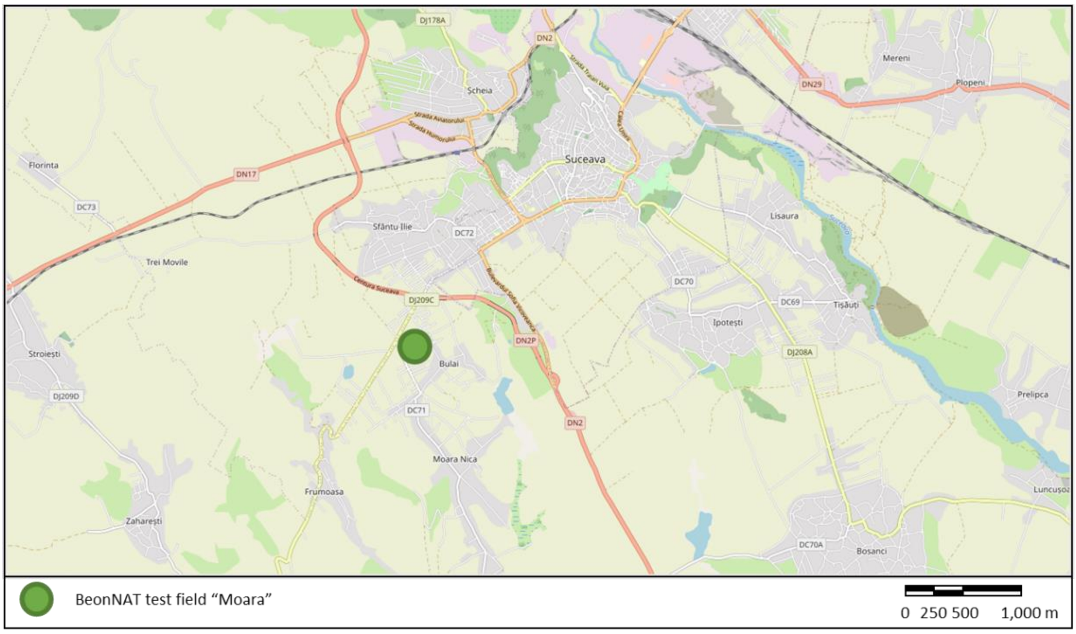

Fig. 7: Location of test site “Moara” (Romania) (map: OpenStreetMap)

3 Assessing marginal soil conditions – methodology

3.1 Soil Quality Rating (SQR)

The SQR tool was developed by the German Center for Agricultural Landscape Research (Muencheberg) in 2007 (Mueller et al., 2007). The original main objective of this tool is providing a guide for land users to assess the potentials of their lands for commercial agricultural crops (cereals, root crops) but also for grazing, based on soil quality (Mueller et al., 2013). The tool is designed to quantify the soil quality by one single value – theoretically ranging from 0 (very poor) to 100 (optimal soil conditions) points – which is calculated on basis of a comprehensive set of indicators (s. Fig. 8). It is, therefore, inspired by the official German soil capability assessment which also uses a scale between 0 and 100 (Mueller et al., 2010). The final scores are classified as follows:

- < 20 very poor
- 20-40 poor
- 40-60 moderate
- 60-80 good
- > 80 very good

This SQR tool was used by the German Federal Institute for Geosciences and Natural Resources to derive a map of agricultural yield potentials of German arable soils (Hennings et al., 2016). Vice versa, it also offers opportunities to quantify marginality based on soil conditions (Gerwin & Repmann, 2016), as it can be assumed that poor and very poor soil quality indicates marginal land conditions. Following this approach marginal land can be defined accordingly by SQR scores below 40 (poor/very poor soil quality) (Galatsidas et al., 2018).

Generally, the SQR provides two sets of individual indicators: 8 indicators describing basic soil parameters and an additional set of so-called “hazard” indicators. For each indicator a list of thresholds is given for valuing the respective parameters and assigning the SQR scores. The basic indicators include soil properties like soil depth, soil texture and profile available water. The single basic indicators are multiplied by weighing factors for arable land or grassland (wf, shown in brackets in Fig. 8) and then summed up. In BeonNAT the weighting factors for arable land are used as mainly the limitations for agricultural crop production are analyzed. The resulting basic score has a range between 0 and 34, whereas 0 stands for absolutely infertile soils and 34 can only be reached by best suited croplands.

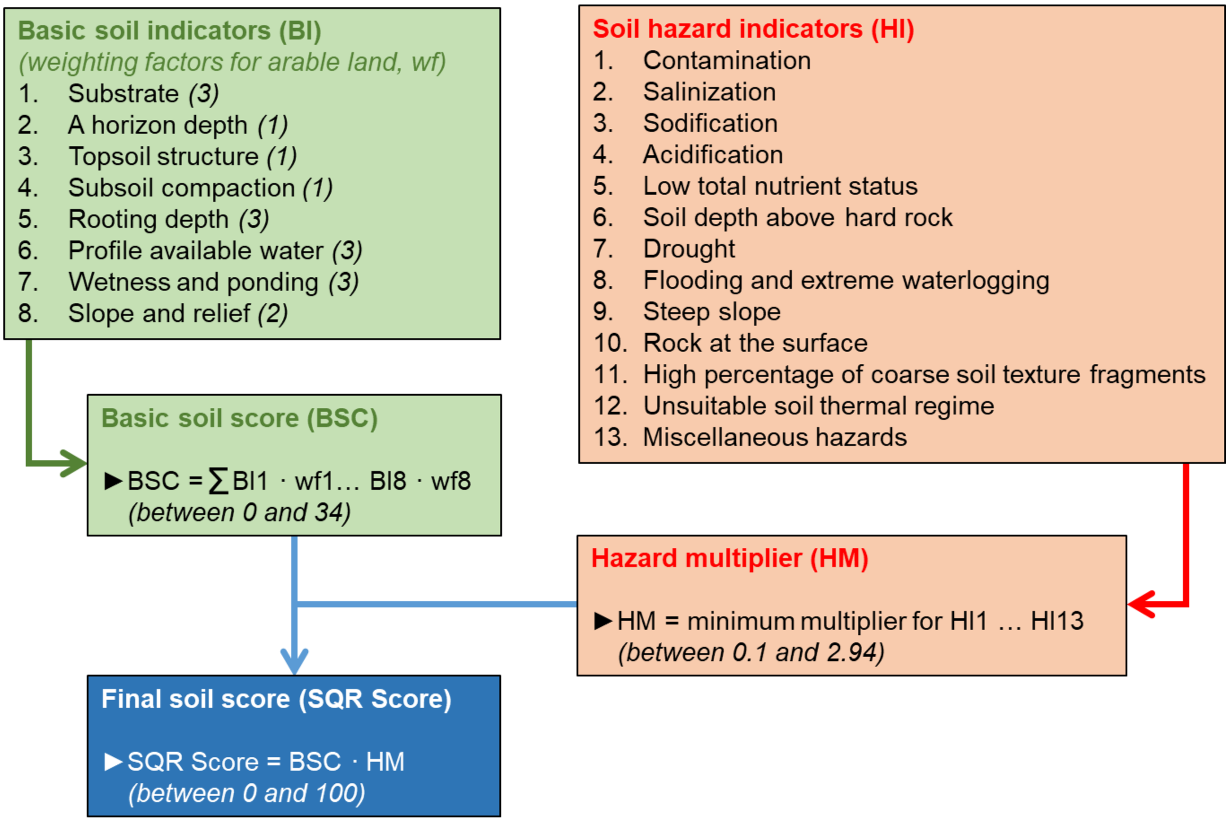

Fig. 8: Overview of the Muencheberg SQR method

In the second step hazard indicators are examined. These hazard indicators include further factors influencing the yield capacity of arable lands related to soil conditions and ecological functions. Hazards can be contamination, salinization or acidification of the soil, risk of flooding or ponding as well as risks for agriculture from climatic regimes. Depending on the characteristics of each hazard indicator so-called "multipliers" are assigned by the SQR guidelines, which are in a range between 0.1 (highest influence of this factor) and 2.94 (no influence of this factor detectable). The lowest multiplier found (i.e. the most important hazard for the respective site) is used to calculate the final SQR score by multiplying the basic score. Sites with a final score of 100 can be seen as sites with the best suitable soils for agriculture.

3.2 Simplified assessment of soil marginality

As explained in the introduction, the direct practical application of the SQR tool in the field was not possible in 2021 due to travel restrictions in all European countries. Thus, an alternative assessment of site conditions was carried out for the selected BeonNAT test fields. An informal scoring card was developed (see Appendix) with main indicators for poor or very poor land conditions according to the SQR methods. The cards were sent to all regional project partners responsible for test fields in Spain, Germany and Romania. Partners were asked to check which of the provided indicators for poor soil and site conditions are applicable for their sites.

This scoring card considers different site, climate and soil conditions. It includes all basic SQR as well as most of the hazard indicators in a modified order. The selection was made to provide easily testable indicators based on existing knowledge and without further field works or laboratory analyses. The included soil chemical indicators had to be assessed only if knowledge or data already existed, other soil indicators could mainly be checked by means of simple finger tests. Critical characteristics for each indicator were given so that a rapid, but consistent assessment could be performed for each field site. (Tab. 1). The following indicators were included (SQR indicators in brackets):

a) Site conditions:
   - Slope and relief (SQR basic indicator 8)
   - Wetness and ponding (SQR basic indicator 7)
   - Hard rock (SQR hazard indicator 6)
b) Climate
   - Drought (SQR hazard indicator 7)
c) Soil physics
   - Soil texture (SQR basic indicator 1)
   - Coarse fragments (SQR hazard indicators 10 and 11)
   - Depth of top-soil (SQR basic indicator 2)
   - Soil structure and compaction (SQR basic indicator 3 and 4)
   - Rooting depth (SQR basic indicator 5)
   - Profile available water (SQR basic indicator 6)
d) Soil chemistry
   - Acidification (SQR hazard indicator 4)
   - Nutrient status (SQR hazard indicator 5)
   - Salinization (SQR hazard indicator 2)
   - Contamination (SQR hazard indicator 1)

Received data were merged and compiled in an overview for all BeonNAT test fields by BTU. Sites with at least three applicable indicators are considered as clearly "marginal". If less than three indicators turned out to be applicable other reasons for the marginality of these sites have to be discussed.

Furthermore, the critical characteristics shown in Tab. 1 are oriented towards the thresholds given by the SQR scheme for poor and very poor soil conditions. The SQR tool values soils with such properties with a minimum basic score of 0.5 or gives low multipliers in case of hazard indicators between 1 and 2.5 (see Tab. 1). Thus, these minimum SQR scores (basic indicators) and multipliers (hazard indicators) can be provisionally assigned if one of the indicators from the scoring card is applicable. If an indicator is not applicable, the respective maximum basic score (2.0) and the highest multiplier (2.94) is assigned as the needed information on real soil and site conditions are not yet available for a proper and more differentiated valuation. For calculating the basic soil score the respective weighting factors for arable land provided by the SQR method were applied for each basic indicator (see Tab. 1).

Tab. 1: Assigning SQR scores (basic indicators [BI] with weighting factors [wf]) and multipliers (hazard indicators [HI]) to applicable indicators and thresholds of the preliminary scoring card

Indicator	Characteristics	SQR Indicator	BI score	wf	HI multipl.
Predominantly poor substrate	Pure sand or pure clay; peat soils	B1	0.5	3	
Shallow depth of A-horizon	< 15 cm	B2	0.5	1	
Unfavorable structure and compaction	Coarse sharp-edged blocky aggregates of clay soils, or platy aggregates, no or few earthworm burrows or worms, no or extremely hampered root penetration	B3	0.5	1	
	Signs for compaction	B4	0.5	1	-
Low rooting depth (RD)	RD ≤ 0.8 m (arable land), restricted rooting of grasses (< 30 cm) (grassland)	B5	0.5	3	
Profile available water	Strong to extreme water deficit: sandy soils with deep water table or very shallow RD	B6	0.5	3	
Wetness and ponding	Significant wetness in the root zone for longer periods, moderate to significant surface ponding	B7	0.5	3	
Slope and relief	Moderate to steep; arable land > 9-14 %	B8	0.5	2	
Contamination	Exceedance of threshold as result of frequent sewage sludge application or vicinity of industrial emitters, artificial soil etc.	H1			1
Salinization	Strong salinization, salt-tolerant plants will grow, most others show severe restrictions to extreme salinization with salts crusts at the surface	H2			1
Acidification	Plant growth affected by high acidity	H4	-	-	2.2
Insufficient nutrient status	Clear deficit of nutrients, cannot be compensated by fertilization within one year	H5			2
Hard rock	Hard rock ≤ 30 cm below soil surface	H6			0.5
Drought	Aridity Index according to De Martonne (AI) < 20 (semiarid – arid)	H7			2.5
Coarse soil texture fragments (> 2mm)	Extremely stony soil surface and/or very high amount of coarse fragment in topsoil (> 60 %)	H10/11			1

With this approach it is possible to calculate provisional SQR scores for each test site based on the preliminary scoring method described here. However, it has to be considered that assigning the highest scores and multipliers in case of not applicable marginality indicators may lead to a significant and systematic overestimation of soil quality. Therefore, this roughly estimated provisional final SQR score may only provide a first approximation of soil conditions at the selected test sites. Due to the most likely systematic overestimation of soil quality by this preliminary assessment the threshold score value of 40 for marginal lands from literature cannot be directly applied. To overcome this bias a higher score of 50 is suggested here as a preliminary sign for poor soil quality and land marginality.

4 Soil marginality – results for case study sites

The number of applicable indicators for each test site is given as an overview in Tab. 2. The highest number of in total 5 marginality applicable indicators was found for the test site "Velefique" in Southern Spain, for both sites in Germany as well as for the Romanian site "Zamostea". The other test site at "Lubia (Soria)" in Northern Spain is characterized by 3 applicable signs of marginality. For the second Romanian site "Moara" no applicable indicator could be identified. The respective results are discussed below more in detail.

Tab. 2: Results of the preliminary marginality assessment (applicable indicators are marked with "x"), the test sites are sorted by the number of applicable marginality indicators

Indicator	**Test sites**					
	Velefique (ES)	**Kromlau (DE)**	**Zamostea (RO)**	**Welzow-South (DE)**	**Lubia (Soria) (ES)**	**Moara (RO)**
Predominantly poor substrate	-	x	x	x	-	-
Shallow depth of A-horizon	-	-	-	x	-	-
Unfavorable structure	-	-	x	-	-	-
Compaction	-	x	x	-	-	-
Low rooting depth (RD)	-	-	-	-	x	-
Profile available water	x	x	-	-	-	-
Wetness and ponding	-	-	x	x	-	-
Slope and relief	x	-	-	-	-	-
Contamination	-	-	-	-	-	-
Salinization	-	-	-	-	-	-
Acidification	-	x	-	x	-	-
Insufficient nutrient status	x	x	x	x	-	-
Hard rock	-	-	-	-	-	-
Drought	x	-	-	-	x	-
Coarse soil texture fragments (> 2mm)	x	-	-	-	x	-
number of applicable indicators	**5**	**5**	**5**	**5**	**3**	**0**

Results of the provisional assignment of SQR scores based on this rough estimation of potential limiting factors are shown in Tab. 3. It turned out that Spanish test field sites are most probably clearly marginal sites with regard to their soil quality. The provisional final SQR scores are below 30. The results of the preliminary assessment for the "Zamostea" site in Romania and the two German test field sites resulted in higher provisional final SQR scores but below 50, which should also be regarded – as described above – as an indication of potentially poor soil conditions. The only exception, again, is the Romanian site "Moara" which received the highest score in this preliminary valuation as no limiting factor was reported. Generally, however, it should be noted that these provisional final SQR scores need a careful interpretation as they are the result of a rough estimation not of a proper SQR application.

Tab. 3: Provisional calculation of SQR scores based on the preliminary assessment results; test sites are sorted by increasing provisional final SQR scores

SQR indicators	Test sites					
	Velefique (ES)	Lubia (Soria) (ES)	Zamostea (RO)	Welzow-South (DE)	Kromlau (DE)	Moara (RO)
B1	6.0	6.0	1.5	1.5	1.5	6.0
B2	2.0	2.0	2.0	0.5	2.0	2.0
B3	2.0	2.0	0.5	2.0	2.0	2.0
B4	2.0	2.0	0.5	2.0	0.5	2.0
B5	6.0	1.5	6.0	6.0	6.0	6.0
B6	1.5	6.0	6.0	6.0	1.5	6.0
B7	6.0	6.0	1.5	1.5	6.0	6.0
B8	1.0	4.0	4.0	4.0	4.0	4.0
H1	2.9	2.9	2.9	2.9	2.9	2.9
H2	2.9	2.9	2.9	2.9	2.9	2.9
H4	2.9	2.9	2.9	2.2	2.2	2.9
H5	2.0	2.9	2.0	2.0	2.0	2.9
H6	2.9	2.9	2.9	2.9	2.9	2.9
H7	2.5	2.5	2.9	2.9	2.9	2.9
H10/11	1.0	1.0	2.9	2.9	2.9	2.9
basic soil score	26.5	29.5	22.0	23.5	23.5	34.0
minimum multiplier	1.0	1.0	2.0	2.0	2.0	2.9
final SQR score	26.5	29.5	44.0	47.0	47.0	100.0

4.1 Spain

It turned out for the test site in Southern Spain that particularly the climatic situation is a limiting factor for land use. This site is clearly endangered by drought periods, mainly during the summer season. This is expressed by low values of the De Martonne Aridity Index (< 20) showing semiarid to arid conditions. This missing precipitation can be also seen as a reason for the reported water deficit in the soil profile. Furthermore, the parcel is characterized by soils with high amounts of stones at the surface or within the soil profile. Slight compaction has been reported as well as a clear deficit of nutrients. In addition, the "Velefique" site is located in a mountainous region with steep slopes. It can be concluded that this test site has been established as a site with clear marginal site and soil conditions. The test field in Northern Spain is also affected by a semiarid Mediterranean climate. In addition, this site has stony soils with low rooting depths due to physical barriers in the subsoil. With this characterization, also this test site can be assessed as marginal.

4.2 Germany

Both sites in Germany have been affected by mining activities in the past. Site "Welzow-South" is located within the reclaimed part of a still active lignite open-cast mine. Generally, soils of post-mining landscapes in this part of Germany are characterized by poor soil conditions. The texture varies between pure sands and pure clay substrates, frequently found in direct neighborhood. In areas with clayey substrate soils are significantly endangered by excessive wetness and ponding at the surface. Rooting depth is often limited by missing nutrients in the deeper parts of the soil as well as by extreme acidification due to pyrite oxidation. The other site "Kromlau" is also partly affected by mining activities in the beginning of the 20th century but has soils developed on naturally sedimented glacial deposits of the Pleistocene. However, the main limiting properties here are generally representative for marginal forest sites in Northeastern Germany. Typically, poor sandy substrate is found at these sites with low profile available water, acidic soil conditions and poor nutrient contents. Furthermore, at "Kromlau" signs of soil compaction were found as an additional indicator of marginality.

4.3 Romania

In Romania, only one of the selected two test sites turned out to be marginal concerning soil quality according to this preliminary test. Site "Zamostea" shows clear signs of soil marginality. The soil is affected by wetness and the danger of surface ponding and consists of unsuitable substrate and structure. In addition, a certain deficit of nutrients is known for this soil. The site has been used in the past for cultivating hybrid poplar with poor results. In contrast, the site "Moara" does not fit into the scheme of soil marginality as no one of the tested indicators was applicable. However, as stated above, the degree of marginality can be defined differently and not necessarily through poor soil and site conditions. In the case of the "Moara" site, the socioeconomic reasons could explain why this site has not been used for agricultural purposes for more than 15 years. The site can be assimilated to other Romanian areas or even with other former socialist countries from Eastern Europe. The post-socialist restitution laws (e.g., Law no. 18/1991, Law no. 1/2000, Law no. 247/2005) have fragmented the properties and created uncertainty about the ownership status due to ownership overlaps or, in some instances, identification difficulties of the owners or heirs. Consequently, the land-use patterns were considerably different from those whose ownership condition was well established. These lands were frequently abandoned or avoided being utilized for agricultural purposes until the property's status was clarified. Although this type of land is not the majority, it represents a local reality. Therefore, Moara site could be representative because it is reflecting a fundamentally different condition than other sites where social and institutional realities, rather than a lack of fertility, led to abandonment.

5 Conclusions

This preliminary assessment of marginality showed that most of the selected test field sites can be most probably assessed as "marginal" based on poor soil and site conditions. The only exception is the Romanian site "Moara" which does not show any of the tested biophysical indications of soil marginality. In this case socioeconomic reasons for the land abandonment can be assumed. Generally, the long-term abandonment of potential arable land can also be seen as an indicator of marginality (Campbell et al., 2008).

The methodological process of this preliminary assessment described here does not allow for more detailed descriptions of the respective site conditions. Particularly, the calculated provisional final SQR scores cannot be directly interpreted and are only thought to give first orientation. However, the results shown here illustrate that the selection of test fields has been made in clear accordance with the objectives of BeonNAT. The potential socioeconomic reasons for land abandonment at the “Moara” site in Romania need to be further investigated. In summary, it can be concluded that the starting field experiments are carried out at suitable sites for demonstrating the BeonNAT approach.

It is obvious that the results presented in this report need a further refinement and a careful revision after implementing the SQR tool during field visits. Even if the selected indicators in the preliminary scoring cards used for this first assessment here were easy to evaluate, inconsistent or subjective interpretations of the environmental situation by the different regional project partners cannot be excluded. The clear advantage of applying the SQR procedure by only one fixed team of scientists is that this subjective influence on the outcome of the assessment can be minimized to the greatest possible extent. It is therefore supposed that a complete SQR assessment is needed for confirming main findings of this preliminary characterization. This later full assessment will be complemented by a detailed description and classification of the respective sites and soils as well as by laboratory analyses according to a fixed protocol.

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Appendix

Informal protocol for preliminary assessment of soil marginality

1 Site conditions

Indicator	Characteristics
Slope and relief	Moderate to steep; arable land **> 9-14 %**
Wetness and ponding	Significant **wetness in the root zone** for longer periods, moderate to significant surface ponding
Hard rock	Hard rock **≤ 30 cm** below soil surface

2 Climate

Indicator	Characteristics
Drought	Aridity Index according to De Martonne (A_I) **< 20** (semiarid – arid) $A_I = [P/(T+10) + 12\ p/(t+10)]/2$ with: P: annual precipitation [mm] T: mean annual temperature [°C] p: precipitation of the driest month [mm] t: temperature of the driest month [°C]

3 Soil physics

Indicator	Characteristics
Predominantly poor substrate	**Pure sand** or **pure clay**; **peat soils**
Coarse soil texture fragments (> 2mm)	**Extremely stony** soil surface and/or very high amount of **coarse fragment in topsoil (> 60 %)**
Shallow depth of A-horizon	**< 15 cm**
Unfavorable structure and compaction	Coarse **sharp-edged blocky aggregates** of clay soils, or **platy aggregates**, no or few earthworm burrows or worms, no or extremely hampered root penetration
Low rooting depth (RD)	RD **≤ 0.8 m** (arable land), restricted rooting of grasses (< 30 cm) (grassland)
Profile available water	Strong to extreme **water deficit**: sandy soils with deep water table or very shallow RD

4 Soil chemistry (only where known)

Indicator	Characteristics
Acidification	*Where known:* Plant growth affected by high acidity *[pH ≤ 4 in topsoil]*
Insufficient nutrient status	*Where known:* Clear deficit of nutrients, cannot be compensated by fertilization within one year
Salinization	*Where known:* Strong salinization, salt-tolerant plants will grow, most others show severe restrictions to extreme salinization with salts crusts at the surface *[EC > 2 mS/cm in topsoil]*
Contamination	*Where known:* exceedance of threshold as result of frequent sewage sludge application or vicinity of industrial emitters, artificial soil etc.