Final conference

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Sustainable exploitation of biomass for bioenergy from marginal lands (MagL) in Europe

Understanding Marginal Lands – challenges and expectations

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What is marginal land?

1) **Economic definition – that is an area where a cost-effective production is not possible, under given site conditions, cultivation techniques, agricultural policies as well as macro-economic and legal conditions"** (Schroers 2006); **where revenue is just equal to costs of production** (Galbraith 1932)

2) Physical and production definition **is based on soil suitability and restrictions are often adopted by soil scientists and agronomists for the purpose of land use planning. It refers to land of poor quality for agriculture or susceptible to erosion or other degradation** (Lal 2005)

Terms of marginal land:

unproductive land, waste land, under-utilized land, idle land, abandoned land, degraded land, surplus land, conservation reserve programme land (CRP), barren land, carbon-poor land, fallow land, set aside land, waste land, reclaimed land, contaminated land, etc.

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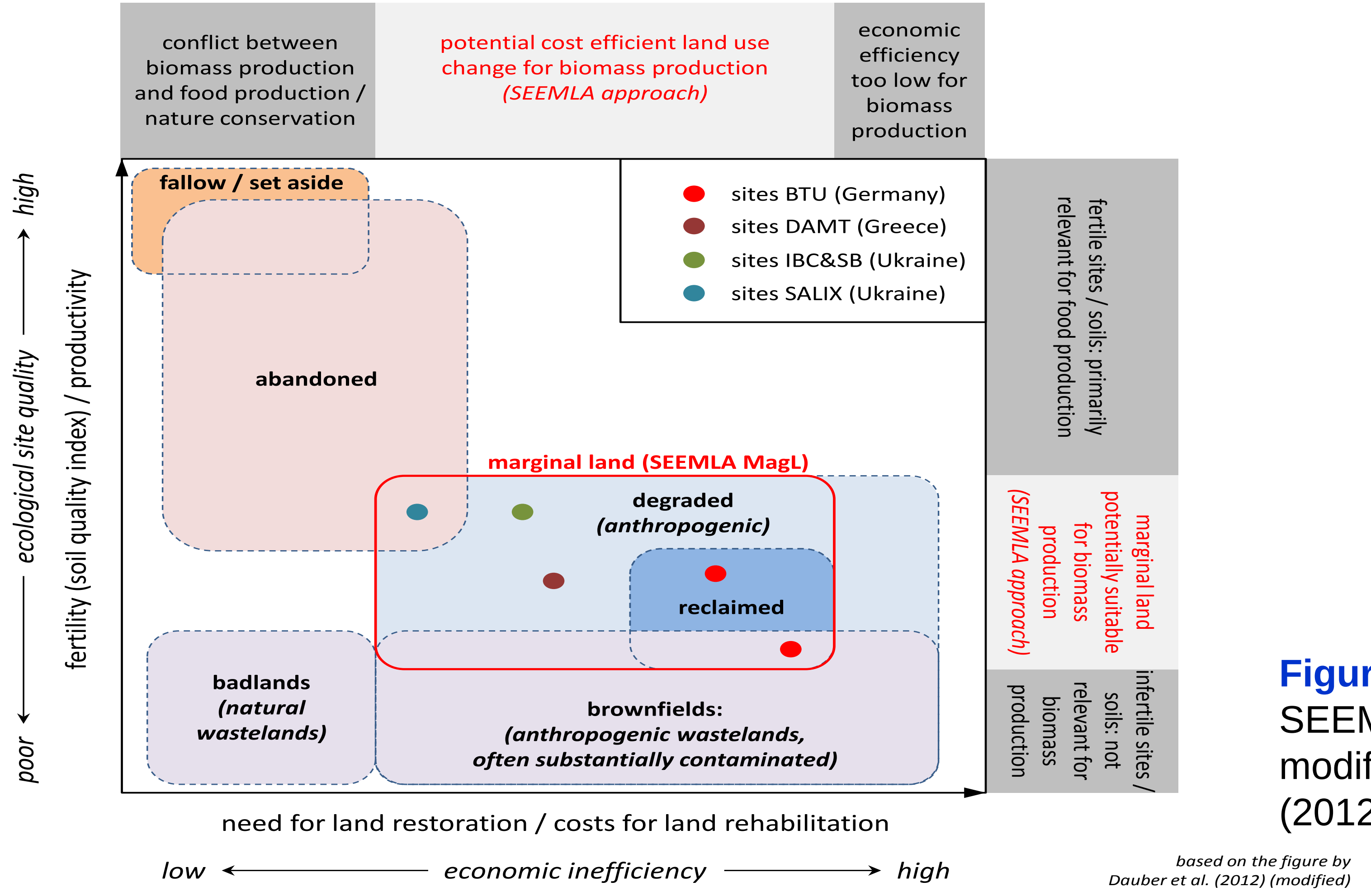

Figure 1. Terms attributed to marginal land in the SEEMLA approach (developed by BTU-CS) modified after and adapted from Dauber et al. (2012)

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SEEMLA approach for MagLs definition and classification

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Figure 2. Criteria of MagLs definition and classification by SEEMLA

Soil biophysical properties

Ecological and environment constrains

Soil productivity potential

Climate

Economic

Area of suitability and efficiency for bioenergy crops to grow on MagL

Basis for MagLs classification

Factors of influence:

- a number of bioenergy crops with different requirements to soil and climate;
- productivity and efficiency of crops differ through soils and climate conditions

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Table 1. Scientific vision to key soil properties of MagLs definition

Author	Criteria of land marginality								
	soil biophysical							ecologic	
	low fertility	shallow rooting	unfavo-rable texture	saline	sodicic	acidic	overwet	steep slop (eroded)	contami-nated
Gopalakrishnan et al. (2011)							+	+	+
Confalonieri et al. (2014)		+	+	+	+	+	+	+	
Orshoven et al. (2014)		+	+	+	+	+	+	+	
Milbrandt & Overend (2009)	+	+	+	+	+	+	+		
Liu et al. (2011)	+	+	+	+	+	+	+	+	+
Kang et al. (2013)	+			+	+		+	+	

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Table 2. MagLs classification:

Categories of MagL	Criteria
1. Shallow rooting	low soil depth with down hard pan
2. Low fertility	low ranking scores (SQR)
3. Stony texture	high volume percentage of stones
4. Sandy texture	high sand percentage
5. Clay texture	high clay percentage
6. Salinic	high content of salts
7. Sodicic	high exchangeable sodium content
8. Acidic	low pH
9. Overwet	low underground water table, gleyic color pattern
10. Eroded	steep slop
11. Contaminated	high content of nitrate in groundwater

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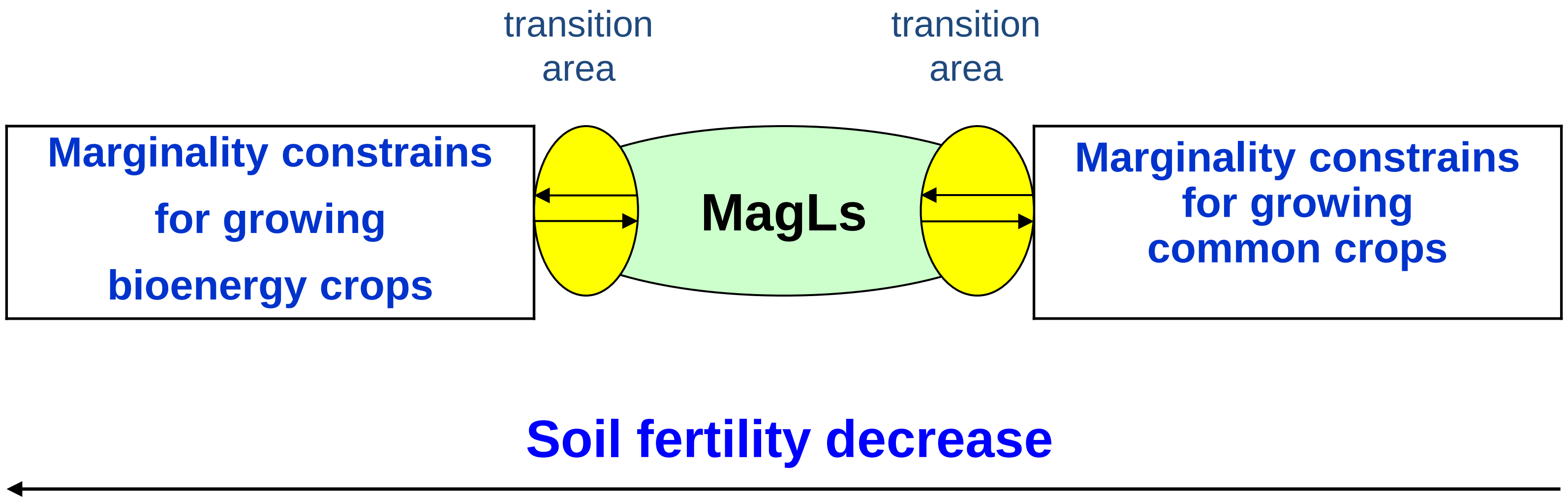
Figure 3. Two constrains of marginality indicators in bioenergetics



Gopalakrishnan et al. (2011) emphasized that the key features of current definitions of marginal lands, based on economic, soil health, and environmental criteria, require the development of new **methods that can identify land that is marginal for conventional crops but not marginal for bioenergy crops**.

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Table 3. Regulation EU(1305)2013 – indicators of MagLs for conventional agriculture

Category	Criterion	Threshold (indicator) for conventional agriculture
	Soils unfavorable biophysical properties	
Shallow rooting depth	Depth of soil to hard pan	**≤ 35 cm**
Low natural fertility	Fertility rating	SQR scores **≤ 40**
Unfavorable textured and stoniness	Relative abundance of clay, sand or coarse material in topsoil	**≥ 10** volumetric % of rocks, boulder
		Sand, loamy sand **≥40%** within 100 cm
		≥ 50% clay
Salinic	Content of salts	**≥ 3.2 dS/m** in topsoil
Sodicic	Content of exchange sodium	**≥ 4.8 ESP** within 100 cm
Acidic	Content of hydrogen ion	**pH**(H_2O) **≤ 5,5** in topsoil
Overwet	Soil wetting and gleyic	**Gleyic color** pattern within 40 cm
		Wet 80 cm > 6 months
	Ecologic constrains	
Eroded	Slope steepness	**≥ 12%**
Contaminated	Presence of nitrate in groundwater	**≥ 10 mg L−1**

Table 4. Range of MagL indicators in bioenergetics

Categories of MagL	Criteria	Range of indicators
shallow rooting	low soil depth with down hard pan	within 25-**35** cm
low fertility	ranking scores (SQR)	less **40**
stony texture	high volume percentage of stones	within **10-**20%
sandy texture	high sand percentage	within **40**-60%
clay texture	high clay percentage	within **50**-60%
salinic	high content of salts	within **3.2**-16 dS/m
sodicic	high exchangeable sodium content	within **4.8**-8%
acidic	pH level	within 4**-5,5**
overwet	low underground water (over 6 months), gleyic color pattern	within **0-80** cm within **0-40** cm
eroded	steep slop	within **12-**15%
contaminated	content of nitrate in groundwater	over **10** mg L^{-1}

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Table 5. Possible MagLs in soil classification of Department of Agriculture, USA

Order	Soil characteristics	% of world area	Involving to bioenergy	Marginality features
Entisols	Without genetic horizons either young in years or parent material only, some soils occur on steep slop	16	Part use	Young soils, some suitable for bioenergy; - Low SQR; - Some meet erosion and salinity hazards
Inceptisols	With only slight profile development (area of mountings, Asia), some rich in humus	9		
Andisols	Formed on volcanic ash, they have high water-holding capacity, some soils are fertile	1		
Gelisols	Tundra soil with slight profile	8,6	No use	Permafrost for 2 years or more
Histosols	Undergone little profile, thick layer of organic material	1	No use	Overwetting
Aridisols	With horizon of accumulation carbonate (calcic), gypsum (gypsic), soluble salts (salic), exchangeable sodium (natric)	12	Part use	Salinity, sodicity, hardpan, dryness
Vertisols	With more than 30% of clay, shrinking and swelling	2,5	Part use	Unfavorable texture
Molisols	Best fertile soil	7	No use	Erosion
Alfisols	Higher weathered than molisols, high fertility	10	No use	Erosion
Ultisols	Medium fertile, relatively acidic B-horizon	9	Part use	Acidity, erosion, low SQR
Spodosols	Soils of fir-forest of wet and cold climate, poor fertility	3	Part use	Acidity, overwetting, low SQR
Oxisols	Most highly weathered soil of Tropics	8	Part use	Acidity, overwetting
	Whole	87		

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Table 6. Global area and bioenergy potential of marginal lands (FAO, UNEP, 2014)

Source	Lands included	Area, million ha	Biomass yield, t/ha/year	Bioenergy potential, EJ/year
Hoogwijk et al. 2003	Abandoned agricultural land and degraded grassland systems	430-580	1-10	8 -110
Tilman et al. 2006	Agriculturally abandoned and degraded lands	500	4.7	45
Field et al. 2008	Abandoned pastoral lands and croplands not in use as urban or forest	**386**	3.6	**27**
Campbell et al. 2008	Abandoned pastoral lands and croplands not in use as urban or forest	385-472	4.3	32-41
Nijsen et al. 2012	Based on downscaling of lands classified in GLASOD database	**1836**	2.2–10.1	**344**
Wicke et al. 2011	Salt-affected soils (suitable for woody biomass)	971	3.1	56

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Two ways of MagLs definition:

1 – by SQR, Mueller et al. (2007) (SEEMLA approach);

2 – by marginality indicators as separate criteria.

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Figure 4. SQR rating developed by Mueller et al. (2007)

Uncertainties in SQR methodology:

- required special methodic and complicated in calculation;
- low weight of ecological criteria (overflooding, slope steepness, contamination), including shallow rooting, in definition of marginal value. Ecological criteria are not attributed to soil fertility and must be seen as individual factors;
- best way applied to arable lands and can be the reason for the deviation of soil boundaries in the case of overall mapping of MagLs;
- not allow determining suitable bioenergy crop for MagL's practice;
- rang of SQR score is often indefinite in terms of bioenergy crops potential.

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Figure 5. Pilot case at Poltava Region, Ukraine

Pilot site in early March 2018

SQR = 40

Pilot site at the beginning of April 2018

Pilot site at the beginning of May 2018

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Uncertainties and advantages of individual criterion methodology of MagLs definition:

- limited information for identification the rang of marginality indicators. It can be a reason for deviation of MagLs boundaries;
- weight of ecological indicators in MagLs definition is increased;
- better adopted for definition the overall area of MagLs. Allow proper extending boundaries over arable lands and pastures area;
- not require unified complicated methodology for soil samples analysis;
- easier adopted by stakeholders and thus of higher practical value

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Figure 6. Algorithm of MagLs definition by individual criteria

Suitability of soil biophysical properties and environment constrains for bioenergetics

Criteria:
- shallow rooting;
- low fertility;
- texture;
- pH;
- overwet;
- erosive;
- contamination

→

Climate suitability to grow separate bioenergy crop

Criteria:
- latitude;
- average annual precipitation, mm;
- average annual temperature, 5°C;
- hydro-thermal coefficient

→

Economic efficiency to grow separate bioenergy crop

Criteria:
- income

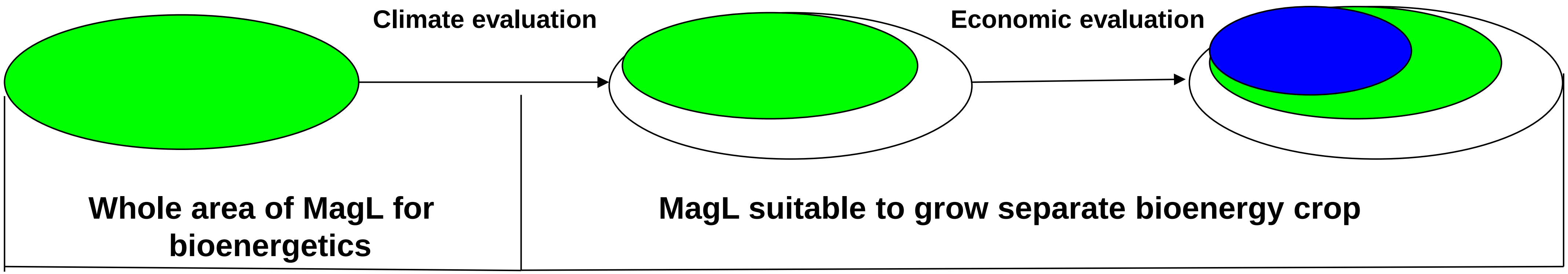

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Table 7. Matrix of bioenergy crops suitable to MagLs in Europe

Categories of MagL	Marginality indicators	Mediterranean P=300-500 mm T=14-17°C HTC=0.3-0.5	Maritime		
			1000-700 mm; 10-15°C HTC=1.5-2	700-600 mm; 8-10°C HTC=0.8-1.5	600-300 mm; 2-8°C HTC=0.8-0.5
shallow rooting	within 25-**35** cm	Pine, Switchgrass	Pine, Switchgrass	Pine, Switchgrass	Pine, Switchgrass
low fertility	SQR scores **≤ 40**	Black locust, Pine, Switchgrass	Willow, Poplar, Black locust, Pine, Miscanthus, Switchgrass	Willow, Poplar, Black locust, Pine, Miscanthus, Switchgrass	Black locust, Pine, Switchgrass
stony texture	stones **10**-20%	Black locust, Pine	Willow, Poplar, Black locust, Pine	Willow, Poplar, Black locust, Pine	Black locust, Pine
sandy texture	sand **40**-60%	Black locust, Pine, Switchgrass	Willow, Poplar, Black locust, Pine, Miscanthus, Switchgrass	Willow, Poplar, Black locust, Pine, Miscanthus, Switchgrass	Black locust, Pine, Switchgrass
clay texture	clay **50**-60%	Black locust, Pine, Switchgrass	Black locust, Pine, Miscanthus, Switchgrass	Poplar, Black locust, Pine, Miscanthus, Switchgrass	Black locust, Pine, Switchgrass
salinic	salts **3.2**-16 dS/m	Black locust, Pine, Switchgrass	Poplar, Black locust, Pine, Miscanthus, Switchgrass	Poplar, Black locust, Pine, Miscanthus, Switchgrass	Black locust, Pine, Switchgrass
sodicic	exchange sodium **4.8**-8%	Black locust, Pine, Switchgrass	Black locust, Pine, Miscanthus, Switchgrass	Black locust, Pine, Miscanthus, Switchgrass	Black locust, Pine, Switchgrass
acidic	pH 4-**5,5**	Black locust, Pine, Switchgrass	Willow, Poplar, Black locust, Pine, Switchgrass	Willow, Poplar, Black locust, Pine, Switchgrass	Black locust, Pine, Switchgrass
overwet	und.water **0-80**cm gleyic **0-40** cm	Pine, Switchgrass	Willow, Poplar, Pine, Miscanthus, Switchgrass	Willow, Poplar, Pine, Miscanthus, Switchgrass	Pine, Switchgrass
eroded	slop **12**-15%	Pine, Switchgrass	Poplar, Black locust, Pine, Miscanthus, Switchgrass	Black locust, Pine, Miscanthus, Switchgrass	Pine, Switchgrass
contaminated	over **10** mg L^{-1}	Black locust, Pine, Switchgrass	Willow, Poplar, Black locust, Pine, Miscanthus, Switchgrass	Willow, Poplar, Black locust, Pine, Miscanthus, Switchgrass	Black locust, Pine, Switchgrass

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Conclusions:

1 – SQR methodology requires improvements in terms of increasing value of ecological indicators, giving them status of individual criteria;
2 – IT computer programme must reflect this individual approach in terms of ecological indicators;
3 – To increase precision of marginality indicators, more data are required;
4 – Climatic and economic features are beyond this methodology and measures to depict this criteria would be topical;
5 – To involve economic criteria to marginality evaluation, next step are important:
- soil productivity have to be evaluated by unified index – yield of dry matter per hectare presented in ton of carbon;
- create data bank of prices for one ton of carbon per hectare of soils across Europe.

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Thank you for your attention

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