

1 Supplementary materials

2 Table S1. Definitions of grassland types

Semi-natural grassland	Self-seeded herbaceous and shrub vegetation used for extensive grazing by livestock and/or mowing [22]. Semi-natural grasslands are not further addressed in our study because of their high biodiversity values and our focus on sustainable measures for intensifying grasslands to create space for energy crop production.
Permanent grasslands	Defined by the European Commission as “land used permanently (for five years or more) to grow herbaceous forage crops, through cultivation (sown) or naturally (self-seeded) and that is not included in the crop rotation on the holding. The land can be used for grazing or mowed for silage or hay.” [88]
Temporary grassland	Defined by the European Commission as “grass plants for grazing, hay or silage included as a part of a normal crop rotation, lasting at least one crop year and less than five years, sown with grass or grass mixtures. The areas are broken up by ploughing or other tilling or the plants are destroyed by other means such as by herbicides before they are sown again. Mixtures of predominantly grass plants and other forage crops (usually leguminous), grazed, harvested green or as dried hay are included here.” [88]

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Table S2: Overview of grasslands in Europe - Utilized agricultural area and area of permanent and temporary grasslands in EU-28 Member States, Norway and Switzerland in 2013 [16]

Country	UAA	Permanent grassland and meadows		Temporary grasses	
	1000 ha	1000 ha	% of UUA	1000 ha	% of UUA
Austria	2,727	1,296	48%	60	2%
Belgium	1,308	487	37%	69	5%
Bulgaria	4,651	1,271	27%	1	0%
Croatia	1,571	618	39%	15	1%
Cyprus	109	2	2%	0	0%
Czech Republic	3,491	960	27%	35	1%
Denmark	2,619	195	7%	320	12%
Estonia	958	325	34%	124	13%
Finland	2,258	31	1%	640	28%
France	27,739	8,242	30%	3,140	11%
Germany	16,700	4,621	28%	360	2%
Greece	4,857	2,102	43%	111	2%
Hungary	4,657	703	15%	15	0%
Ireland	4,959	3,916	79%	652	13%
Italy	12,099	3,316	27%	1,025	8%
Latvia	1,878	654	35%	353	19%
Lithuania	2,861	560	20%	563	20%
Luxembourg	131	67	51%	12	9%
Malta	11	-	0%	-	0%
Netherlands	1,848	773	42%	210	11%
Poland	14,410	3,206	22%	216	2%
Portugal	3,642	1,817	50%	35	1%
Romania	13,056	4,398	34%	106	1%
Slovakia	1,902	518	27%	76	4%
Slovenia	486	285	59%	22	5%
Spain	23,300	7,962	34%	264	1%
Sweden	3,029	443	15%	1,131	37%
United Kingdom	17,096	10,792	63%	1,396	8%
EU-28	174,351	59,561	34%	10,951	6%
Norway	987	176	18%	476	48%
Switzerland ¹	1,048	620	59%	131	13%

¹ Data from 2010

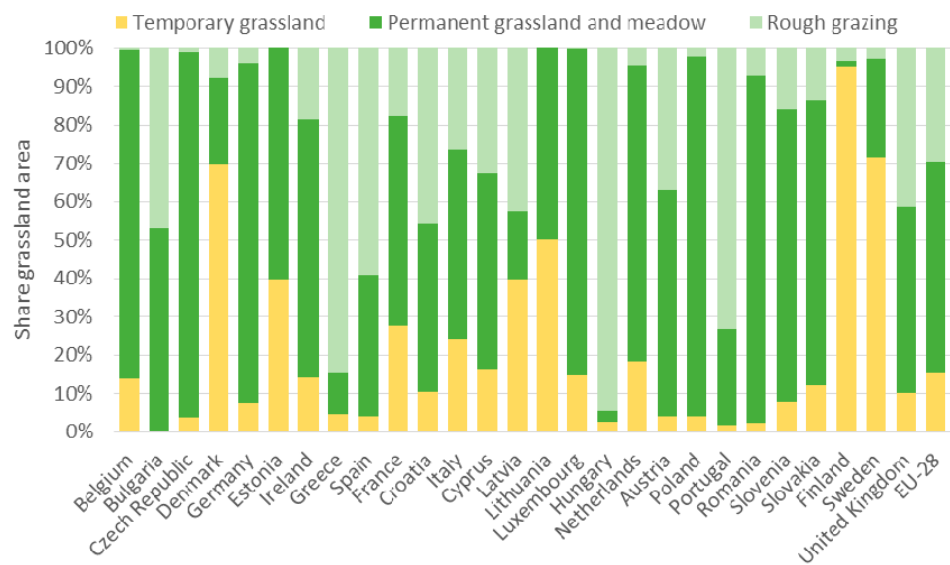


Figure S1. Distribution of grasslands by type [63]

Table S3: Intensification of permanent grasslands – first-order approximation

Context	Suitable measures for intensifying permanent grasslands are increased and/or improved fertilizer application, and improved grazing and cutting management (for a description of these options, see Section 2). For both options, data availability was very low (especially fertilizer management) and results of a few existing studies on grazing and cutting management show such different trends that it was not possible to determine precise estimates of the effects on productivity.
Assumption on yields	5% productivity increase over the study period (2015-2030)
Ethanol conversion	Additional grass is used for ethanol conversion as defined in main text ¹
Results & comparison	162 PJ yr ⁻¹ grass biomass or 55 PJ yr ⁻¹ bioethanol. This is lower than bioethanol potential from intensifying temporary grasslands and using the surplus area for herbaceous energy crop production (72 PJ yr ⁻¹ bioethanol). But there is a large additional benefit of soil organic carbon sequestration though, which could amount to 4 MtCO ₂ -eq yr ⁻¹ .

¹ Conversion to herbaceous energy crops is not considered as this would require ploughing of the soil for the planting and lead to large carbon losses in the soil.