SUPER-G

SUSTAINABLE PERMANENT GRASSLAND

Deliverable 3.7

Assessment of innovative permanent grassland management options

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Contact Details

Name of Contact:	Nina Buchmann
Address:	ETH Zurich, Universitästr. 2, 8092 Zürich, Switzerland
Telephone:	+41 (0)44 632 3959
Email:	nina.buchmann@usys.ethz.ch

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Leader: Marija Klopčič

Person in charge: Nina Buchmann

Author(s): Buchmann N., Bufe C., Hejduk S., Hiron M., Janicka M., Oenema J, Rankin J., Vanwalleghem T., Klopčič M., Newell Price P.

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Forschungsinstitut fuer Biologischen Landbau	FiBL	CH

Abstract

Field trials and experiments to study innovative permanent grassland (PG) management options were carried out across a network of 23 farms and on 17 experimental platforms, located across five biogeographic regions (Atlantic, Continental-Pannonian, Alpine, Boreal, Mediterranean). Management options and innovative technologies focused on the provisioning of ecosystem services (ES) while maintaining productivity and profitability. The following four overarching themes, identified in WP3 (Task 3.3) were assessed: i) new grassland species, diverse species swards, ii) precision grassland management, iii) nutrient management, and iv) agri-environment options. As a next step, as part of Task 3.4, a set of seven criteria were used for their assessment, i.e., improved provision of studied ES, potential for provisioning multiple ES, technology readiness level, ease-of-use by farmers, useability for pastures and/or meadows, potential to improve profitability, and relevance and/or transfer beyond local context.

All options were ranked as being relevant for transfer to other regions, and most of them were seen as applicable to both pastures and meadows. Most options increased provision of the main ecosystem service under study and in some cases had the potential to increase the delivery of multiple ecosystem services. However, some of the options were not seen to provide further ecosystems services as an add-on. Technology readiness levels for all options were typically ranked high (TRL 8 and 9), but techniques linked exclusively to drones and satellites or modelling were ranked lower (TRL7, i.e., system prototype demonstration in an operational environment). This was reflected in the assessment that most of the options seemed to be easy to use by the farmers, apart from innovations based on drone and satellite technologies or modelling. In addition, precision nutrient management, variable rate fertiliser application as well as precision grazing management were rated lower, indicating a large need for knowledge transfer from science to practice. The potential to improve profitability was rated medium to high for about 70% of all options. About 40% of the options were considered highly profitable. Three options (modelling, agroforestry, and use of locally collected seeds) were considered as showing low potential to improve profitability. This clearly indicated a gap between scientific evidence, anticipated ease-of-use and readiness levels of innovative management options for permanent grasslands and their expected adoption by farmers, which is driven by many factors, including profitability.

The most promising options were found within the theme *new grassland species / diverse species swards* as well as *agri-environment options*. The least promising (in early 2024) were identified within the themes of *precision grassland management* and *nutrient management*. Thus, increased uptake of these options will require further proof of concept, clear cost-benefit analyses, and both technical and financial support to farmers before being adopted.

1. Introduction

SUPER-*G* WP3 activities were aimed at identifying, co-developing, testing and assessing different innovative management options for sustainable permanent grassland (PG) use, which allowed both increasing ecosystem service (ES) delivery and increasing profitability. Twenty-three farm networks with over 40 trials, demonstrations and experiments were located across five biogeographic regions (Atlantic, Continental-Pannonian, Alpine, Boreal, Mediterranean), i.e., over 10 trials/experiments per region. Results from the field **trials** and **experiments** were described in detail in the report for Deliverable D3.6 (Task 3.3; Rankin *et al*., 2023), which also identified synergies and trade-offs between productivity, biodiversity, and delivery of other selected ES. As part of task 3.4, which focused on the field experimentation and demonstration aspects of SUPER-*G* testing activities, 22 of those innovative management options and technologies were assessed according to a set of seven criteria.

2. Objectives

To assess innovative PG management options across Europe using seven criteria (Task 3.4)

3. Methods

Field trials and experiments were carried out across the five biogeographic regions to test different innovative management options (Table 1). Results were then aggregated and described in task 3.3 (Rankin et al. 2023). Here, as part of task 3.4, the most relevant PG management options, innovations, and technologies, covering four themes: i) new grassland species, diverse species swards, ii) precision grassland management, iii) nutrient management, and iv) agri-environment options, were assessed based on a set of seven criteria.

Tab. 1 SUPER-*G* field experiments and demonstrations used within WP3 (based on Rankin *et al*. 2023).
Ecosystem services (ES) investigated: P = food production, B = biodiversity, C = carbon sequestration and greenhouse gas (GHG) mitigation, W = water quality, F = flood control, E = erosion control. Type of agriculture: Con = conventional, Org = organic. Livestock types: S = sheep, D= dairy, B = beef, H = horses, P = pigs, G= goats.

Site	Pedo-climatic region	Country	Lead organ.	Management option(s)	Measurements	ES studied	Type of agriculture	Livestock type
Centre for Sustainable Recultivation (ICSR) Vremščica	Alpine / Mediterranean 800 - 1,000 m a.s.l.	SI	UL	Grazing management. Monitoring sensitivity of grass and livestock to drought. Virtual fences and camera drones to protect animals against predators.	Grass yield and quality, botanical, species composition, use of innovative sensors, camera drones and virtual fencing	P, B, C, W, E	Org. / low input	D, S, H, P
Santa Clotilde	Mediterranean	ES	UCO	Grazing management, fertilisation	Grass yield and quality, water balance and quality, soil quality, animal behaviour (telemetry)	P, B, C	Org / Low input con / High input con	B, P

Site	Pedo-climatic region	Country	Lead organ.	Management option(s)	Measurements	ES studied	Type of agriculture	Livestock type
MITANET	Continental / Alpine	IT	UNITO	Mowing/Grazing management, irrigation, fertilisation	Grass yield and quality, botanical biodiversity, nutrient balances and components, C sequestration and GHG emissions, quality of livestock products	P, B, C, W	Low input con / High input con	D, B
Cows and Opportunities in combination with KTC De Marke	Atlantic	NL	WR	Sustainable nutrient use, testing ANCA (annual nutrient cycling assessment) and a new farm water use assessment tool	Sustainable farming with low losses and relative high input (focus on nutrient use efficiency) 16 farms	P, C, W	Con / High input, high efficiency	D
Ossekampen Grassland Experiment	Atlantic	NL	WR	Long term (60 years) fertilisation and utilisation (cutting vs grazing) experiment	Species composition, soil fertility, DM production ; changes in time and interactions	P, B, C	Con	S

Site	Pedo-climatic region	Country	Lead organ.	Management option(s)	Measurements	ES studied	Type of agriculture	Livestock type
Ecology of Dutch grassland species	Atlantic	NL	WR	Relations between soil fertility, fertilisation, water management, utilisation and species composition of permanent grasslands before intensification started	Extensive survey of Dutch grasslands between 1940 -1960	P, B	Data base	D, S
Chamau	Alpine region (at 400 m a.s.l.)	CH	ETH Zurich	Intensive meadow	GHG flux measurements, grass yield and quality. Experiment to test for N_2O mitigation strategies	P, B, C	Con	S, D
Früebüel	Alpine region (at 1000 m a.s.l.)	CH	ETH Zurich	Medium intensive meadow	Grass yield and quality, GHG flux measurements, sward productivity	P, B, C	Con	S, D
Alp Weissenstein	Alpine region (2000 m a.s.l.)	CH	ETH Zurich	Extensive pasture	Grass yield and quality, GHG flux measurements.	P, B, C	Con	S, D

Site	Pedo-climatic region	Country	Lead organ.	Management option(s)	Measurements	ES studied	Type of agriculture	Livestock type
Relliehausen	Atlantic / Continental	DE	UGOE	Cattle grazing experiment three intensities of continuous stocking and permanent grassland under cutting/simulated grazing.	Cattle grazing experiment established 2002 (FORBIOBEN project): botanical and animal biodiversity, grass yield and quality, livestock productivity, soil fertility and quality, animal behaviour/telemetry, remote sensing	P, B, C	Con / low input Con / high input	S, B
La Blanche Maison	Atlantic West	FR	LBM	Rational pasture system applied to dairy cows, calves, heifers and oxen Testing methods for the renovation of degraded grasslands in agroecology	Monitoring of cost and products, carbon storage, water quality, recycling of mineral elements, biodiversity, soil quality	P, B, C	Con	D
Cockle Park (including the Palace Leas hay meadow plots)	Atlantic	UK (England)	UNEW	Grassland management (e.g., compaction, alleviation, timing of mowing / grazing, fertiliser rate)	Grass yield and quality, bird foraging, soil macro- invertebrates (e.g., earthworms), water infiltration, C-sequestration	P, B, F, C	Low input con / High input con	D, B

Site	Pedo-climatic region	Country	Lead organ.	Management option(s)	Measurements	ES studied	Type of agriculture	Livestock type
Hillsborough Precision Grazing Platform	Atlantic	UK (Northern Ireland)	AFBI	150-hectare integrated precision grazing platform (including cutting and grazing) for dairy, beef and sheep production, Evaluating methods for sustainable production of milk and meat from grassland and the role of precision technology in managing soil, nutrients, plants and animals	High frequency data collection for: grass yield and quality animal grazing behaviour and location, animal performance from pasture, nutrient transfer, GHG emissions and botanical biodiversity	P, B, C, W	Con	D, B, S
Skierniewice near Warsaw	Continental (Lowland)	PL	UWA	Long term fertilisation trials, crop rotation and nitrogen balance	Botanical composition, soil nutrient status and Quality, C-sequestration	P, B, C	Con / field experiment	D, B
The educational research centre (PRC) Logatec	Continental (470 m a.s.l.)	SI	UL	Mowing / grazing management for suckler cows with calves or heifers. Nutrient management (application of organic manure or mineral fertiliser), Monitoring of grassland sensitivity to drought (heat stress of	Grass yield and quality, botanical species composition, livestock productivity, soil nutrient status and quality. Animal health and welfare (with use of sensors cameras and drones)	P, B, C, W, E	Con / filed experiment	B

Site	Pedo-climatic region	Country	Lead organ.	Management option(s)	Measurements	ES studied	Type of agriculture	Livestock type
				both grass and livestock)				
Forage Research Station, Moravian Uplands	Continental / Pannonian	CZ	MENDU	Grazing management, fertilisation, species mixes, over-seeding methods	Grass yield and quality, water balance and flows	P, W, F, E	Con & Org	D, B
Durmitor	Alpine region (1,300 – 1,700 m a.s.l.)	ME	UOM	Extensive pasture	Livestock productivity, forage quality, forage yield and DM production, soil nutrient status and quality	P, B, C	Low input Con	S, B

The following **17 management options** were assessed:

i) New grassland species, diverse species swards:

1. Introduction of new grassland species
2. Overseeding with diverse species or mixtures

ii) Precision grassland management:

3. Plate meter, other yield estimation techniques
4. Grazing management tools, rotational grazing
5. Satellite or drone technologies for yield and quality estimation
6. Use of other precision technologies for grazing (e.g., in field weighing / virtual fencing / GPS collars / apps)

iii) Nutrient management:

7. Quantification of nutrient balances
8. Precision nutrient management, variable rate fertiliser application
9. Use of slow-release fertilisers
10. Modelling soil carbon (C) dynamics to increase soil C stocks

iv) Agri-environment options:

11. Agroforestry, promotion of tree establishment and growth
12. Grazing management and other management strategies for productivity, biodiversity and other public goods
13. Cutting management and other management strategies for productivity, biodiversity and other public goods
14. New livestock breeds for PG and/or ES
15. Increasing legume cover to reduce mineral N fertiliser and decrease N_2O emissions
16. Mechanical loosening for improved drainage and productivity
17. Use of locally harvested seeds for re-vegetation

The following set of **seven criteria** and assessment levels were used by WP3 contributors:

1. Improved provision of studied ES (yes, no)
2. Potential for provisioning of multiple ES (yes, no)
3. Technology readiness level (TRL 7 — System prototype demonstration in an operational environment, 8 — System complete and qualified, 9 — Actual system proven in an operational environment)
4. Ease-of-use by farmers (low, medium, high)
5. Useability for pastures and/or meadows (pasture, meadow, both PG types)
6. Potential to improve profitability (low, medium, high)
7. Relevance/transfer ability beyond local context (yes, no)

4. Results and Discussion

All 17 management options were assessed based on the seven criteria (Tab. 2).

Tab. 2 Assessment of 17 innovative management options for PG based on seven criteria. The color code used the cumulative number of all ratings: green represents ≥75% support, orange represents 50 to 75% support.

	Innovative management options and new technologies	1. Improved provision of studied ES		2. Potential for provisioning of multiple ES		3. Technology readiness level			4. Ease-of-use by farmers			5. Useability for pastures and/or meadows			6. Potential to improve profitability			7. Relevance/transferability beyond local context	
		yes	no	yes	no	7	8	9	low	medium	high	pasture	meadow	both	low	medium	high	yes	no
	i) new grassland species / diverse species swards:																		
1	• Introduction of new grassland species																		
2	• Overseeding with diverse species or mixtures																		
	ii) precision grassland management:																		
3	• Platemeter, other yield estimation techniques																		
4	• Grazing management tools, rotational grazing																		
5	• Satellite or drone technologies for yield and quality estimation																		
6	• Use of other precision technologies for grazing (e.g., in field weighing / virtual fencing / GPS collars / apps)																		
	iii) nutrient management:																		
7	• Quantification of nutrient balances																		
8	• Precision nutrient management, variable rate fertiliser application																		
9	• Use of slow-release fertilisers																		
10	• Modeling soil carbon (C) dynamics to increase soil C stocks																		
	iv) agri-environment options:																		
11	• Agroforestry, promotion of tree establishment and growth																		
12	• Grazing management and other management strategies for productivity, biodiversity and other public goods																		
13	• Cutting management and other management strategies for productivity, biodiversity and other public goods																		
14	• New livestock breeds for PG / ES																		
15	• Increasing legume cover to reduce mineral N fertiliser and decrease N_2 emissions																		
16	• Mechanical loosening for improved drainage and productivity																		
17	• Use of locally harvested seeds for re-vegetation																		

All options were ranked as being relevant for transfer to other regions, and most of them were seen as applicable to both pastures and meadows. Many options improved the delivery of multiple ecosystem services. However, some options only improved the ecosystem service under study. For example, using plate meters or other yield estimation techniques, such as drones and satellites, were limited to yield estimates, and did not provide further advantages. Technology readiness levels for all options were typically ranked high (TRL 8, i.e., system complete and qualified; TRL 9, i.e., actual system proven in an operational environment), but techniques linked exclusively to drones and satellites or modelling were ranked lower (TRL7, i.e., system prototype demonstration in an operational environment). This was reflected in the assessment that most of the options were easy to use by the farmers, except drone and satellite technologies or modelling. In addition, precision nutrient management, variable rate fertiliser application and precision grazing management were rated lower, highlighting the need for knowledge transfer from science to practice. The potential to improve profitability was rated medium to high for about 70% of all options. About 40% of the options were considered highly profitable (including use of plate meters, grazing management tools, rotational grazing, quantification of nutrient balances, precision grazing, and the use of legumes). Three options (modelling, agroforestry, and use of locally collected seeds) were considered to have low potential to improve profitability. This suggests there is a need to improve knowledge exchange, demonstration activities and technical and financial support for these options in order to increase adoption by farmers.

The ratings are synthesised in Table 3 and show differences in the assessment of the different management interventions. Options within the theme *new grassland species / diverse species swards* as well as *agri-environment options* were rated the most promising, i.e., (i) introduction of new grassland species; and (ii) overseeding with diverse species or mixtures. Other options that had the highest rating were (iii) increasing legume cover to reduce mineral N fertiliser and decrease N_2O emissions; (iv) mechanical loosening for improved drainage and productivity and quantification of nutrient balances and (v) use of other precision technologies for grazing (e.g., in field weighing / virtual fencing / GPS collars / apps). Other promising options included (i) agroforestry, promotion of tree establishment and growth; (ii) grazing management; and (iii) cutting management and other management strategies for productivity, biodiversity and other public goods.

Tab. 3 Identification of the most promising management options of permanent grasslands. The following colour coding was used: dark green represents the most promising options, followed by light green and yellow. The least promising options and technologies are in orange.

	Innovative management options and new technologies	Most promising
	i) new grassland species / diverse species swards:	
1	• Introduction of new grassland species	
2	• Overseeding with diverse species or mixtures	
	ii) precision grassland management:	
3	• Platemeter, other yield estimation techniques	
4	• Grazing management tools, rotational grazing	
5	• Satellite or drone technologies for yield and quality estimation	
6	• Use of other precision technologies for grazing (e.g., in field weighing / virtual fencing / GPS collars / apps)	
	iii) nutrient management:	
7	• Quantification of nutrient balances	
8	• Precision nutrient management, variable rate fertiliser application	
9	• Use of slow-release fertilisers	
10	• Modeling soil carbon (C) dynamics to increase soil C stocks	
	iv) agri-environment options:	
11	• Agroforestry, promotion of tree establishment and growth	
12	• Grazing management and other management strategies for productivity, biodiversity and other public goods	
13	• Cutting management and other management strategies for productivity, biodiversity and other public goods	
14	• New livestock breeds for PG / ES	
15	• Increasing legume cover to reduce mineral N fertiliser and decrease N_2O emissions	
16	• Mechanical loosening for improved drainage and productivity	
17	• Use of locally harvested seeds for re-vegetation	

Options within the themes *precision grassland management* and *nutrient management* generally had lower ratings, in particular plate meter, other yield estimation techniques; use of slow-release fertilisers; new livestock breeds for PG / ES; satellite or drone technologies for yield and quality estimation; and modelling soil carbon (C) dynamics to increase soil C stocks. This suggests that increased uptake of some options will require further proof of concept, clear cost-benefit analyses, and both technical and financial support to farmers before being adopted. In addition, factors such as political boundary conditions, socio-economics and the risk attitude of farmers can limit the adoption of scientifically proven, reliable management techniques (Hofmann *et al.*, 2022). When agri-environmental policies support certain management options, or when innovators successfully implement new technologies and are successful, their adoption is likely to be higher (see also outcomes of WP4). When risks for farmers increase, e.g., losing yields due to climatic extreme events, more diverse swards are already and are likely to become

more attractive. Understanding the barriers to adoption can be just as important as collecting and providing new scientific evidence for existing knowledge gaps.

5. Conclusions

Based on the seven criteria, a wide range of innovative PG management options were assessed, and a clear picture emerged. Options within the theme *new grassland species / diverse species swards* as well as *agri-environment options* were rated the most promising, while options within the themes *precision grassland management* and *nutrient management* generally had lower and less consistent ratings. This suggests that increased uptake of some options will require further proof of concept, clear cost-benefit analyses, and both technical and financial support to farmers before being adopted. There is a need for policymakers in different areas (agriculture, environment, economy) to develop increased incentives towards sustainable grassland use, e.g., through the implementation of national policies such as Common Agricultural Policy (CAP) Strategic Plans, considering the systems approach necessary to increase provisioning of ES from PG across Europe. Researchers need to complement such activities with co-designed research, as well as open and FAIR data sharing. All these aspects are prerequisites to increase adoption of innovative, sustainable management options and tools in the future.

6. References

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