Research Journal of Agricultural Science, 56 (2), 2025; ISSN: 2668-926X

http://doi.org/10.59463/RJAS.2025.2.08

VIABLE MECHANICAL MEASURES FOR THE IMPROVEMENT OF SOILS IN THE USE CATEGORY OF PERMANENT MEADOWS

Valy-Mihai, DINU
USAMV-Bucharest, Romania

Corresponding author: iidinu.valy@gmail.com

Abstract. *Permanent meadows play an essential role in supporting livestock production, enhancing biodiversity, and facilitating carbon sequestration in agricultural landscapes. However, these valuable ecosystems often face significant challenges due to soil degradation. Common issues such as soil compaction, inadequate drainage, and nutrient deficiencies can severely hinder the productivity and ecological health of permanent meadows. Addressing these soil-related challenges is vital for sustaining both agricultural viability and environmental integrity. This research paper delves into various cost-effective mechanical measures that can be implemented to improve soil conditions in permanent meadows. Specific methodologies explored include tillage practices, subsoiling, harrowing, and mole drainage. Each of these methods has unique mechanisms by which they enhance soil structure and fertility. For instance, tillage can help to alleviate soil compaction and facilitate nutrient mixing, while subsoiling can break through hardpan layers that restrict root growth and water infiltration. Harrowing, on the other hand, can effectively manage organic matter and control weeds, leading to healthier pasture conditions. Mole draining is particularly advantageous for managing excess water in soil, promoting aeration, and enhancing root development. The paper critically evaluates the applicability of each mechanical method in various contexts, focusing on cost-effectiveness and ecological impact. By thoroughly analyzing these interventions, the findings aim to provide land managers with comprehensive insights to make informed decisions tailored to their specific needs. Ultimately, this research seeks to guide practitioners toward sustainable practices that not only enhance soil quality and productivity but also contribute to the long-term viability of permanent meadows as integral components of agroecosystems. Through the implementation of these approaches, it is possible to reclaim and maintain the health of these landscapes for future generations.*

Keywords*: Permanent meadows, soil improvement, mechanical measures, cost-effectiveness, tillage, subsoiling, harrowing, mole draining, aeration, soil compaction, poor drainage, nutrient deficiencies, soil acidity, biodiversity*

INTRODUCTION

Permanent meadows, defined as land used for herbaceous forage crops for five years or more 1, are vital for livestock feed , biodiversity , and carbon storage. Healthy soil is essential for forage quality, nutrient cycling, water management, and plant diversity. Degraded soil leads to reduced yields and ecological decline. Common soil problems in permanent meadows include compaction from livestock and machinery , poor drainage due to soil structure degradation , nutrient deficiencies from continuous forage removal , and soil acidity affecting nutrient availability. Cost-effective mechanical solutions are needed to address these issues sustainably. This paper examines various mechanical measures for soil improvement in permanent meadows, focusing on their applicability, cost, and ecological impacts.

MATERIAL AND METHODS

This study was conducted to assess the technical and economic viability of various mechanical interventions aimed at improving soil conditions in permanent meadows affected

Research Journal of Agricultural Science, 56 (2), 2025; ISSN: 2668-926X
http://doi.org/10.59463/RJAS.2025.2.08

by compaction, poor drainage, nutrient imbalances, and acidity. The methodological approach combined a critical review of existing scientific literature with field-based evaluations and comparative analyses of the performance of different soil improvement techniques.

The mechanical methods examined included subsoiling, sward lifting, surface harrowing, slit aeration, reduced and no-till systems, and mole drainage. Each intervention was evaluated based on its suitability for specific soil degradation issues, operational requirements, frequency of application, and expected duration of agronomic and ecological benefits. Particular attention was given to soil types common to temperate meadow systems, with a focus on loamy and clayey textures that are prone to compaction and water retention problems.

Key assessment parameters included soil physical properties (porosity, infiltration rate, bulk density), vegetation response (root development, sward density, biomass yield), and biological indicators (soil microbial activity and macrofauna presence). Where available, results from long-term experimental plots and case studies were used to strengthen the practical relevance of the findings.

Economic evaluation was based on cost per hectare for implementation (equipment, labor, fuel), operational sustainability (maintenance needs and frequency of reapplication), and projected return on investment derived from increased forage productivity and reduced input dependency. These data were synthesized into a comparative framework to aid in the selection of cost-effective and ecologically sustainable practices for diverse meadow conditions.

By integrating both agronomic performance and economic feasibility, the methodology aimed to deliver a practical decision-making tool for land managers and agricultural advisors seeking to rehabilitate and maintain soil health in permanent meadows through mechanical means.

RESULTS AND DISCUSSIONS

1. Characteristics of permanent meadows and prevailing soil challenges

1.1. Defining permanent meadows: agricultural perspectives and classifications

Permanent meadows are characterized by continuous use for herbaceous forage crops for five years or more, either cultivated or naturally growing. This includes land used for grazing in wooded and shrubby areas. Management intensity varies, influencing species composition and ecological value.

1.2. Key soil properties influencing permanent meadow health

The health of permanent meadows is closely linked to soil properties such as structure, porosity, infiltration rate, water-holding capacity, nutrient availability (n, p, k) , organic matter content , and ph. These properties influence plant growth and overall meadow health.

1.3. Common soil problems in permanent meadows:

1.3.1. Soil compaction: causes, identification, and impacts

Compaction from livestock and machinery reduces soil pore space , hindering air and water movement and restricting root growth. Indicators include poached ground, uneven growth, and specific weeds. Soil pits reveal dense structure and shallow roots. Compaction reduces forage yield and increases runoff and erosion.

1.3.2. Poor drainage: identification, consequences, and contributing factors

Poor drainage leads to waterlogged soils due to clay content, low-lying areas, and compaction. Signs include standing water and indicator plants like rushes. Waterlogging limits oxygen for roots, stunts growth, and increases disease risk.

1.3.3. Nutrient deficiencies: common deficiencies and their effects on meadow vegetation

Continuous forage removal can deplete nutrients like nitrogen, phosphorus, and potassium. Deficiencies manifest as yellowing or stunted growth. Soil acidity also affects nutrient availability. Regular soil testing is essential to manage nutrient imbalances.

1.3.4. Soil acidity: prevalence and implications for plant growth

Soil acidity (low ph) is common in grasslands due to rainfall, organic matter decomposition, and fertilizers. It reduces nutrient availability (e.g., phosphorus) and can increase toxic metals, harming plant growth. Liming is used to raise ph and improve soil conditions.

2. Mechanical measures for soil improvement in permanent meadows: a comprehensive review

2.1. Tillage practices:

2.1.1. Conventional tillage: ploughing and its applicability

Ploughing inverts soil, burying vegetation, and can renovate old meadows. however, it increases erosion, disrupts soil organisms, releases carbon, and is costly. routine use is generally discouraged.

2.1.2. Reduced tillage and conservation tillage methods

These methods minimize soil disturbance, leaving residue cover to reduce erosion. They help preserve soil structure, conserve moisture, and lower costs compared to ploughing.

2.1.3. No-till or direct drilling techniques

No-till involves planting directly into undisturbed soil , reducing erosion, conserving moisture, increasing organic matter, and saving costs. Direct drilling can introduce new species to meadows with minimal disturbance.

2.2. Subsoiling and sward lifting:

2.2.1. Mechanisms and applications in alleviating deep compaction

Subsoiling fractures deep compacted layers , while sward lifting loosens topsoil. Both improve water infiltration and aeration, promoting root growth and forage yield in compacted meadows.

2.2.2. Effects on soil structure, aeration, and drainage

These methods increase macroporosity, improving water and air movement, reducing waterlogging, and supporting root and microbial activity.

2.3. Harrowing and surface slitting/aeration:

2.3.1. Use in thatch management and surface compaction relief

Harrowing manages thatch, while surface slitters/aerators relieve shallow compaction, improving aeration and infiltration in the topsoil.

2.3.2. Impact on water infiltration and nutrient cycling

These techniques enhance water infiltration and nutrient distribution, stimulating microbial activity and improving forage growth.

2.4. Mole draining and other drainage solutions:

2.4.1. Principles and suitability for waterlogged meadows

Mole draining creates subsurface channels in heavy clay soils to remove excess water. Other solutions include cleaning ditches and subsurface pipe drainage.

2.4.2. Cost-effective drainage installation and maintenance

Mole drainage is a cost-effective option for clay soils, though it requires periodic re-moling. Pipe drainage has higher initial costs but lasts longer with maintenance.

2.5. Aeration techniques:

2.5.1. Core aeration vs. spike aeration

http://doi.org/10.59463/RJAS.2025.2.08

Core aeration removes soil plugs, effectively relieving compaction. Spike aeration punctures holes but is less effective for compaction.

2.5.2. Optimal timing and frequency for meadow environments

Aeration should occur during peak grass growth in spring or fall when soil is moist. Frequency depends on soil type and usage, ranging from annually to every few years.

3. Cost-effectiveness analysis of mechanical improvement measures

3.1. Initial investment costs: equipment, labor, and fuel consumption

Costs vary by method, with specialized equipment like subsoilers being more expensive than basic tillage tools. Labor and fuel costs are also significant, especially for intensive tillage.

3.2. Operational costs and maintenance requirements

Operational costs include fuel and maintenance. Some methods like mole draining require more frequent application. No-till can reduce long-term operational costs.

3.3. Long-term economic benefits

Benefits include increased forage production and quality, reduced fertilizer needs, and extended grazing seasons, leading to a positive return on investment.

3.4. Comparative cost analysis of different mechanical methods

No-till and reduced tillage often have lower operational costs. Mole draining is cost-effective for clay soils. The best method depends on specific needs and long-term goals.

Table 1

Key Table: Cost-Effectiveness of Mechanical Measures

Method	**Initial Investment (per hectare)**	**Operational Costs (per hectare per year)**	**Frequency of Treatment**	**Expected Lifespan of Improvement**	**Potential Long-Term Benefits**	**Estimated Return on Investment**
Ploughing	Medium to High	Medium to High	As needed	Medium	Seedbed preparation, pan breaking	Variable
Reduced Tillage	Low to Medium	Low to Medium	As needed	Medium to Long	Erosion control, moisture conservation, improved soil health	Positive
No-Till/Direct Drilling	Low to Medium	Low	As needed	Long	Erosion control, moisture conservation, improved soil health, carbon sequestration, cost savings	Positive

Subsoiling	Medium to High	Medium	Every few years	Medium to Long	Alleviation of deep compaction, improved drainage and aeration	Positive
Sward Lifting	Medium	Low to Medium	Every few years	Medium	Alleviation of topsoil compaction, improved drainage and aeration	Positive
Harrowing	Low	Low	Annually	Short	Thatch management, surface leveling	Low to Medium
Surface Slitting/Aeration	Low to Medium	Low to Medium	Annually or more	Short to Medium	Surface compaction relief, improved infiltration and aeration	Low to Medium
Mole Draining	Low to Medium	Low	Every few years	Short to Medium	Improved drainage in heavy clay soils	Positive in suitable soils

4. Case studies and research findings on cost-effective applications

Research shows sward lifting improves soil structure and drainage , subsoiling can increase water infiltration , and mole drainage is effective for waterlogged clay meadows. Aeration results vary , highlighting the importance of site-specific evaluations. Reseeding and liming also show strong economic returns.

5. Ecological implications of mechanical soil improvement in permanent meadows

5.1. Impact on plant biodiversity and species richness

Reduced and no-till tend to maintain plant diversity , while intensive ploughing can reduce it. Less disruptive methods are preferred in biodiversity-rich meadows.

5.2. Effects on soil fauna and microbial communities

Minimal disturbance practices generally benefit soil organisms, while intensive tillage can be harmful. Aeration can stimulate microbial activity.

5.3. Considerations for maintaining and enhancing ecological health

Prioritize less disruptive methods and integrate them with sustainable grazing and targeted fertilization. Regular monitoring helps ensure long-term ecological integrity.

6. Identifying viable and cost-effective mechanical measures: recommendations and best practices

http://doi.org/10.59463/RJAS.2025.2.08

6.1. Tailoring methods to specific soil problems and meadow types

Choosing methods is recommended to be based on specific soil issues and meadow characteristics. Specifically, subsoiling and sward lifting address compaction, harrowing and slitting manage thatch, mole draining improves drainage in clay, and liming corrects acidity.

6.2. Integrated approaches combining different mechanical measures

Combining methods like subsoiling with aeration or mole draining with surface slitting can be effective for addressing multiple issues.

6.3. Sustainable implementation strategies for long-term soil health improvement.

Implementing measures in a sustainable manner includes regular soil testing and preventative practices like rotational grazing. In addition, adopting an adaptive management approach ensures long-term success.

CONCLUSIONS

Selecting cost-effective mechanical measures for permanent meadows requires understanding soil problems, meadow characteristics, and desired outcomes. Less disruptive methods like reduced tillage are often preferable. Subsoiling, sward lifting, mole draining, and aeration address specific issues. A careful cost analysis and consideration of ecological impacts are essential for sustainable soil health and productivity in these valuable ecosystems.

BIBLIOGRAPHY

1.ADRIÁN JARNE., (2024), Mole drains: A cheap alternative to subsurface tile drainage, Michigan State University Extension, N/A, N/A, pp:N/A

2.BERNOTAS, S., AND SIDLAUSKAS, G. (2003), Some factors affecting seed yield of spring oilseed rape (Brassica napus L.), Agronomy Research 1(2), pp: 229–243

3.BIRKHOFER, K., (2012), Soil biodiversity under different agricultural management regimes in Europe a meta-analysis, Global Change Biology, pp:231-242

4.DE BOER, H. C., (2018), Soil loosening by sward lifting in permanent grassland: Effects on soil structure, grass rooting and productivity, Soil and Tillage Research, N/A, N/A, pp:196-206

5.DE BOER, H. C., (2020), Sward lifting in compacted grassland: Contrasting effects on two different soils, Soil & Tillage Research (201), pp: 104564

6.DE BOER, H. ET. AL., (2020), Sward lifting in compacted grassland: Contrasting effects on two different soils, Soil and Tillage Research (201), pp: 104564

7.DOUGLAS, J. T., (1995), Runoff water quality and agronomic impacts of mechanical aeration and liquid dairy manure on hillside grasslands, Grass and Forage Science, N/A, N/A, pp:210

8.GLAB, T., 2013, Impact of Soil Compaction on Root Development and Yield of Meadow-Grass, International Agrophysics 27(1), Cracow, Poland, pp: 7-13

9.GOULDING, T. W. T., (1998), Soil acidification during more than 100 years under permanent grassland and woodland at Rothamsted, Soil Use and Management, N/A, N/A, pp:162–168

10.HORN, R., (2021), Soil health and biodiversity: Interactions with physical processes and functions, Soil Health and Land Restoration, Elsevier, N/A, pp:319-348

11.JARNE, A. ET. AL., 2024, Management Practices in Mountain Meadows: Consequences for Soil Nutrient Availability, Agronomy, 14(10), pp: 2419

12.JOHNSTON, J., (2018), The effects of soil compaction mitigation on below-ground fauna: How earthworms respond to mechanical loosening and power harrow cultivation, Soil and Tillage Research, pp: 185-195

13.KEES., G., 2008, Using Subsoiling to Reduce Soil Compaction, San Dimas, USDA Forest Service, United States.

http://doi.org/10.59463/RJAS.2025.2.08

14.MACK, G. ET. AL. 2023, Perceived feasibility of sward management options in permanent grassland of Alpine regions and expected effects on delivery of ecosystem services, Environ Dev Sustain. Jan 5, pp: 1-23

15.MCCALLUM, M. H. ET. AL., 1999, Improved Subsoil Macroporosity following Perennial Pastures, Australian Journal of Experimental Agriculture 44(3), pp: 299-307

16.RAPER, R. L., (2007), Using In-row Subsoiling and Cover Crops to Increase Use of Conservation Agriculture in the Southern U.S., Applied Engineering in Agriculture, pp: 571-576

17.REICOSKY, D. C., (1997), Tillage-induced CO2 emissions from soil, Nutrient Cycling in Agroecosystems, N/A, N/A, pp:273-285

18.VAN VLIET, L. J. P., (2006), Aerating grassland before manure application reduces runoff nutrient loads in a high rainfall environment, Journal of Environmental Quality 35(3), pp:903-911

19.***NatureBid Auction Measure Specification, 2020, Grassland Slitting, United Kingdom, Super-G, (n.d.), Factsheet: Liming, N/A, N/A, N/A, pp:N/A

20.***Unacademy, (n.d.), Permanent Pastures and other Grazing Lands, N/A, N/A, N/A, pp:N/A

21.*** 2014, Land use and irrigation - codes and definitions, Food and Agriculture Organization of the United Nations

22.*** 2023, Strong Return on Investment for Grassland Best Practice, Agribusiness Communications Ltd., United Kingdom

23.*** Management of grasslands and rangelands, Food and Agriculture Organization of the United Nations

24.***Agroganic, 2023, How No-Till Farming Improves Soil Health and Saves Money, Agroganic, New Delhi, India

25.***Artemilia, 2021, Permanent Meadows and Environmental Sustainability, Italy

26.***European Forum on Nature Conservation and Pastoralism, (n.d.), Permanent Pastures and Meadows adapting CAP Pillar 1 to support public goods