

Review

Effects of Grazing on Water Erosion, Compaction and Infiltration on Grasslands

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Abstract: Seventy-seven percent of all agricultural land is related to livestock, meat and dairy, including grazing land and arable fields used for animal feed production. The effect of livestock on the natural environment is well documented. Many types of research describe these effects on biodiversity. The surface runoff and soil erosion on grasslands and pastures are investigated with smaller intensity since grasslands are one of the two major land uses that are considered as natural or at least semi-natural lands. Still, mainly due to overuse, grazing on sloping pasture lands can cause severe soil damage, the trampling can cause compaction, compaction decrease infiltration and thus increase runoff and, consequently, soil loss. There are several consequences of the grazing pressure that cause water erosion and surface runoff above the acceptable limit, such as a dramatic decrease in grass densities and/or above-ground bio-mass, compaction, animal tracks, etc. Related research started as early as 1911 and continues until today. There are several methods to analyse the consequences of grazing pressure, e.g., in situ rainfall simulations, infiltration and soil resilience measurements, modelling of runoff, soil loss and infiltration, calculation of ecological costs, etc. Furthermore, most importantly, scientists are investigating the possibilities for improvement of the achieved unstable grazing system due to bad management. Numerous publications have been publishing results on positive changes with the removal of grazing livestock from the grasslands. However, since the socio-economic situation is changing on Earth, more people requiring the products of the pastures, an optimal grazing solution is greatly needed. One of the solutions can be the planning of the optimal animal unit per area, based on the expected grass yields. However, due to the big differences in yields, caused by the greatly unreliable weather, the solution for the future must be a multifunctional agriculture and a flexible land use.



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1. Introduction

There are several estimations on the areal distribution of grazing livestock and the number of people whose everyday life is supported by grazing. Grasslands cover about 40% of the terrestrial area of the globe, excluding Greenland and Antarctica [1]. This 40% increases tremendously, up to 77% if all agricultural land is considered, related to livestock, meat and dairy, including grazing land and arable fields used for animal feed production [2]. According to the FAO report from 2006 [3], the total area of grazing covers 26% of ice-free surfaces and adding the 33% of total arable land dedicated for forage production it adds up to 70%.

Grasslands are considered as semi-natural areas, along with forested areas; however, they are known to suffer from land degradation due to their overuse. Based on the FAO Report from 2006 [3], 20% of pastures and rangelands are degraded to some extent. It is obvious that intensive use of grasslands, overgrazing or sub-optimal grazing regimes can cause damages, sometimes serious damages to grasslands. According to the FAO, there are no available global figures but, in the USA (with the world's 4th largest land area), livestock is responsible for an estimated 55% of erosion and sediment [3]. Various authors

are concerned about water [4] and wind [5] erosion, loss of grass community diversity [6], protection of ecosystem services [7,8], impact on infiltration patterns [9], enhancing carbon sequestration capacity [10], responses of exclosure of livestock [11], etc.

Further worries arise if we have an insight to the situation of Brazil's pastoral activities: the largest commercial cattle herd in the world with 176 million heads on 102 million hectares of cultivated pastures [12–14]. Ninety-three percent of the Brazilian cattle is pasture fed. The cost of this cattle raising is very low, it costs 50–60% of those in the USA and Australia; that also means poor management, so it is not surprising that 70% of these pastures are degraded [15]. These results have an important message about the reduced cost of management: they cause degradation.

There is a relatively new methodology that is used to describe the state of the natural and anthropogenic environment, and it is an obligatory task in the EU countries, so it has become inevitable; it is called ecosystem service evaluation. Concerning grasslands, it is important to know what ecosystem services they provide:

1. providing forage for livestock [16],
2. producing food through livestock [17,18]
3. regulation and storage of water flows [18,19],
4. nutrient cycling, and C sequestration [20–22],
5. shifting focus from supply to reconciling supply and demand [23], etc.

Realizing and understanding the importance, furthermore, the effects of loss or reduction of these ecosystem services is further improving our perception of the problems behind soil compaction, which leads to reduced infiltration capacity, which leads to water erosion, etc. There is still a lot to do related to the understanding of ecosystem services as there are still important knowledge gaps [24].

One of the main aims of ecosystem service research is to prove to people the importance of natural values: what nature provides for people. It is extremely difficult to evaluate the economic value of an ecosystem and especially its single components like the soil; however, Dominati et al. [25] worked out a methodology to evaluate soils as supporting processes, not services. The authors [25] calculated the value of a sheep pasture as USD 3717/ha/y, furthermore, they also calculated that the loss of this value after an erosion event is 65%.

Why is it important to know these worries, the possible degradation processes and related numbers? Well, it is estimated that livestock provides employment for appr. 1.3 billion people worldwide and subsistence for another 1 billion people [14]. At the time of writing the Earth's population is about 7.9 billion, so about 1/3 of the population is affected by grazing, pastures and grasslands. Its importance is huge.

The importance of the subject is reflected by the number of references, introducing all aspects of grazing related issues. There were also several reviews, detailed summary tables published related to soil erosion, infiltration and compaction. The aim of this paper is to list some of these review papers, so interested researchers can find these data. On the other hand, some overview of the triangle of compaction–infiltration–erosion related researches is provided, including some examples of soil erosion models used on grasslands. As this is a review paper and numerous references are cited, it is also a kind of historical overview, and we need to go back to the beginning to see how and why the whole issue was born. A final aim is to raise attention, so related parties might learn from this historical knowledge. The source of the data, for the purpose of using scientific articles, is the search engine of Google Scholar [26].

2. First Attempts to Describe the Situation and Explaining the Problem

Before the overview of the recent state of the grassland–erosion situation, the beginning of these studies needs to be shown, so we can see where the history of the related field investigations started. It is always important to know the history of a subject so we can place the present situation in context. On the other hand, we can evaluate the present if we have information on the past. How early did the research start, in which countries, with

what motivation, and what is the range of the interest of the scientists? What were the main research questions?

Robert V. R. Reynolds was a forest examiner. He published a paper as early as 1911 [27] about grazing and floods, a study of conditions in the Manti National Forest, Utah. Reynolds gave some historical background about the grazing activity in the area that started in 1850, when settlers arrived and grasslands were used by an increasing number of cattle and horses. The erosion problems occurred due to the introduction of sheep. A fight began for the control of the summer ranges and resulted in an overgrazed and trampled dust bed (1888 to 1905) in the examined area that also suffered from numerous burnings, an erratic customary “management” method, believed to improve the grasslands.

Sampson and Weyl [28] (1918) published information about range preservation and erosion control in the grazing lands of the western part of the USA, in their “bulletin”, as they refer to their book. Interestingly, none of them was a soil scientist or erosion expert: Arthur W. Sampson was a plant ecologist, Leon H. Weyl was a grazing examiner. Besides introducing the main influencing factors causing soil degradation, the authors also listed preventive and remedial measures in five points as follows: “1. Avoidance of overgrazing. 2. Avoidance of too early grazing. 3. Deferred and rotation grazing. 4. Artificial reseeding (in choice sites only). 5. Proper control and distribution of stock”. We have to admit that the factors causing problems related to grazing have been identified very early and a very thorough description of remedial measures has been done very early as well.

Korstian [29] (1921) from the US Forest Service also published a paper about the same national forest area as the previous authors. He shows photos of bad examples of overgrazing and describes the potential mitigation possibilities (exclosure of stock, regulated grazing, replanting).

Chaplin [30] also published some results about erosion on rangelands in 1929, partly describing the research done by Reynolds, Sampson and Weyl.

Unfortunately, Renard and Foster [31] (1985) report a tremendous decrease in erosion research activities on rangelands until the 1970s.

3. Recent Review Papers on the Subject

There are several review papers summarizing various aspects of grazing management's impacts. These review papers reflect some of the most recent interest of researchers, giving a wide range of aims.

Greenwood and McKenzie [32] (2001) found it difficult to determine the response of pasture to soil conditions but considered the effect of defoliation by grazing much bigger than the negative effects on poor soil conditions. They also stated that compaction caused by grazing is limited to the upper 50–150 mm of the soil. They concluded that it is only a secondary aim of grazing management to maintain acceptable soil physical conditions. The review paper was cited by 288 articles (5 January 2022).

Drewry et al. [33] (2008) published a paper about soil compaction caused by treading and grazing. They found a data gap on the effects of cattle treading on soil physical properties. This way, it is hard to provide practical and carefully tested decision support tools for land managers.

As soil carbon has a considerable effect on soil erosion and also on infiltration, the review of McSherry and Ritchie [34] (2013) needs to be mentioned. They found that the grazer effect would shift from negative to positive with decreasing precipitation, finer soil texture, photosynthesis type C3 to C4 and decreasing intensity, based on 17 papers in their review. Another review about the effects of grazing on soil organic carbon (SOC) was prepared by Abdalla et al. [35] (2018), based on 83 studies. Soil organic carbon and total nitrogen data were normalized to 0–30 cm depth to meet compatibility with IPCC guidelines. Authors found that all grazing intensity levels increased SOC stocks under the moist warm climate (+7.6%) while reductions were found under the moist cool climate (−19%). Furthermore, only the low (+5.8%) and low to medium (+16.1%) grazing intensities increased SOC stocks in the dry warm and dry cold climates. High grazing intensities

significantly increased SOC when C4-plants dominated the grasslands compared to C3 and C3–C4 mixed dominations. The final conclusion is that grazing intensities and management should be based on climate regions and grassland types (C3, C4, C3–4).

Aiken [36] (2016) summarizes the grazing management options in meeting objectives of grazing experiments in order to find out how to best manage forages and grazing in an experiment.

A detailed review was published about the effects of rangeland fires on hydrology and erosion [37]. The objectives of the handbook were to (1) introduce rangeland hydrology and erosion concepts for understanding hydrologic impacts of fire; (2) describe the effects of climate, vegetation and soils on rangeland hydrology and erosion; and (3) show examples for interactions of fire and postfire with key ecohydrologic relations and hydrologic recovery of the affected area. Studies presented in the review demonstrated that burning may increase runoff and/or soil erosion during high-intensity rainfall events by factors of 2–40 over small-plot scales and more than 100-fold over bigger, large-plot to hillslope scales. Authors made conclusions for the western USA. They also concluded that runoff and erosion from frequently occurring small fire events or less frequent large events are not yet known.

Furthermore, there is a 108 pages handbook, written for the purpose of improving the understanding of hydrologic processes and sediment transport mechanisms on rangelands [38]. This is a handbook in which the authors review publications on hydrologic and erosion processes on hilly rangelands related to ecohydrologic processes, raindrop erosion, concentrated flow erosion, influence of vegetation and management on soil erosion processes, modelling soil erosion and runoff.

Byrnes et al. [39] (2018) conducted a global meta-analysis of grazing impacts on soil health indicators, including soil organic carbon, total N, C/N ratio, soil compaction, bulk density and the effect of rotational grazing strategies on soil properties, based on 64 studies from around the world. They found that continuous grazing significantly reduced SOC, C/N and total N, and increased compaction compared with no grazing. Rotational grazing did not change SOC content, compared to no grazing, which already offers a possible mitigation option for climate change.

Lai and Kumar [40] (2020) analysed 287 papers about grazing impacts on soil properties from 2007 to 2019. They found that heavy and moderate grazing both caused a significant increase in bulk density and penetration resistance and a decrease in soil organic carbon and total nitrogen content in the 0–10 cm layer. Heavy grazing also increased soil erosion due to the decreased surface cover and the increased bulk density/compaction. Meanwhile, they found that light grazing increased the level of soil organic carbon and organic nitrogen.

There are also international congresses where abstracts and proceedings are always providing new information on the subject, “including grassland and rangeland ecology; forage production and utilization; livestock production systems; wildlife, tourism and multi-facets of grassland and rangeland; drought management and climate change in rangelands; pastoralism, social, gender and policy issues and capacity building, extension and governance” [41]. One of these congresses is the International Grassland Congress [41], while the other one is the International Rangeland Congress [42].

4. Effects of Grazing on Water Erosion and Infiltration in Various Countries

To show some examples and varieties of the evaluation of grazing on erosion and infiltration and other related effects from different countries, on different soils, climate, grazing periods and lengths, and various grazing animals, a timeline is used in the following section, starting in 1943.

Croft et al. [43] found that erosion has a considerable effect on organic matter, total nitrogen and moisture equivalent. Erosion is severe on heavily grazed land and is much more severe on south- than on north-facing hillsides. The authors classified the soils according to the degree of erosion and found that with a natural erosion rate, the soil

organic matter content of the upper 1 inch of the soils was 13.8%, while in the moderate accelerated class, it was 7.9% and in the severe accelerated class, it was only 4.2%. The authors compared soils' organic matter content under the non-natural rate of erosion to those under the natural erosion rate and called this number an "index of normality" for expressing the erosion status.

Busby and Gifford [44] (1981) measured the effects of livestock grazing on infiltration and erosion rates on sandy loam soils in Utah (USA) in 1971 and 1972. Neither the removal of forage, nor the soil compaction, had an impact on infiltration rates. Areas excluded from grazing from 1967 to 1971 resulted in significantly higher infiltration rates than grazed areas. However, exclusion of grazing from 1969 to 1971 had comparable infiltration rates to grazed plots. Grazing did not affect the infiltration of chained, debris-windrowed sites. Infiltration rates increased on all sites along with the duration of rest from grazing. Sheet erosion rates were not significantly affected by forage removal and it is very unusual. There must have been some information that we are not aware of to judge this result.

Bari et al. [45] (1993) evaluated the grazing impacts on the infiltration rate in Pakistan in 1987 and 1988. They used rainfall simulation for the experiments and found that control plots with no grazing and standing phytomass resulted in the highest infiltration rate.

Bari et al. [46] (1995) evaluated the grazing impacts on interrill erosion in Pakistan in 1987 and 1988. Since the amount of phytomass suffers a significant decrease during grazing, they analysed the effect of 4 different levels of residual phytomass on the soil surface and found that soils with 3024 kg/ha produced the lowest and soils with 624 kg/ha produced the highest erosion.

Proffitt et al. [47] (1995) evaluated the impact of sheep grazing on an Alfisol (red duplex soil) in Australia. The plasticity limit of the soil was found to be the greatest influencing factor, so the mitigation against compaction and structure deterioration is the removal of the grazing stock from the area.

Mwendera et al. [4] evaluated the effects of various grazing pressures and slope angles on runoff, infiltration and soil loss during a rainy season of 1995 in Ethiopia. The authors found that lower slopes can support higher grazing pressure without jeopardizing the regeneration of the vegetation and causing erosion problems. The final conclusion is that grazing management needs slope-specific schedules in these highland ecozones.

Shinjo et al. [48] (2000) investigated the impact on water erosion under natural rainfall during the 1994/95 and 1995/96 rainy seasons in the Abd Al-Aziz Mountain region, in NE Syria. Grazed and non-grazed (for 10 years) areas were compared with each other, and, in addition, these were compared with tilled plots on a Calcixerollic Xerochrepts. The authors found no significant effects of grazing on soil erosion ($<0.4 \text{ Mg ha}^{-1} \text{ y}^{-1}$) which they explained with the relatively abundant vegetation.

Elliott et al. [49] analysed cattle's treading on interrill erosion using a rainfall simulator in New Zealand. The authors found a linear relation between sediment runoff concentration and the amount of bare ground. The speed of hydraulic conductivity halved when the bare ground surface reached 100%. The recovery of the degraded surface was also assessed and bare ground found to be halved after 2 months.

Peth et al. [50] analysed the impact of grazing reindeer on the infiltration rate of the soil. The reduction of the hydraulic conductivity of grazed sites compared to non-grazed controls was caused by the reduction of macropores by 15–18 Vol%, regardless of the increase of mesopores by 5–6%. The most important finding of the research that the examined tundra sites (Näkkälä) did not prove a clear trend in pore size distribution change that could be related to trampling intensities or management types.

Dec et al. [51] (2012) illustrated the effect of 2 grazing intensities (50 and 200 cows per hectare) in the winter, on an Andosol in Chile. Trampling of cows induced an increase in precompression stress; however, they concluded that due to the low bulk density of the Andosol ($<0.9 \text{ Mg m}^{-3}$), this change may not affect root growth. These results do not necessarily mean that soil can support large stresses indefinitely.

De Andrade Bonetti et al. [52] (2019) evaluated grazing with cattle for 2 years on an Oxisol in Brazil. They highlighted that intensive grazing has effects on soil physical conditions at 0–5 cm depth, and, similarly to no-tillage soil management, long-term and moderate pasture management improves the quality of the examined soils.

Sone et al. [53] (2020) evaluated the effect of high N fertilisation on soil erosion and infiltration with rainfall simulator experiments in Brazil. They found that high doses of N fertilizer result in water and soil loss decrease. Furthermore, 67% stocking rate resulted in a 33% increase of infiltration rate.

Bijan and Afzali [54] (2020) improved the performance of the Century model (soil carbon model) in Iran.

5. Erosion Modelling

Erosion models are widely used to calculate soil loss, either its amount in t/ha/y or its volume m³/ha/y. The oldest of these models is the USLE (Universal Soil Loss Equation), introduced by Wischmeier and Smith [55] (1978). The erosion modelling schools are divided into two groups; one of them is still using the USLE model (searching on Google Scholar resulted in 5700 hits for “USLE” + “grazing” keywords), while the other group is the believer of physically based models, such as RUSLE (Revised USLE [56]) (searching on Google Scholar resulted in 4120 hits on “RUSLE” + “grazing” keywords), WEPP (Water Erosion Prediction Project [57]) (searching on Google Scholar resulted in 2230 hits on “USLE” + “grazing” keywords), EUROSEM [58] (searching on Google Scholar resulted in 569 hits on “EUROSEM” + “grazing” key-words), etc. For those who are sceptic about the dominance of USLE based models, these results are as follows since 2018: 1180 for USLE, 1340 for RUSLE and 424 for WEPP, 133 for EUROSEM (Table 1).

Table 1. Applied soil erosion models in some countries related to grazing.

| Country | Model Used | Aim | Main Conclusions | Reference |
|-------------|-----------------------|--|---|-----------|
| Australia | RUSLE | Examine the capability of the SIBERIA landscape evolution model to quantify short-term erosion and deposition on a well-managed cattle grazing landscape | Both soil erosion and landscape evolution predictive tools need robust calibration and validation using multiple datasets | [59] |
| Brazil | RUSLE | Evaluate soil erosion by water on the pasture of Goiás State and the Federal District. | Soil erosion modeling is an important tool for land use planning and supporting public policies for planning sustainable use of natural resources | [14] |
| Iran | GLEAMS, WEPP, ANSWERS | Improve the performance of the soil carbon related Century model by soil erosion modelling under semi-arid rangelands. | The GLEAMS model output helped the Century model to predict the SOC stock the most precisely. | [54] |
| New Zealand | RUSLE | Fulfill the gap if missing information on grazing in soil erosion models | Reduced treading and low-density grazing exceed reactive practices seeking to trap sediments lost from grazed lands. | [60] |

Table 1. *Cont.*

| Country | Model Used | Aim | Main Conclusions | Reference |
|---------|-----------------------|--|---|-----------|
| Turkey | USLE/RUSLE | Erosion estimation on a volcanic cone | There is irreversible soil loss in the area | [61] |
| USA | USLE | Application of USLE on rangeland watersheds | The USLE is easy to use and its factors can be easily adjusted to local conditions. | [62] |
| USA | WEPP | Parametrization of WEPP on rangelands | Canopy cover has little direct effect on runoff, infiltration and erosion rate. Protection from raindrop impact is not large in rangeland runoff and erosion responses. | [63] |
| USA | USLE RUSLE WEPP | A synthesis paper about the state of knowledge on the influence of factors measuring and modeling soil erosion on rangelands | More data needed for proper modelling; threshold must be identified to stop erosion. | [64] |
| USA | RUSLE | Analyzing Long-term effects of grazing management and buffer strips on soil erosion from pastures | RUSLE predict soil losses well; it overpredicts continuous grazing effects | [65] |

Soil erosion models were also used for the preparation of future scenarios on soil erosion predictions, including the incorporation of possible effects of climate- [66] and land-use changes [67]. The climate change can be considered through the rainfall erosivity (R) factor of the USLE and USLE-related models

6. Effects of Grazing on Soil Compaction and Infiltration

There are some contradictory evaluations of the impact of animals on soil compaction and the closely related infiltration rate.

All livestock grazing strategies and intensities increased soil compaction under relative to no grazing [68–70]. Willatt and Pullar [68] have also stated that soil compaction caused by trampling has not been considered a serious problem in Australian soils (this statement raises other questions but that is for another paper). Based on a 2-year experiment (1983/1984), Abdel-Magid et al. [71] found that the three grazing systems (light, medium and strong pressure) evaluated did not affect the bulk density of the soils, nor the water infiltration in a consistent manner; however, the stocking rate resulted in reduced infiltration in the USA (Cheyenne, Wyoming).

Besides this Australian and US experience, grazing is widely known as a land use causing compaction, reduced infiltration rate and increased runoff. However, the depth of the effect is widely described as shallow by many researchers. Mulholland and Fullen [72] found that trampling produced very dense zones at depths of 7–10.5 cm, which impeded drainage, despite the presence of large macropores.

Tuffour and Bonsu [73] analysed the effects of cattle grazing on compaction, using infiltration as indicator. Grazed and non-grazed plots were compared. Grazing was done with 120 cattle for 3 weeks on a 100 × 75 m plot. Infiltration rate was three times higher on

non-grazed plots compared to the plot after three weeks grazing. The authors found the infiltration rate as a useful tool for evaluation soil compaction and soil degradation processes.

Pearson et al. [74] found that the infiltration rate at saturation was reduced from an initial value of 2–2.5 cm/hr to a final value of 0.3 cm/hr by trampling of 2-year grazing of animals. Savadogo et al. [75] (2006) also found that livestock grazing had a negative effect on infiltrability ($p = 0.038$).

De Andrade Bonetti et al. [52] (2019) found that a moderate pasture management (with moderate number of stock) and a sward height of 30 cm improve the infiltration and retention rate of the examined soils in the Brazilian sub-tropics.

Onyegbule et al. [76] analysed four land use types with a double infiltrometer and found significant difference between them in Nigeria. Grazing land had the second lowest after cultivated land.

A more complex grazing system was analysed by Murphy et al. [77]. The grazing was done for two grazing seasons (1989–1990) with cattle only (C); cattle followed by topping (CT); cattle followed by sheep grazing (CS); and sheep grazing only (S). The authors found differences between the four types of grazing in soil compaction, bulk density and in the number of earthworms. After 2 years, soil bulk densities (g cc^{-1}) were 1.37, 1.37, 1.27 and 1.12; soil penetrometer measurements ($\text{kg cm s}^{-1} \text{ s}^{-1}$) to 20-cm soil depth were 9.8, 9.3, 9.5 and 6.7; and earthworms m^{-2} (and their biomass (g m^{-2})) were 262 (205), 157 (162), 344 (409) and 294 (343) for C, CT, CS and S treatments, respectively.

Jordon [78] (2020) found that “mixed sheep-cattle grazing” improved soil bulk density compared to “cattle grazing only” in a 3 months long experiment in the UK. Jordon also found that the direction from sheep only to mixed and then to no-grazing did not influence the bulk density.

7. Negative Impacts of Grazing on the Soil—Regardless of Ancient, Indigenous Knowledge

There are certain positive effects of well managed pastures on natural values but excessive use can induce numerous negative effects, such as soil erosion by water and wind, soil compaction, reduced infiltration of rainwater, etc.

Indigenous people are known in many contexts as people who care about their environment.

Socio-cultural values of grazing are well-known, described in detail, and sometimes these values outshine the damage that the overuse of the activity is causing. Mousavi et al. [8] (2020) analysed the impacts of nomadic livestock grazing in 2020 and found that the damage through grazing activities is more (USD 794,839) than the net value of direct benefits (USD 601,562; furthermore, with the inclusion of personal costs, it is only USD 193,276).

Savadogo et al. [75] also found that indigenous site-specific knowledge does not always meet sufficient management capacity that might lead to soil degradation and reduced infiltration, etc.

8. Possible Future Methods Concerning the Evaluation of Grazing Effects

The digital tools are evolving with an ever-growing speed. The remotely sensed information is getting easily available and derived data provide an important possibility to gain more detailed data about the Earth’s surface than ever before. This could speed up the research that can help optimization of grassland management.

Multispectral data are one of the well-known, available data for many purposes, including grasslands.

Lanteri et al. [79] used the 1-day MODIS 250 m NDVI for water erosion modelling. The authors found high correlations between biophysical ground measurements and spectral MODIS data. MODIS NDVI and ground canopy cover correlated very well over the studied semi-arid site. EO-1 Hyperion sensor had lower reliability due to the high noise level. Rocks are an important influencing factor on the rate of soil water erosion. More

permanent monitoring sampling areas are needed in a different ground-vegetation cover condition to increase model performance.

Sepehry and Mottaghi [80] used vegetation indices of a rangeland vegetation derived from Landsat Thematic Mapper imagery for estimating the rangeland vegetation canopy cover percentage of the Jahan-Nama protected area of Iran. The Landsat data were only capable of detecting high canopy cover classes after field data categorization.

Dymond et al. [81] used a Multispectral SPOT imagery to map vegetation cover in the Mackenzie Basin of the South Island of New Zealand. The authors used 20 quadrats ($60 \times 60 \text{ m}^2$) to relate percentage vegetation cover to normalized vegetation index.

Geerken et al. [82] (2005) used MODIS and SPOT VEGETATION data and repeated hyperspectral measurements in the 2001 growing season to investigate the separability of vegetation types based on their temporal-spectral signatures in the Syrian Steppe. Two different perennial shrubs and annual grasses were compared and show differences in the length of their growing period.

Due to the rarity of the physically based models available for evaluating the effects of grazing animal stock on soil quality, there is a great need for their development. Roesch et al. [83] developed a new modelling approach for the evaluation of grazing on soil quality, taking into account several input parameters. Several hundred Swiss dairy farm data on stocking density (livestock unit/ha), grazing event duration (days) and daily grazing hours (hours) (data collected between 2011 and 2014) were used and a plausible connection was found between soil compaction and macropore volume and aggregate stability.

In the last few decades, public hearings and stakeholder meetings also became widespread to find out the perceptions of the interested/involved local groups [84]. Malatin-szky [84] found that regardless of the knowledge of and interest in the climate, some farmers were surprised that the predictions of different models vary. This stresses the need for education about climate issues, improved dialogues between stakeholders and providing funding to implement proper management approaches.

9. Conclusions

Research done on pastures, grasslands and/or grazing lands related to soil erosion, compaction and hydrological parameters found that there is a lack of data on many input parameters. I need to emphasize that this conclusion is based on the literature found on the Google Scholar search engine. Furthermore, on the one hand, this data gap is announced by research done on a very specific area (e.g., pastures on volcanic soil with dairy, etc.), and on the other hand, it is concluded by review articles that were based on the analyses of several articles (e.g., Abdalla et al. [35] with 83 studies or Byrnes et al. [39] with 64 studies from around the world or Lai and Kumar [40] with 287 analysed papers), thus having larger geographical coverage.

There are countries where the amount of research and data is high but there are many countries where the reason for deterioration is the lack of knowledge and research which, often along with poor socio-economic conditions, leads to overgrazing and erosion problems [46].

Furthermore, if we apply a qualitative research approach with stakeholder involvements, we can find that there is a lack of knowledge regardless of interest [84], especially economic interest in the subject.

It is an important finding of the recent literature review (also supported by other reviews) that—following the initial starting point of having a lack in the data—results and conclusions are site-specific (see Mousavi [8], who made calculations for a local sheep breed, called Lori, according to forage productivity of vegetation types and animal daily forage requirement ($=1.5 \text{ kg day}^{-1}$), so we cannot find a universal solution for thresholds of proper grazing management [64].

Another good example of the results being site-specific is the findings of Greenwood and McKenzie [32], who found that infiltration rate is not affected by different management types but it is by stock size; however, it is only true for the grazing period as the infiltration

rate is changing in the winter due to freeze–thaw effects. This means that this change is only true to those climates where there is long enough freezing period for having freeze–thaw effects.

Researchers found that only the upper few centimetres are affected by trampling, so intensive animal traffic affects soil physical conditions at 0–5 cm depth [52]; however, according to other authors, these effects go as deep as 5–7.5–10–12.5 cm [85] or 50–150 mm [32], so we can conclude that authors agree that traffic effects the upper few centimetres but there is no comprehensive data(base) about how deep these effects are under different climates, soil types, texture types and animals and/or breeds. Furthermore, increase of the bulk density does not necessarily mean decrease in infiltration rate on pastures.

Besides in-detail scientific conclusions, there are more international/global conclusions of the researches, especially of review works, such as there is a much greater need for coordination of efforts for sustainable grassland management and also a consistent guideline for soil health, condition and quality evaluation to increase our common understanding of grazing impacts. This could result in much better management and policy impacts.

As final conclusions and messages for future generation managers, farmers landowners and all involved parties, I wish to quote two points from the definitions of well-managed rangelands from Bremer et al. [24] that should have always been a minimum requirement; they seem like they are still futuristic but may be the only chance for the optimal and sustainable management of not only rangelands but also for all other area of our life on Earth:

1. have managers who actively acknowledge, support and engage with the rights and interests of their neighbours and surrounding communities; and
2. apply management practices that protect other valuable habitats such as forests and streams.

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