

Overgrazing

Large grazers vs. grasslands

Worldwide, grasslands (see page 81) comprise roughly 40 % of the terrestrial surface. Only a small part of these grasslands can be considered 'natural', meaning that in the absence of grazing these grasslands would turn into shrub and, subsequently, forest. A large proportion is used by humans for livestock grazing. These are often located on marginal soils, where arable farming is not possible because of nutrient deficiency or lack of or excess water.

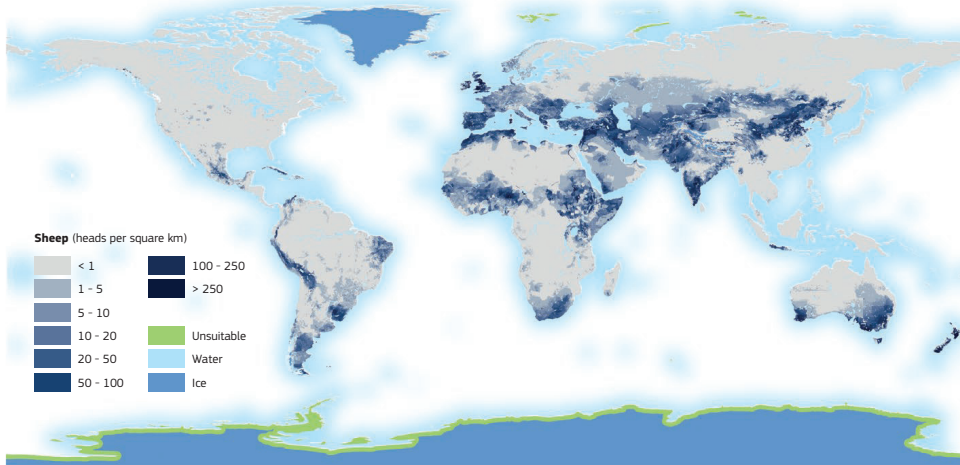
Grazing by large mammals can have both positive and negative effects on soil organisms and, because these processes occur simultaneously, the overall outcome for soil biodiversity will depend on the stocking density of the large grazers. With increasing densities, the negative effects (e.g. trampling, soil compaction, denudation, resource competition, reduction of shelter, and in many cases anthelmintic residue in faeces), will soon overshadow the positive effects (e.g. increased root exudation, nutrient return through defecation). When exactly this tipping point is reached is difficult to determine, and is likely to vary with ecosystem type, geographic location and land-use history. [151]



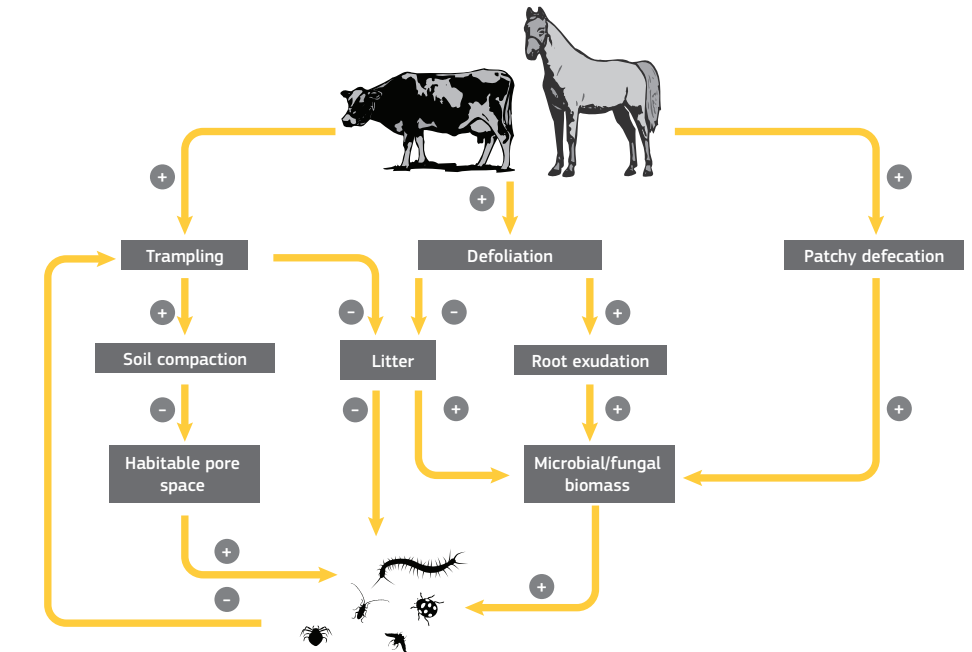
Overgrazing can be defined as the practice of placing too many livestock for too long on the same piece of land, or of grazing ruminants on land unsuitable for grazing (i.e. due to certain physical parameters, such as slope). (DRO)

Grazing at high stocking densities, and especially overgrazing, is probably the largest threat to soil biodiversity in grassland systems. This threat can be expected to increase, which is likely to happen in areas with human population growth. What is considered high or low stocking densities is, however, highly dependent on ecosystem productivity (in terms of water and nutrient availability), grazing system (year-round, seasonal or rotational grazing) or soil type. For example, on a highly productive floodplain a density of five sheep per hectare is considered low, whereas this is considered extremely high for a relatively unproductive arctic grassland.

In general, three actions performed by large grazers affect soil biodiversity: defoliation, defecation and trampling. These processes have contrasting effects on soil faunal diversity, through complex direct and indirect interactions with plants, soil microorganisms and soil physical structure.



Map of global sheep density in 2006 based on statistical relationships between survey and census data and various variables relating to climate and the environment, and other spatial data relating to demography and land cover (derived from Robinson *et al.*, PLOS ONE, 2014). (LJ, JRC) [152]



Conceptual framework of the most important mechanisms through which livestock or other large grazing mammals can affect soil organisms. The arrows represent causal pathways, and the sign (+/-) for each arrow indicates the link between the box in which the arrow starts and the box in which the arrow ends. A pathway from top to bottom with only plus signs (+) indicates general positive effects of large grazers on soil organisms; the minus sign (-) indicates that effects are generally negative. (DV, JRC)

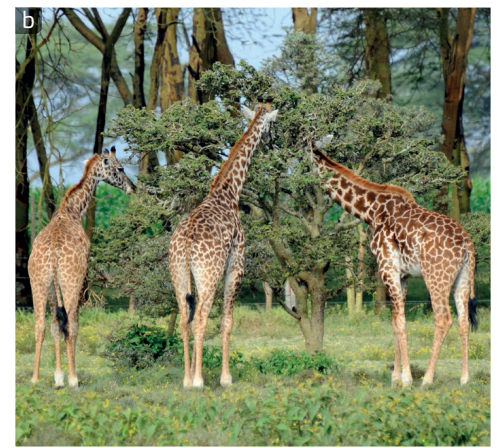
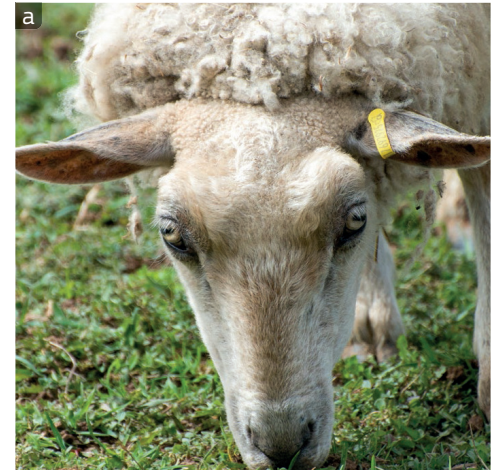
Defoliation

Both large grazers and soil animals depend on plant growth for sustenance. All plant material that is not consumed by large grazers or smaller herbivores will become available to soil invertebrates. Therefore, it can be expected that defoliation (as a result of grazing) takes place at the expense of soil organisms, since they are competing for the same food source. In the short term (hours/days) this is indeed the case: plant material that otherwise would become available to soil animals is consumed by a grazer. However, in the somewhat longer term (days/weeks) grazing can stimulate the activity and abundance of animals in the belowground food web: the network of interactions between soil organisms.

Defoliation forces plants to regrow. In order to do so, they produce sugar-like substances called root exudates that stimulate the growth of microorganisms (e.g. bacteria and fungi – see pages 33-35, 38-41), thus resulting in the release of plant nutrients and an increase in the abundance of soil biota. Defoliation can therefore stimulate plant growth and increase the total amount of available resources for both above- and belowground herbivores.

Moreover, the plant tissue that regrows after defoliation is of much higher quality for herbivorous animals as it is richer in proteins and contains lower amounts of indigestible cell walls. This plant material is also easier for soil organisms to decompose.

Not all organisms profit from defoliation, however. For example, larger-bodied litter fragmenters, such as isopods and millipedes (see pages 56-57), depend on large quantities of poorly degradable plant litter and moist conditions that are present under dense vegetation cover. These often show a pronounced decrease in response to grazing.



Defoliation by (a) domesticated and (b) wild animals can have negative effects on soil organisms, such as isopods, that require large amounts of leaf litter to survive. (KLA, SOG)

Defecation

Patchy deposition of dung and urine (defecation), through which nutrients are returned to the soil, is a second pathway used by large grazers to affect soil organisms. Dung pellets attract a suite of specialised dung-degrading organisms, such as dung beetles, flies and rove beetles (see page 59). These animals are of great importance for the rapid degradation of dung, as well as the redistribution of nutrients through the ecosystem.

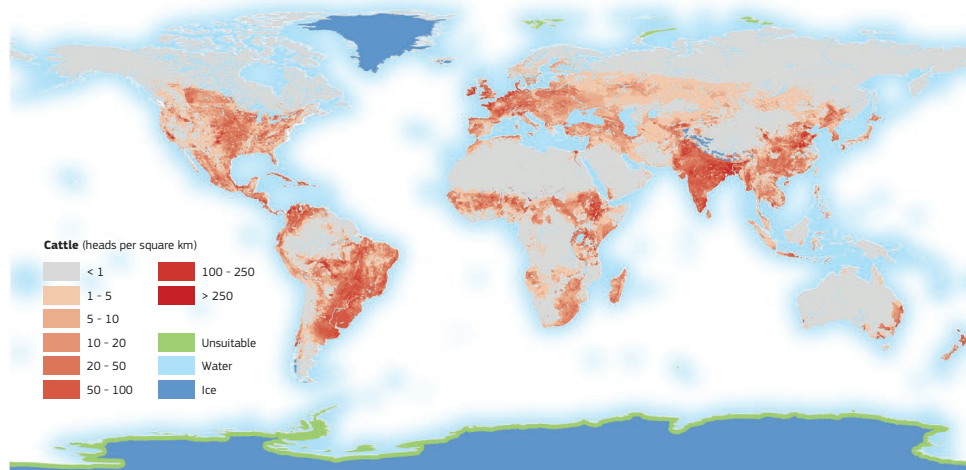
Anti-worming agents (anthelmintics), which are routinely administered to most livestock, can have strong negative effects on dung-degrading fauna as well as on the rates of decomposition of the dung pellet. For example, the use of the broad-spectrum antiparasitic Ivermectin results in delayed or reduced growth of beetle larvae and strong reduction in the number of fly larvae. A number of studies have indicated that earthworms (see page 58) are not negatively affected, but the reason for this is largely not understood. The use of this drug not only negatively affects nutrient cycling, but may also result in a lower abundance of prey items for grassland-inhabiting birds.



⋯. Dung beetle (*Kheper nigroaeneus*) rolls a ball of freshly deposited white rhino dung. (MPV)

Termites and ants as food

- Mammals feed on termites and ants; in fact, 138 different mammal species eat termites and 180 eat ants.
- They range from antelope to elephant shrews. Some, such as anteaters and pangolins, are also specialised in catching them.
- Termites and ants have developed defence strategies to protect themselves from attack by mammals. Bites by the large mandibles of soldier ants is likely the most well-known method; however, some species also produce chemical substances that distance predators. A less well-known strategy considers a diet based on soil particles that make termites poor in terms of nutritional quality and thus less attractive.
- However, none of these defences prevent mammalian predation. Instead, they limit predation by decreasing the food value of the colony on which the mammals are feeding.



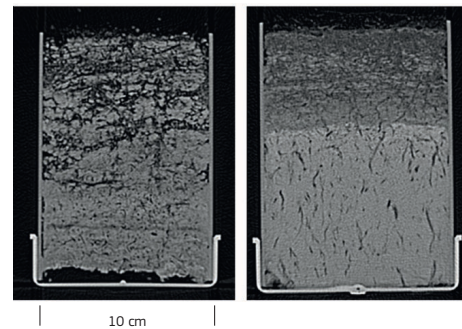
⋯. Map of global cattle density in 2006 based on statistical relationships between survey and census data and various variables relating to climate and the environment, and other spatial demography and land-cover data (derived from Robinson *et al.*, PLOS ONE, 2014). (LJ, JRC) [152]

Trampling

A final major effect that large grazers have on soil organisms is trampling, which can directly affect animals living in the litter layer on, or just under, the soil surface. Indirect effects may be stronger. One indirect effect that trampling can have on soils is denudation, where all vegetation is stripped away from the soil. This usually only happens under high grazer densities.

A second major effect of trampling is the compaction of the soil. Soil organisms inhabit the soil matrix, which consists of pores of various sizes. The largest animals generally live in the largest pores, smaller animals live in smaller pores and the smallest pores are usually only inhabited by bacteria. Trampling by grazing mammals can cause these pores to collapse, with the larger pores collapsing first. Therefore, the largest animals would be expected to face the strongest consequences of trampling. However, many studies show that grazing at low densities is not necessarily detrimental to earthworms. This is probably because earthworms can create their own burrows, thereby shaping a habitat for themselves and other soil organisms. Other animals, and especially soft-bodied soil animals such as collembolans (see page 50), which do not possess this ability, have often been found to be very vulnerable to trampling.

Ungrazed (inside enclosure) Grazed by livestock



⋯. Computed tomography scan of soil cores from ungrazed and grazed temperate salt marshes on clay soil. Dark areas show pore spaces, which are strongly reduced after grazing. (HOL)

The effects of soil compaction are strongest on fine-textured clay and silt soils. The collapse of pore spaces not only affects soil animals directly, but also inhibits the transport of water through the soil. On dry soils, such as the steppes (see page 81) of northern China, soil compaction leads to decreased water penetration. This reduces plant growth and soil biodiversity, and increases superficial runoff and soil erosion (see pages 128-129). By contrast, on very wet soils, such as riverine flood plains and coastal salt marshes, overgrazing of clay soils may result in waterlogged conditions as natural drainage in these soils is blocked. This can result in a decrease in soil oxygen, creating suboptimal conditions for soil fauna and reduced mineralisation rates. In such soils, invertebrate life is often confined to the upper soil layer.



⋯. Soil compaction is caused not only by livestock, such as (a) cattle, but also by wild animals, such as (b) elephants and (c) bison, living in grasslands. The effects on soil organisms can be both direct and indirect, for example, the resulting soil compaction can (d) block water movement, thus affecting soil life. (VI, KBA, MGA, TWA)