Soil carbon - the curent hot topic
Where do floodplain meadows sit in the debate?

Temperate grassland soils have an important role in controlling atmospheric CO_2

The soil carbon pool is several times larger than the atmospheric carbon pool and it has the capacity to absorb and store more (Fig. 1). Globally, soils contain 3.8 times more organic carbon than in above ground biomass (Kobak, 1988). Alluvial soils, such as those supporting floodplain meadows, are particularly important in carbon sequestration because they grow deeper with each flood event providing new soil to fill with carbon. They are precious 'treasure chests', which securely hold large amounts of carbon; in this respect they are probably only second to peat in the UK.

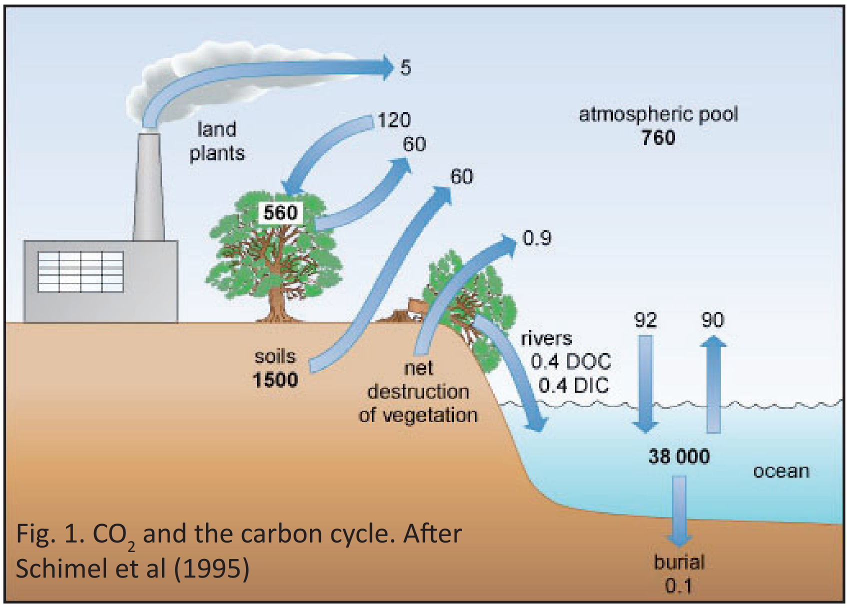


Fig. 1. CO_2 and the carbon cycle. After Schimel et al (1995)

The carbon cycle comprises four major processes: fixation through photosynthesis, release through respiration (above and below ground), sequestration in the soil (short, medium and long-term pools) and precipitation as calcium carbonate in the sea

Carbon, Roots and Humus

Species-rich grasslands support a diversity of root systems (Fig. 2). Where species' mixtures are diverse, plant root systems occupy space more effciently than if growing individually as a monoculture allowing them to lay down carbon in a greater volume of soil. In Fig. 2, the root system of *Knautia arvensis* exploits soil horizontally beneath the root systems of its neighbours. By increasing the diversity of root forms, the occupation of soil will be increased, and hence the overall fixation of soil carbon. A more local example would be great burnet, *Sanguisorba officinalis*, which has a deep rooting distance of around 1m or *Lotus corniculatus* with a rooting depth of around 2m.

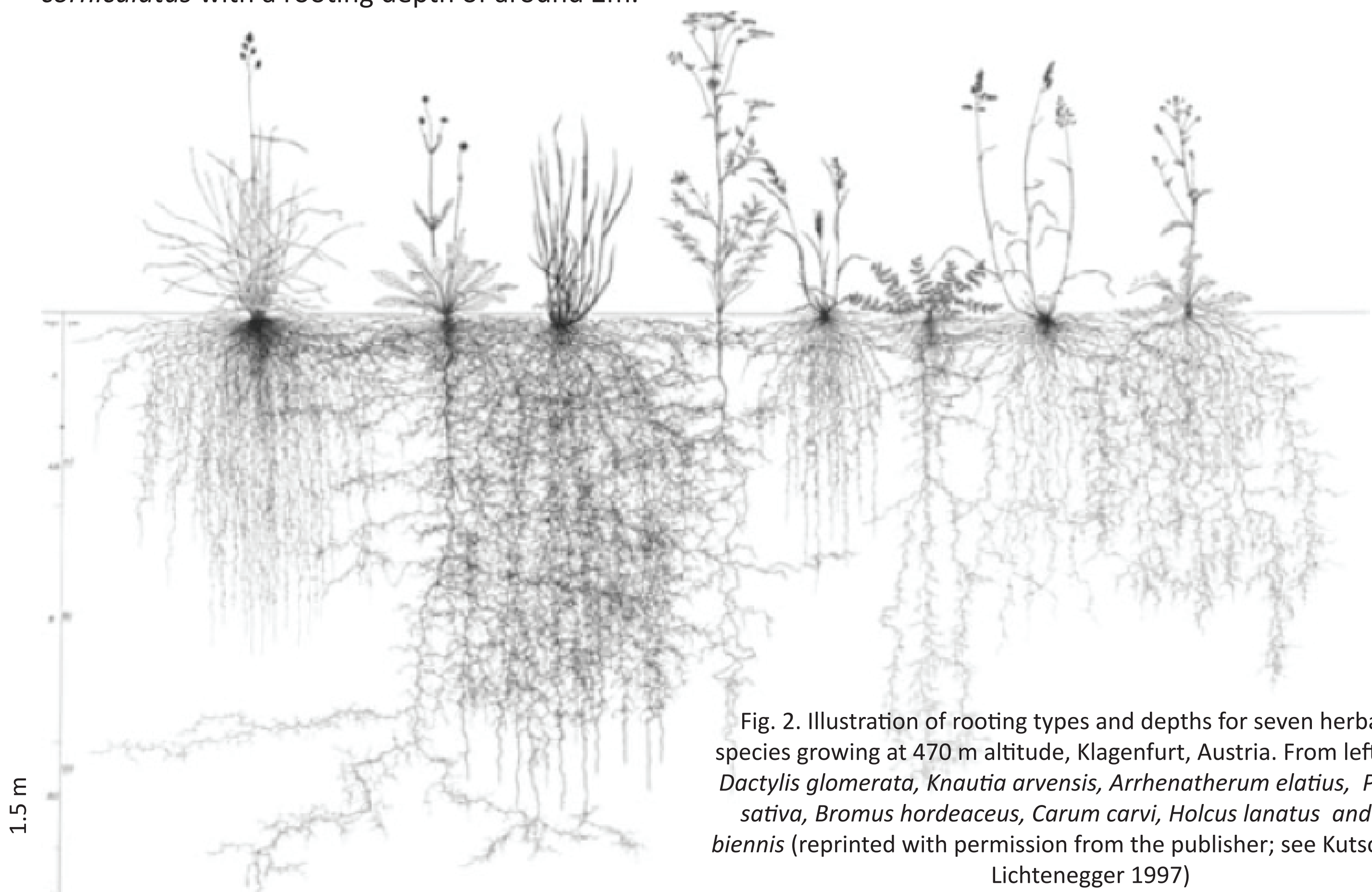


Fig. 2. Illustration of rooting types and depths for seven herbaceous species growing at 470 m altitude, Klagenfurt, Austria. From left to right, *Dactylis glomerata, Knautia arvensis, Arrhenatherum elatius, Pastinaca sativa, Bromus hordeaceus, Carum carvi, Holcus lanatus* and *Crepis biennis* (reprinted with permission from the publisher; see Kutschera and Lichtenegger 1997)

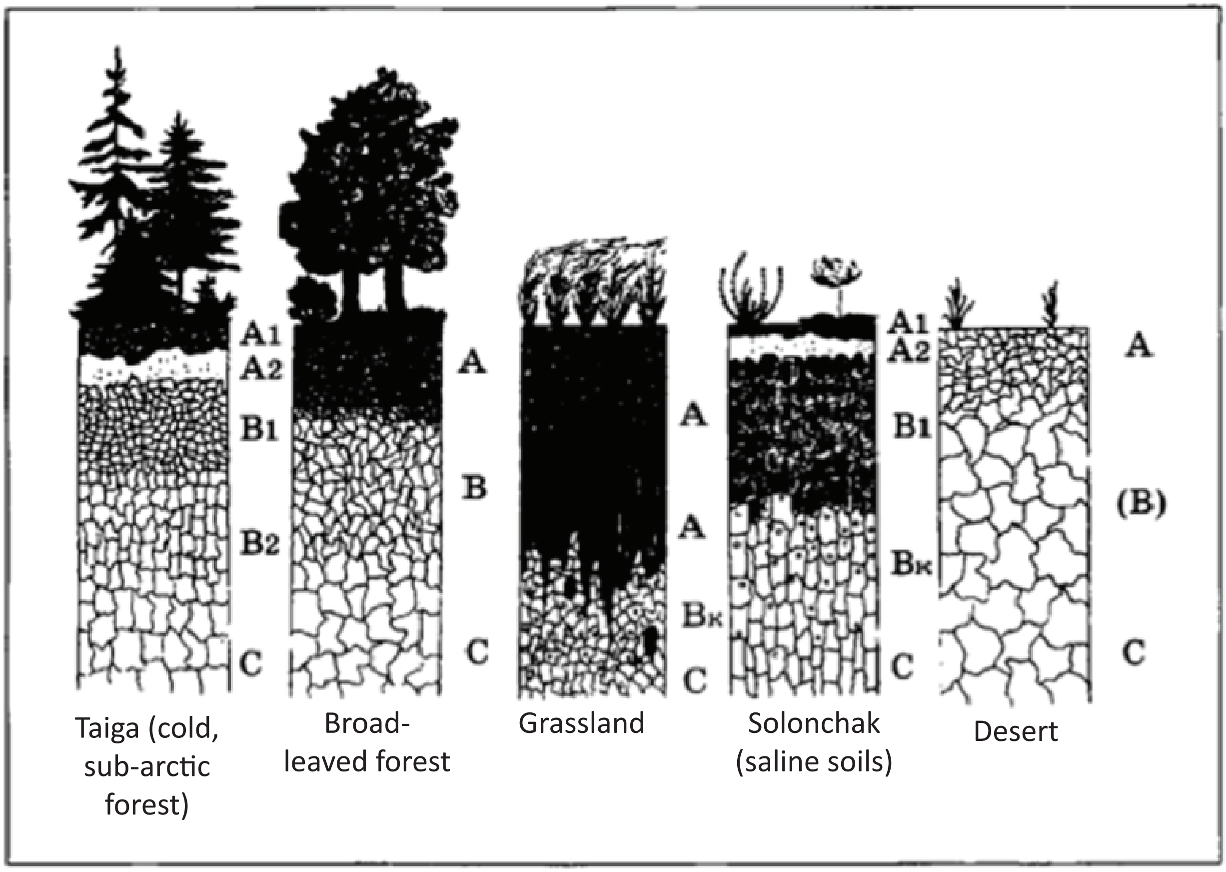


Figure 3. Distribution of humus along the soil profile of different ecosystems (Rozanov, 2004). Dark areas show density and depth of humus.

Established grasslands have a large underground store of humus (Fig. 3) which extends considerably deeper than other ecosystems studied. They also have a root biomass 4-7 times bigger than that of trees (Kobak, 1988), and so grasslands can sustain a higher rate of soil carbon sequestration than arable fields or forests.

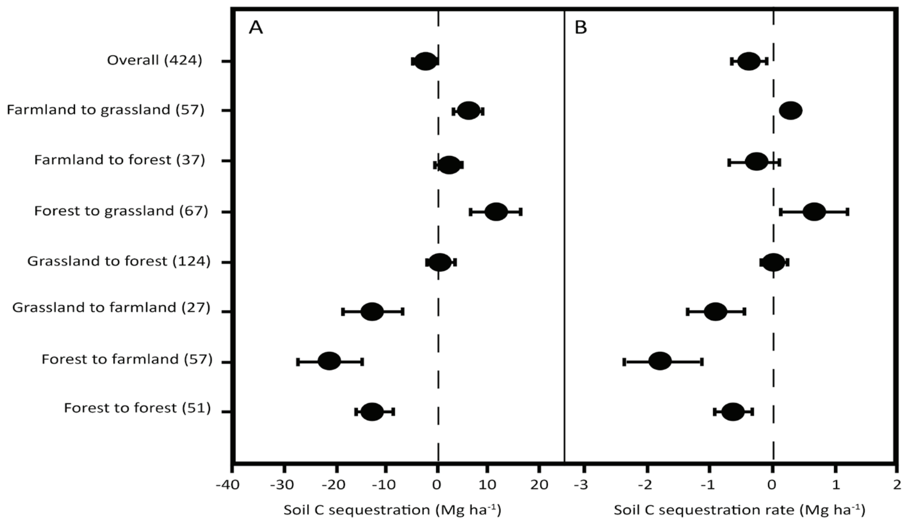
Restoration of grassland and woodland and impacts on soil carbon sequestration rates

The conversion of grassland to woodland shows little effect in capturing carbon from the atmosphere (e.g. Fig. 4) to store in the soil. The biggest losses of CO_2 from the soil to the atmosphere come via respiration. Soils beneath trees tend to respire CO_2 back to the atmosphere at a higher rate than those beneath grassland. High levels of respiration continue after clearance of woodland due to increased respiration of the soil fungi decomposing tree roots. Moreover, wood (lignin) when decomposed, tends to produce large amounts of methane, a more potent greenhouse gas than CO_2.

Soil respiration increases not only after woodland clearances, but also after drainage of peat soils, and conversion of permanent grasslands into arable fields.

Figure 4. The effects of land-use change on soil C sequestration and soil C-sequestration rate.

Note: dots with error bars denote the overall mean values and the 95% CI, and numbers of observations are in parenthesis. Adapted from Deng et al., 2016.



Restoration of species rich grasslands sequesters more carbon than species poor grasslands.

A recent study showed that species-rich grasslands restored from species poor swards, store more carbon in their roots (root C) than species poor grasslands (Fig. 5).

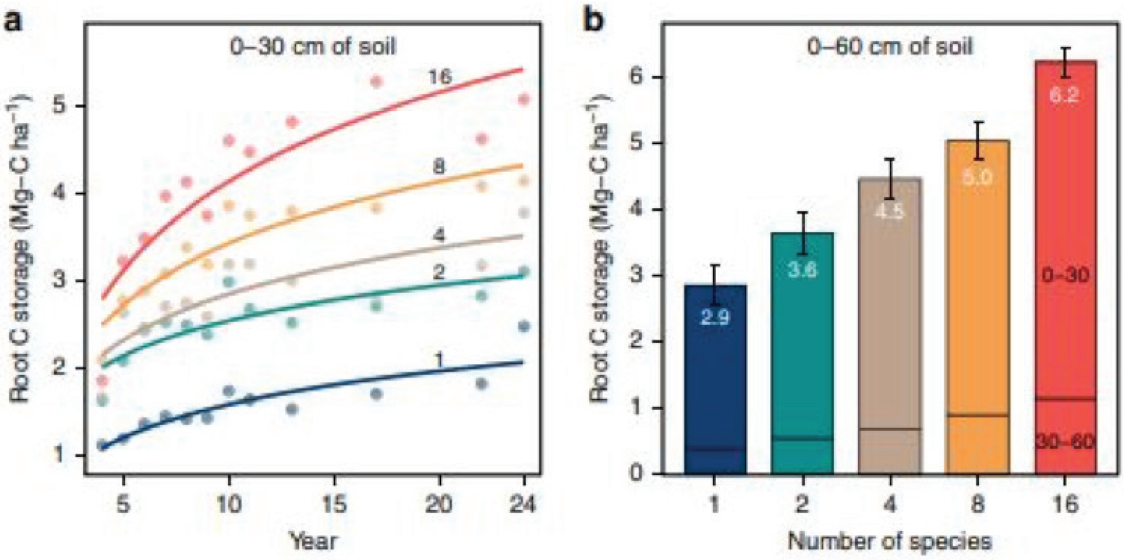


Figure 5. Changes in root C over 24 years (a) Change in root C in upper 30 cm of soil under different experimentally imposed levels of plant species diversity. Data indicate mean root C at a given year, curves fitted with log functions; the number on each curve indicates plant species diversity. (b). Total root C storage after 24 years of growth in upper 60 cm of soil. Numbers in white indicate mean total root C storage, error bars indicate standard errors, and numbers in black indicate soil depth increments (cm) (Yang et al, 2019)

To turn the carbon cycle from emission to storage, areas of disturbed soil need to be left undisturbed and allowed to develop perennial vegetation. This brings us to the main argument: should we plant more trees as a quick solution for capturing excess atmospheric carbon, or should we seek long-term carbon storage, (or both)?

Short-term tree planting is good for above ground carbon storage provided the tree is felled at maturity and the wood is used for something that lasts (e.g. furniture.)

In terms of long-term carbon storage, trees should not be planted into existing permanent grassland as they may both release carbon through soil disturbance and possibly reduce the land's capacity to hold carbon. Young tree plantations sequester carbon into their biomass, but when planted into established grassland they gradually shade out and kill the grass causing the roots to die and much of their carbon to be lost via fungal respiration. As they mature, trees store carbon as cellulose and lignin in their trunks. This can become a large pool of carbon storage, but only until the trees are cut down. At that point, the woodland ecosystem, which has the highest root respiration among all terrestrial ecosystems, becomes a large source of CO_2 emission. Woodland soils tend to have less humus than neutral grasslands (Kobak, 1988). Wood itself is not a reliable store of carbon, compared to peat or humus, because unless it is preserved in buildings or furniture, its carbon is quickly re-released to the atmosphere.

Grassland restoration is good for deep soil carbon storage (unless the grassland is ploughed up!)

In grasslands, root systems of grassland plants can grow to several metres, occupying large volumes of the soil. This ensures a more even distribution of carbon in the soil, compared to restored woodlands (Fig. 6).

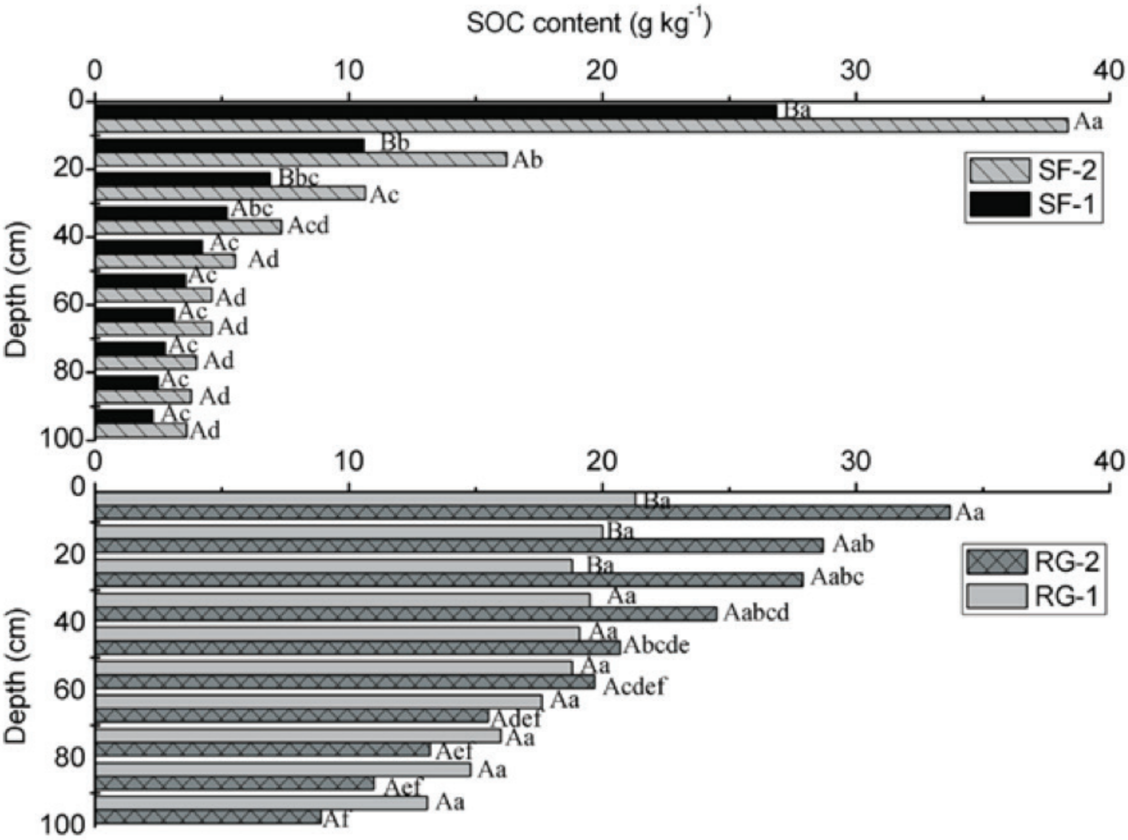


Figure 6. The difference in soil organic carbon (SOC) content. SF-1 and SF-2 are sites of secondary forest while RG-1 and RG-2 are sites of restored grassland. Different lower-case letters denote significant differences among depths within an individual study site; different upper-case letters denote significant differences among vegetation restoration types ($P<0.05$) (plot to plot and depth to depth, $N = 6$). (Adapted from Wei et al., 2012)

Floodplain soils as carbon stores

Biogeochemical processes in floodplain ecosystems are very active. Carbon sequestration and storage in floodplain soils has attracted a range of international researchers. For example on floodplains, deep layers of soil were found to contain large amounts of 'buried' carbon (D'Elia et al., 2017). Our own unpublished data suggest that the amount of carbon stored even in the top 10 cm layer of alluvial soil, is very high - further info here; http://www.floodplainmeadows.org.uk/sites/www.floodplainmeadows.org.uk/files/Soil%20Carbon%20stocks%20summary%20130619.pdf. Investigations into carbon sequestration and storage in floodplain soils under British meadows should therefore be continued (and published).
But even without further study, and based on current evidence, we conclude that floodplain meadows should be conserved together with other established grasslands and restored where possible in order to boost carbon-sequestration rates.

To achieve a global target of decreasing CO^2 in atmosphere:

1) Conservation of peat soils is the top priority.
2) Conservation of established low-input, species-rich grasslands is a key secondary goal
3) Trees planted on woodland clearances and wastelands in urban areas will provide a carbon sink from the atmosphere. Established vegetation and their soils should not be disturbed by tree planting.
4) Grassland restoration provides a long-lasting solution for carbon storage in the soil.
5) Floodplain meadows are a perfect store for soil carbon, they should be conserved, and restored where possible.

'Plant trees and save the planet' but what about the grasslands?

Despite this evidence, grasslands are regularly overlooked in terms of their ability to contribute towards climate mitigation as a nature-based solution, for both sequestration and storage of carbon. For example, there are now carbon codes for peatland https://www.iucn-uk-peatlandprogramme.org/funding-finance/peatland-code and woodland https://www.woodlandcarboncode.org.uk/ to ensure that those trading in carbon are doing so with bona fide projects that are genuinely delivering carbon gains. The carbon gains in restoring species-rich grasslands are significant, and the store of carbon in existing species-rich grasslands is high, so should grasslands also have a code?

Additionally, the drive to 'plant trees and save the planet' is already resulting in some well-intentioned, but potentially damaging incidents in the UK, in which trees have been planted into existing species-rich grasslands. Not only does this damage biodiversity, it can also result in the net release of carbon into the atmosphere.

To avoid this, do we need an up-to-date 'valued grassland' inventory, or at least a proper list against which to check all proposals for tree planting. Current guidance on tree planting says that the Priority Habitat Inventory (PHI), available as a download or through Magic Maps https://magic.defra.gov.uk/MagicMap.aspx is the first place to check to see whether there is any existing interest on a site being considered for tree planting. However, the Priority Habitat Inventory is not comprehensive, or reliable in all circumstances. The best way to check is to have a survey carried out in spring/summer, so that you know for sure you are not about to damage an existing grassland of value.

Action you can take

- If you are planning to plant trees into grasslands, please check that your site does not already have grassland (or other) interest. Follow the good practice guidance, for example on the Woodland trust website here https://www.woodlandtrust.org.uk/plant-trees/advice/where/ Information on locations of floodplain meadows can also be found on our webmap here http://www.floodplainmeadows.org.uk/about-meadows/meadow-map
- If you hear of examples where trees are being planted into species-rich grassland, and particularly floodplain meadows, please let us know. We can compile a list and share with Government agencies.
- We are in the process of working with NE to see if we can put our data into the Priority Habitat Inventory, where it is not already covered by the existing layers. Tell us about any sites you know about that are not listed on our webmap.
- Please share this and similar articles widely. Ask to put information about this topic in your organisational/community magazines.
- Treasure and protect your old meadows and their soil in particular; restore more meadows.

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