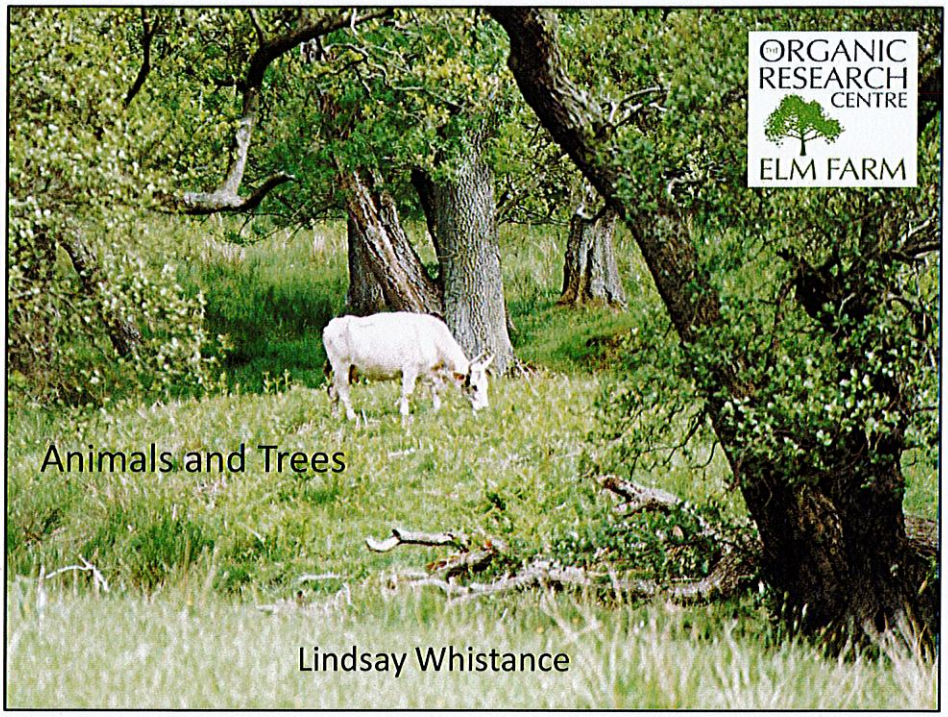
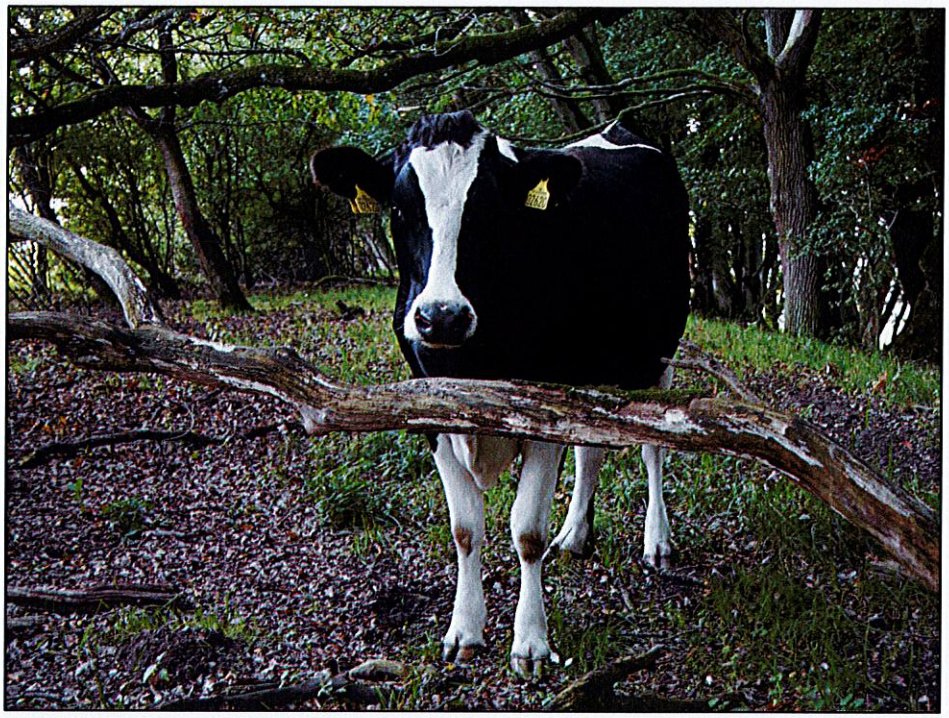


Many behaviour patterns that animals carry out are linked to homeostasis, or the maintaining of balance both internally and externally. For example, if animals are hungry they seek food; if they are cold or hot they seek shelter or shade. Trees and shrubs can play an important role in such behaviour patterns.

The level of poaching around these scrubby trees is similar to that found around the hay rack. This suggests that the resident Dexter cattle spend similar amounts of time in each area indicating that the trees are a valued resource.



In terms of social relations, cattle with access to trees are less aggressive with each other and show more cohesive social behaviour than cows with no access or too little access to trees. In some circumstances, they can also show a lower fear response to humans.

Coat care is an important daily behaviour and trees offer animals a way of dislodging grass seeds, external parasites and the removal of dead coat hairs at moulting time.

For those sheep breeds selected for shedding of fleece, this becomes a more obvious and time-consuming behaviour pattern

How trees are offered will determine which body parts can be groomed. By offering a variety of angles, animals can access most body parts.

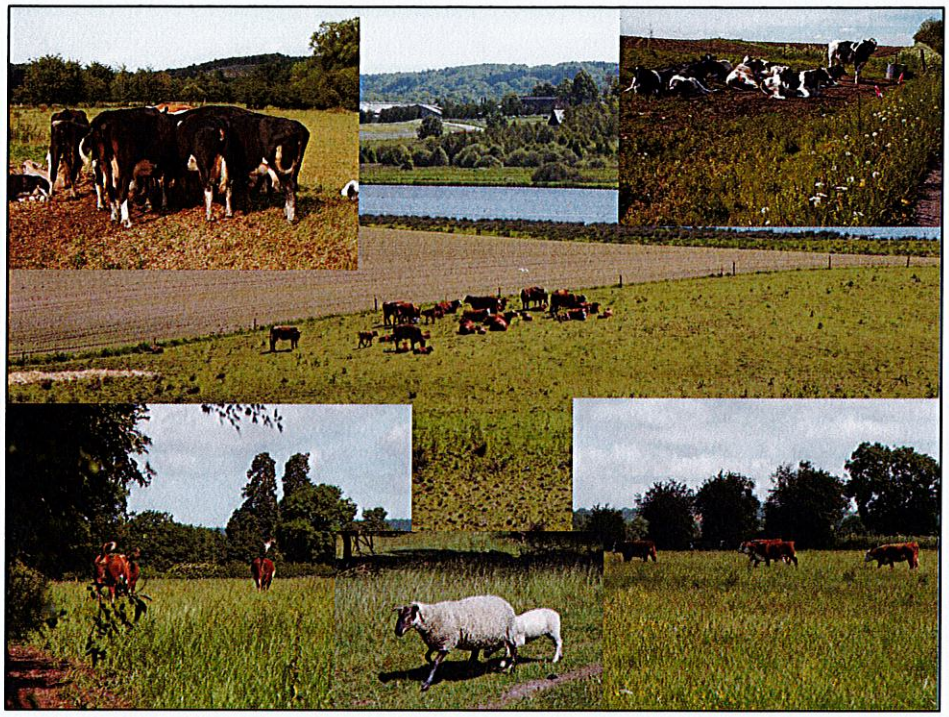
As soon as animals are unable to maintain their thermal comfort, they seek shelter or shade in an attempt to regain comfort.
Globally, the most important thing that trees do for animals is to offer them shade from the sun. For cattle, they are already seeking shade when the temperature hits about 21°C but this of course, depends on acclimatisation, breed, coat colour and yield status.
How shade is offered will determine how it is used and here, in the bottom image, you can see how the herd has split into two clear groups to utilise the shade.

Over use of shaded areas leads to soil compaction and the death of vegetation. It can also lead to an increase in the risk of disease as livestock gather closely together in a more confined space.

In a silvopasture system, cattle utilise the landscape more evenly than in open pasture. This difference is mainly attributed to shelter from the sun.
In the silvopasture system, grazing is the dominant behaviour while loafing is dominant in open pasture. This difference can translate into longer rearing times. For example, cattle with no access to shade take 20 days longer to reach their target weight compared to cattle with access to shade.

Trees provide attractive shade for livestock but they also do the same for flies, including blow flies and head flies. Of course, flies are present in open fields too, but they tend to congregate around the edges of woodland, in particular. As with blow flies, head flies not only cause distress and injury, they are also implicated in the spread of New Forest disease and summer mastitis. So their relationship with trees and disease is not to be taken lightly.

Animals worried by flies show behaviours like hiding, or lying passively, or showing a heightened awareness as well as hiding body parts most at risk (here, where the sheep is hiding its nose, the nostril fly is a problem).



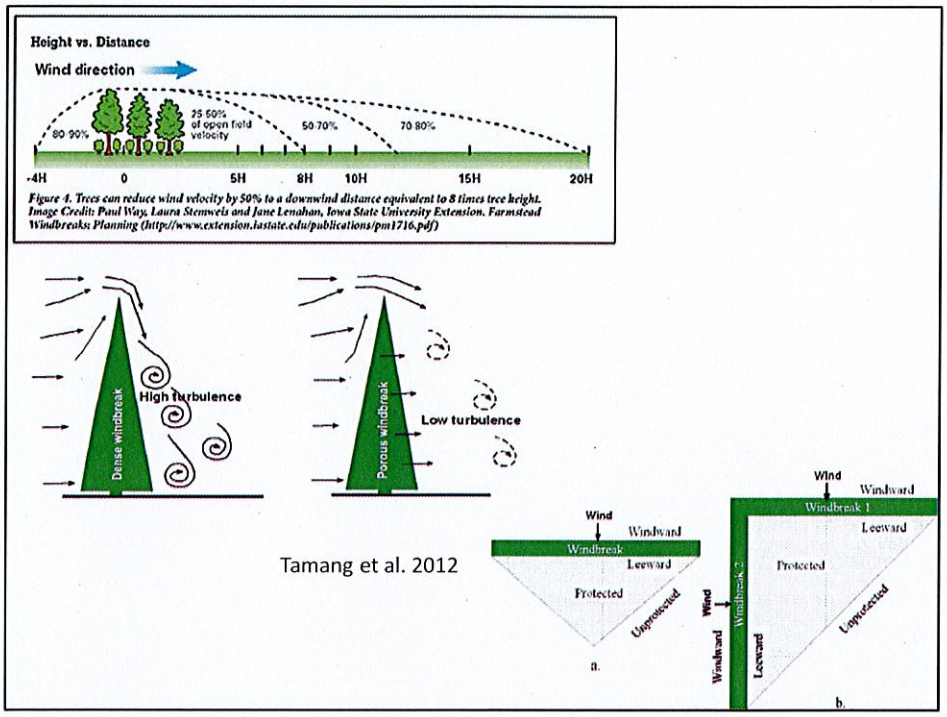
Where animals reject shaded areas due to insects, they may seek places where the wind flow is greatest, or close to water points (these behaviours may also be observed without worry from insects where no shade, or inadequate shade, is offered).
Where head flies are a real problem cattle crowd together attempting to keep their faces free of flies. This can cause overheating.
Another avoidance strategy is to keep on the move either at a walk or faster.
All of these behaviours are highly disruptive to the animal's daily behaviour patterns.

http://blog.phantomforest.com/2012/02/

http://www.bbc.com/earth/story/20170123-how-insects-like-bumblebees-do-so-much-with-tiny-brains

However, allowing sufficient access to trees in the right way can actually reduce the fly burden for livestock.
In established silvopastoral systems, there are more species of dung beetle present and each beetle shows higher activity (1.4 x) when compared to beetles on open pasture. This means that dung is removed more quickly from the surface.
In the more diverse, silvopastoral system there is also an increase in the number of predators of small insects.
Under these conditions, the numbers of head flies trapped are 40% lower than those trapped on open pasture.
So offering more trees and (if allowing animals access to woodland) the opportunity to penetrate trees and move away from the periphery can reduce the fly burden on stock.
For diverse systems, chickens can be considered a useful predator.

Where wind is a problem, the most effective shelter is a windbreak which can be a high hedge, a single row of trees, multiple rows trees, or trees and shrubs combined. Although the day is sunny, the cows in this image are sheltering from a biting, early April wind which is lowering the 'effective temperature'.
The effective temperature includes both air temperature and wind chill. For example, with a temperature of 2°C and a wind speed of 24 kph (15 mph), the effective temperature becomes -7°C. An increase in wind speed to 32 kph (20 mph) and the effective temperature is now -10°C.



Tamang et al. 2012

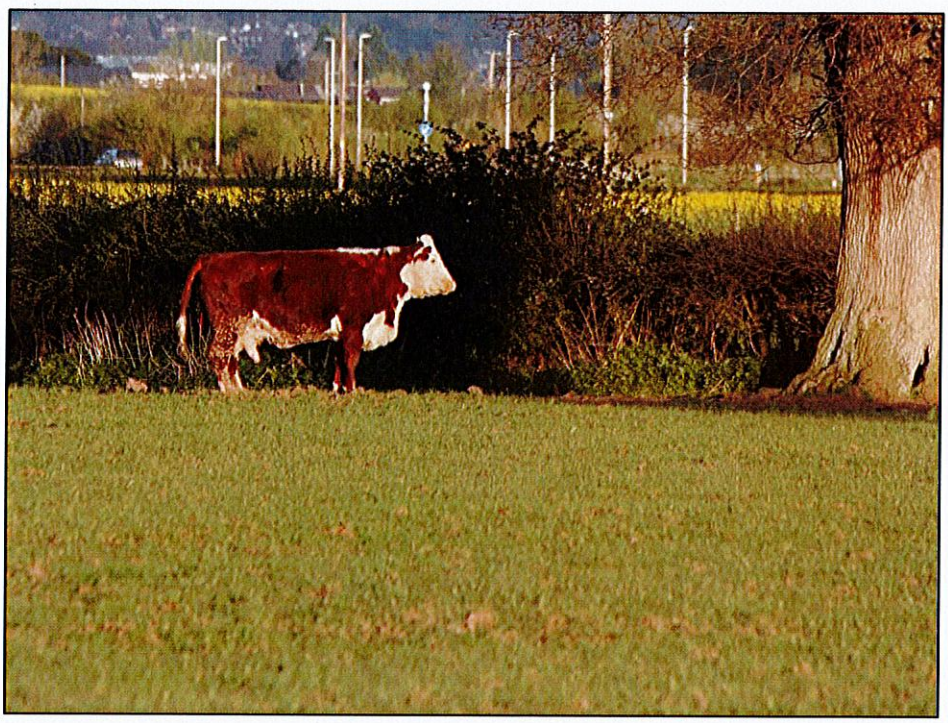
Understanding how shelterbelts work is important since several characteristics have an influence on the wind and the resulting levels of shelter offered to the animals.
The height determines the amount of protected area on the leeward side (note also a potential reduction on the windward side).
Depending on both tree species and how dense the shelter is, the lowest wind speed is between 2-6 x the distance of windbreak height (helping to explain where the cows are lying in relation to the windbreak, in the previous image).
The level of porosity affects wind turbulence on the leeward side of the windbreak. Windbreaks that allow some wind to penetrate through them create less turbulence on the leeward side while more dense windbreaks can create high levels of turbulence on the leeward side.
The direction of the prevailing wind determines how effective windbreaks will be, with the most effective windbreaks being placed perpendicular to the wind. Where wind is a problem from more than one direction, a two leg windbreak perpendicular to each other can offer better shelter.

For shelter from rain, trees with a canopy offer better protection that a windbreak. Here, the settled, relaxed body posture of the dry cow group is in contrast to that of the cows in the milking herd, without shelter from the rain storm.

Trees also offer some protection from night frosts.
When provided with a diverse environment, animals can find the place that best fits their current needs, unlike these cattle in Nebraska, forced to endure severe winter weather without any shelter.
Forcing animals to endure such a harsh environment without shelter raises serious welfare concerns as well as making very little economic sense.
Animals have both higher and lower critical temperatures which are the maximum and minimum body temperatures that can be tolerated without serious risk to health and welfare.
For cattle, the lower critical temperature is around 0°C, if they have developed a normal winter coat and their coat is dry. If they are wet, the lower critical temperature can increase to 15.5°C.
For beef cattle, the general rule of thumb is that for every 1°C drop in temperature below the lower critical temperature, there is a 2 % increase in energy requirements.

These trees are densely planted and their primary function is to produce wood for the farmer.
They also provide a 'living barn' for these heifers both summer and winter, offering shade and shelter.
They may also provide additional protection from insects since pine species have insect repellent properties.
There is limited anecdotal evidence that some deciduous tree species are less attractive to flies and these include elderberry, lime and walnut. Elder trees were traditionally planted outside pantry windows for this reason.

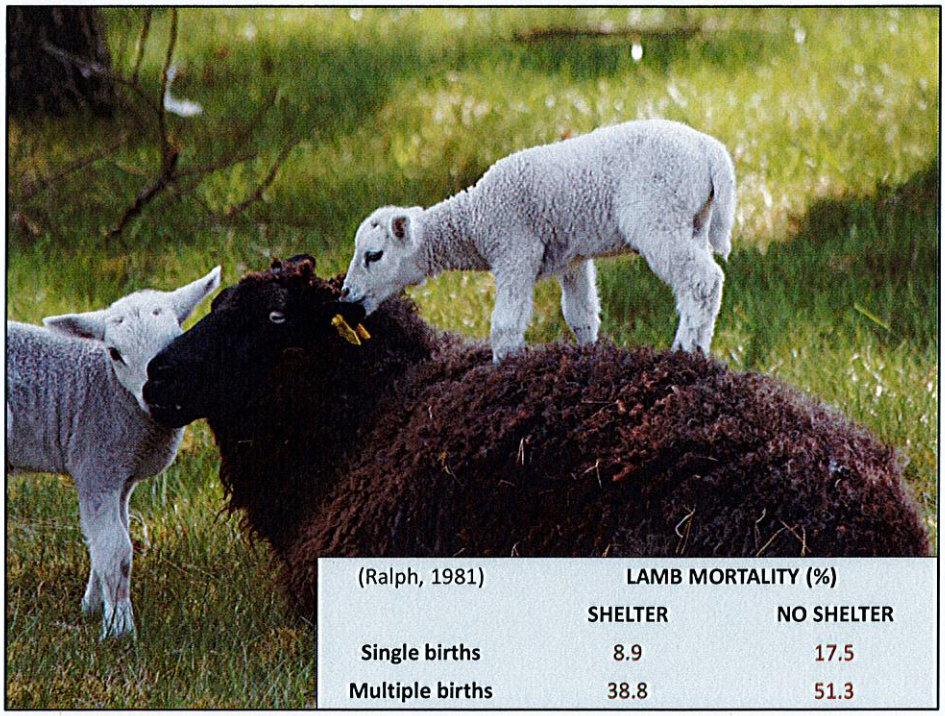
Whether animals are hiders or followers at the beginning of life, trees can play a role in their survival, their welfare and their protection.
The use of trees features heavily in the nest-building of farrowing sows. With full access to resources, a farrowing sow will dig a pit, line it with grasses and leaves and cover the nest with bigger branches for protection from the weather and predators.



Cattle and deer are hider species, utilising trees and vegetation to hide their offspring which can remain hidden for up to several days, with dams visiting their young at regular intervals.

Juvenile animals typically have limited body reserves for compensating for cold stress from low temperatures, wind, snow and rain. Unsurprisingly, the survival of young stock increases with access to shelter in winter.

Sheep are a follower species with lambs being quite mobile after birth, nevertheless, shelter can play a big role in their survival and welfare



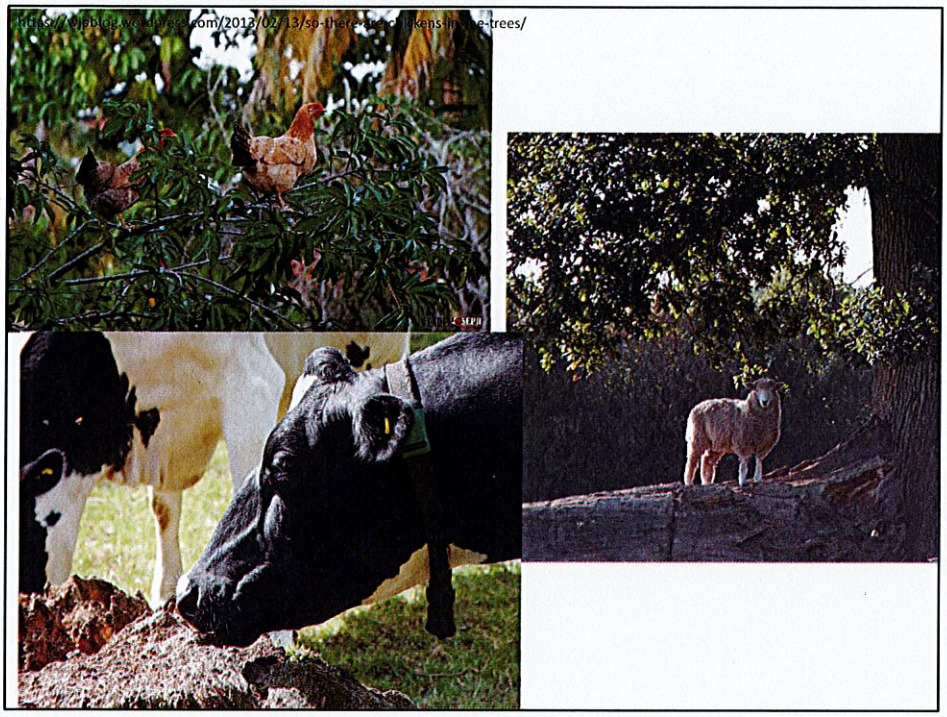
(Ralph, 1981)	LAMB MORTALITY (%)	
	SHELTER	NO SHELTER
Single births	8.9	17.5
Multiple births	38.8	51.3

Exposure to cold (from temperature, windspeed and rainfall) is one of the biggest causes of lamb loss in outdoor lambing systems.
Lamb losses can be reduced by up to 30 % in cold, wet and windy weather if good shelter is provided.

After birth, the ewe and lamb can form a strong bond from 20 – 30 minutes of grooming and there is a 5-6 hour window in which this optimum bonding can occur. Where shelter is offered, ewes spend longer at the birth site, increasing the likelihood of a strong ewe-lamb bond being formed.

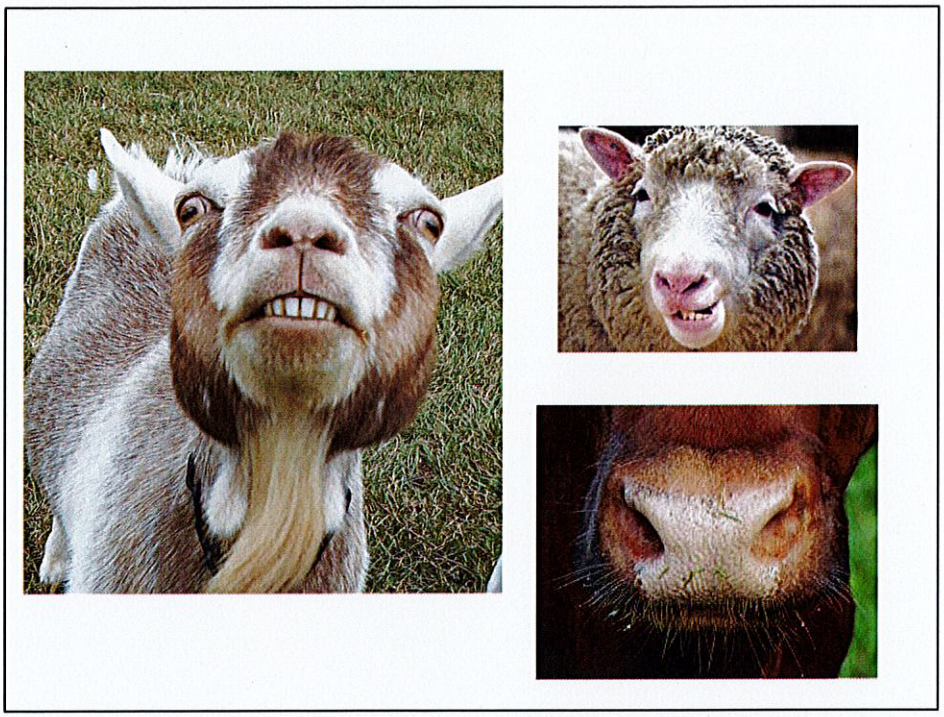
The mother offspring bond is fully complete after 1 day for singles and 3 days for twins and the lamb and ewe can recognise each other visually and vocally. At this point the lambs spend more time in sheltered areas than the ewes, developing their own behaviour patterns appropriate for their needs in maintaining homeostasis.

A secondary benefit of providing trees is that since sheep congregate there, they become easier to shepherd particularly in rough terrain.

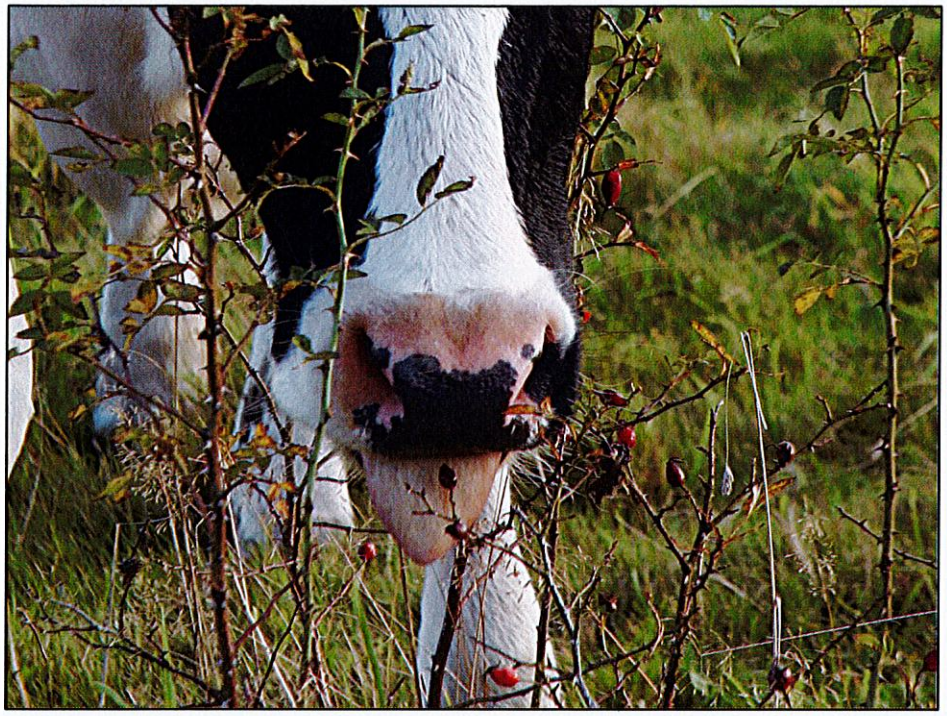


There are other behaviour patterns in which trees can play a role but these are not covered in this presentation.

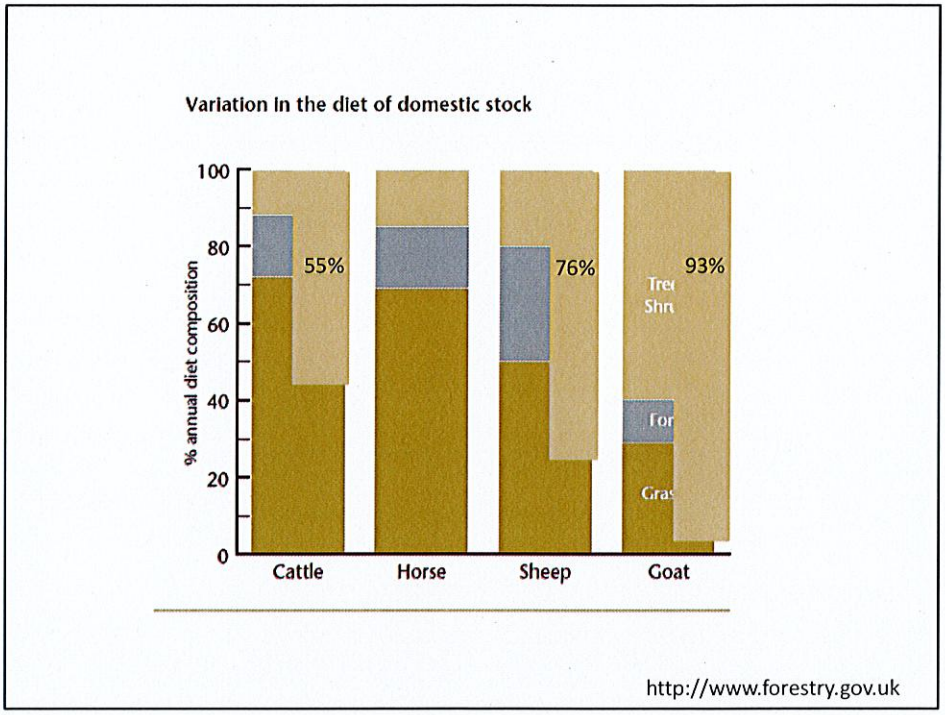
Let us now consider trees as a food source.
Cattle are considered to be grazers,
sheep are non-selective with a preference for grazing and
goats are intermediate selective with a preference for browse.
A browser is something like a camel.
Access to browse is influenced by availability, agility and motivation.
Goats are physically agile animals that can stand on their hind legs to reach high growing forage. They can also use their front feet to pull down branches. Smaller goats can even climb trees to gain access to higher forage.



With a cleft upper lip, sheep and goats can manipulate individual plant items to a greater degree than cattle, for example, selecting leaves and avoiding thorns



However, cattle are still capable of some selective feeding



The average diet of domestic livestock includes grasses, forbs and browse.
For cattle, the average intake of browse is 12 % of total diet, for sheep this is 20 % and for goats it is 60 %.
Intake of browse can increase substantially under different conditions and typically in regions where there is a hot, dry season when grasses and forbs do not thrive. Then, intake of browse can increase to a higher percentage of total diet: cattle = 55 %, sheep = 76 % and goats = 93 %.

Even for a graze animal, browse is a valued resource and upon entering a field, one of the first things that cattle do is to check this out.
When different feeds are readily available in a diverse environment, the general pattern is that cattle spend morning and evening filling up on grazed plants but are more selective in the middle of the day when they can eat more browse.

Hedge: field maple, sycamore, hornbeam, dogwood, hazel, hawthorn, ash, black poplar, oak, false acacia and elder.

All species were browsed at least once except false acacia

Heifers (487 kg) (May – September)	**Time spent browsing (%)**	**Species preferred**
Spring	**19.3**	**Hazel Hawthorn Hornbeam**
Early summer	**5.9**	
Late summer	**5.4**	

Vandermeulen et al 2016

So, livestock species eat both grass and browse in varying degrees, depending on availability and season.
Traditionally, an increase in browse consumption is related to hot and dry periods or winter time when there is no grass growing.
In temperate regions, however, this is not necessarily the case. A study carried out in Belgium, showed that heifers showed most browsing in spring while the shoots and leaves were young and therefore lower in the bitter-tasting tannins than later in the growing season.

http://scotland.forestry.gov.uk/woodlandgrazingtoolbox/grazingmanagement/foraging/palatability-and-resilience-of-native-trees

Palatability	Tree species
1	Aspen, Willow
2	Ash, Rowan
3	Hazel, Oak
4	Scots pine, Juniper, Holly
5	Birch, Hawthorn
6	Beech
7	Alder

Notes on the table:

•In lowland woodlands aspen may be in palatability **class 3**.

•**Scots pine, juniper and holly** are more preferred in **winter** than summer because they are evergreen, however, young holly shoots, before the leaves have hardened, are also often taken.

N.B. There is ongoing debate about whether holly and hawthorn should be higher up the list. They are often seen heavily browsed but this may be only when all other species are either more heavily browsed or are not there at all.

The palatability of native trees was ranked for the woodland grazing toolbox. Note that hawthorn is relatively low on the list here but the toolbox acknowledges that this may be too low, given the high level of browsing on this species.
Determining palatability is not straightforward since palatability is not simply defined by the taste of something. Instead, it is the interrelationship between the senses (primarily taste) and feedback from post-ingestion processes.
This post-ingestive feedback effectively calibrates the hedonistic sensations, controlling whether something is eaten and in what amounts.
For example, the tannin content in browse can help reduce the burden of internal parasites and the palatability of tannin-rich feeds increases for sheep with a high parasite burden.

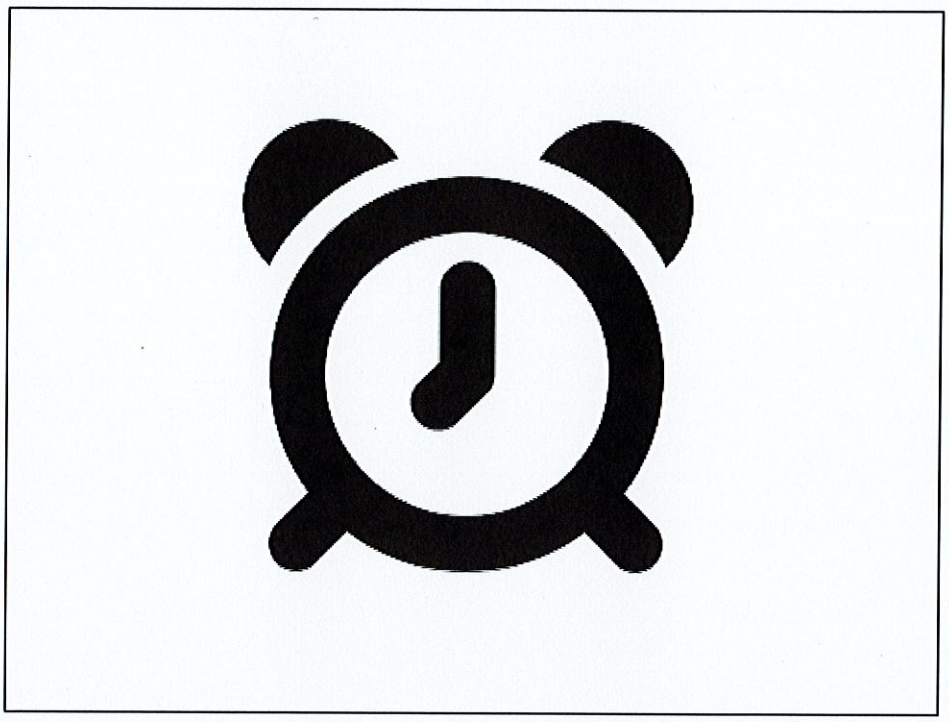
In terms of browse as food, things that can affect intake include novelty, palatability and its relation with other feedstuffs.
The strongest influence on feed preferences is the dam.
First as an unborn foetus and then through the taste in milk. For example, lambs will voluntarily ingest onions and garlic after their mothers were fed them while pregnant.

Second, by young watching what mother does,

And third, by doing what mother does.

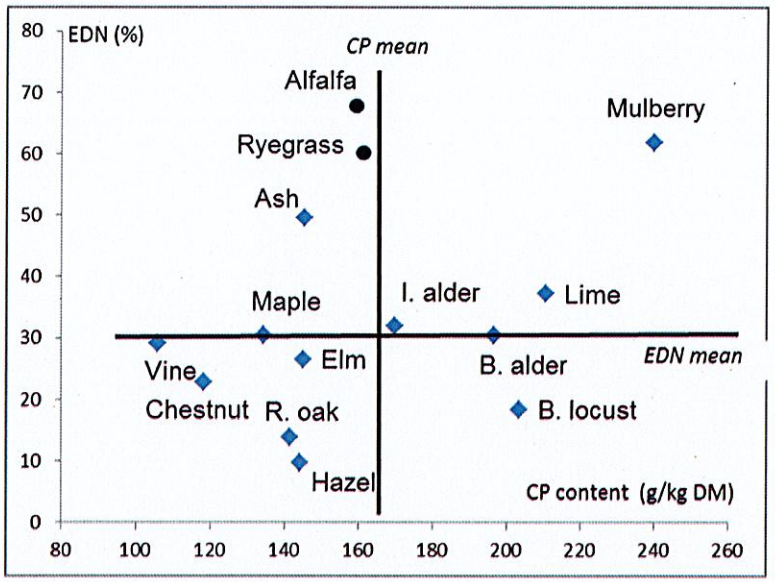
http://chickenbreedslist.com/Vegetarian-Chickens-or-Well-Rounded-Diets.html

The second strongest influence is peer behaviour and for animals faced with novelty, it makes sense to do what other animals are doing since this can reduce the risks associated with adopting novel behaviours, creating shortcuts in learning.



The third influence is increasing familiarity overcoming any cautiousness associated with novelty.
In trials with willows: cattle intake increased from 1.5 kg to 3.5 kg after 81 days with access. The diameter of wood voluntarily ingested also increased from 4 mm to 8 mm.
Lambs also increased their intake from 3 mm to 4.2 mm diameter after a 10-week period.

Figure 2. Relationship between effective degradability of nitrogen (EDN, %) and nitrogen concentration (CP, g/kg DM) in leaves of woody species during summer. (Emile et al., 2016)



This graph compares the crude protein and degradable protein in the leaves of different tree species along with alfalfa and ryegrass. Several species, particularly mulberry, compare very favourably.

In terms of general nutritional content, willow and poplar also compare favourably with grasses grown in the same environment.

Leaves with lower nutritional content can still be an important component of an animal's diet since they can offer high levels of micronutrients and those lower in bitter tannins can act as buffers so that more of everything is eaten.

Additionally, the trees that are lower in nutritional value can offer bulk for animals managed on restricted feed. Sows are usually fed on restricted rations to prevent obesity when pregnant. This means that they are hungry for much of the time and leading to frustration and to abnormal behaviours such as bar biting, sham chewing, stone chewing and cannibalism. Offering a bulky, low quality feed that fills the gut is one way to help them cope and this approach is already being used in Brazil to improve sow welfare.

Trace elements are higher in dried fodder compared to fresh

Sample Reference		A GLUTINOSA 240815	S VIMINALIS 240815	F EXCELSIOR FRESH 21	S CAPREA FRESH210616	U MINOR FRESH 210616	F EXCELSIOR AD 2403	S CAPREA AD 240317	U MINOPR AD 240317
Determinand	Unit	FORAGE	FORAGE	FORAGE	FORAGE	FORAGE	FORAGE	FORAGE	FORAGE
Total Nitrogen DUMAS	% w/w	3.16	2.23	1.78	2.66	2.23	2.21	2.16	2.31
Total Phosphorus	mg/kg	2240	2971	3144	4243	2292	3661	5501	2362
Total Potassium	mg/kg	9051	10364	14065	13942	14722	20015	18977	20884
Total Calcium	mg/kg	13365	18769	12776	10204	10998	15987	14522	16758
Total Magnesium	mg/kg	2481	1764	2235	1930	1889	2881	2682	2798
Total Sulphur	mg/kg	1890	4124	1840	2056	1313	2348	2571	1655
Total Manganese	mg/kg	129	284	25.5	35.5	37.2	31.6	46.3	37.9
Total Copper	mg/kg	11.2	5.5	7.4	7.6	6.5	9.6	10.9	9.3
Total Zinc	mg/kg	53.2	245	18.5	118	31.7	22.9	144	40.1
Total Iron	mg/kg	91.6	73.1	91.2	75.7	138	116	142	258
Total Boron	mg/kg	28.9	36.7	15.7	12.7	19.3	17.5	18.2	26.0

Browse is a very good source of micronutrients, paticularly minerals.
The higher levels of micronutrients is partly explained by the deep roots of trees and shrubs retrieving nutrients that are found (or have leached) below the level available to grasses. The micronutrients can then be made available to pasture plants in the form of leaf litter or ingested by animals browsing.
Furthermore, mineral content is higher in dried tree fodder compared to fresh.

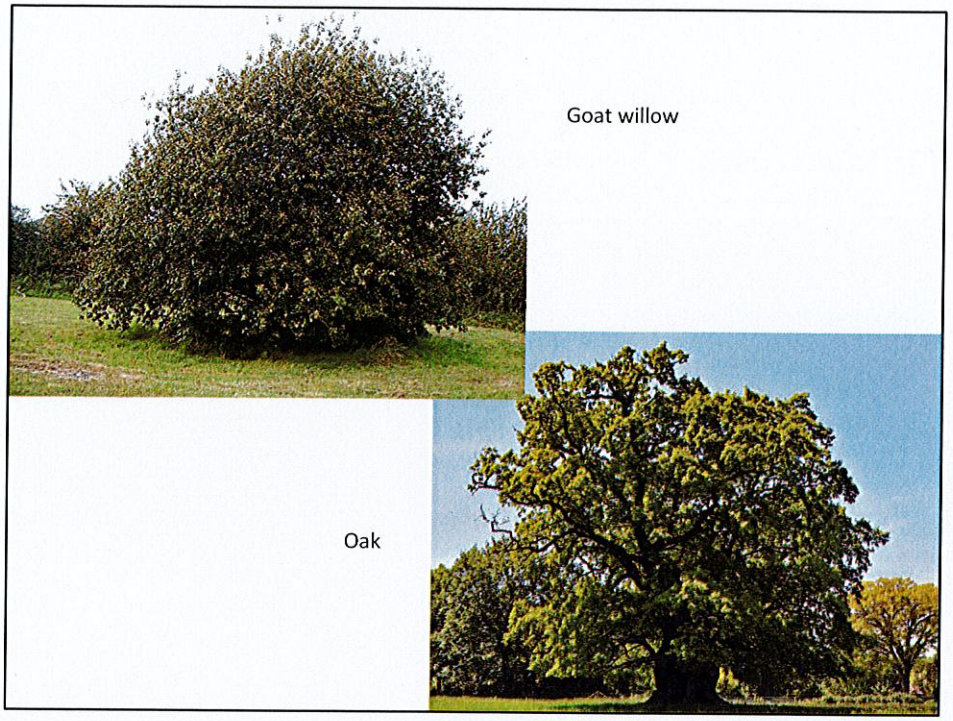
"Why do all plants which an animal likes, have the wrong sort of swallow or too many spikes".

Milne (1928) p.513

Plants, just like animals have defence mechanisms against predation.

These can be physical, like thorns. Thorns offer less defence early in the season when they are still young and soft.

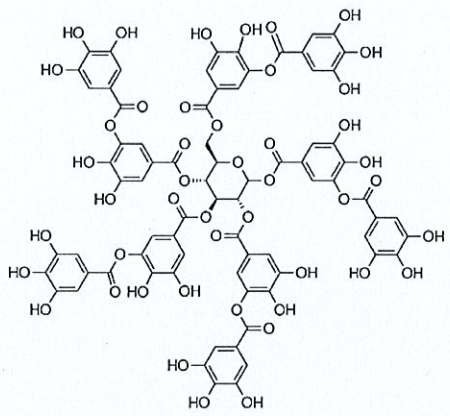
Once hardened, thorny trees can cause injuries. Here, the cow has an infected puncture wound from browsing in a hedge containing blackthorn.



Defence mechanisms can also be chemical and these chemicals are among those collectively termed as plant secondary metabolites (PSMs) and includes tannins. How much energy plants put into chemical defence is partly determined by their successional stage. Early successional trees (such as birch and willow) put more energy into growing quickly, whereas the longer-living, late successional trees produce more PSMs.

Across species, early season growth is lower in chemical defences than later in the season. Shade and poor soil also affect their level since growth trumps defence when there aren't enough nutrients available to do both.

Tannins and other plant secondary metabolites (PSMs)



Condensed tannins are bitter tasting and, once ingested, bind to proteins which inhibits digestion in the rumen. As they reach the more acidic abomasum, the proteins are released, offering the animal a source of higher quality rumen bypass protein, increasing the amino acid supply.
Increasing protein quality can have beneficial effects on body condition, production and fertility, as well as enabling animals to better defend themselves against internal parasite burdens.

Shrubs and trees with edible leaves and shoots, in combination with pasture plants, produce more forage per unit area of land than pasture plants alone.
When animals are offered a varied diet, they tend to eat more of everything, including less palatable feedstuffs. So if browse with high tannin levels is offered, then more of this will be eaten if e.g., grass is offered alongside.

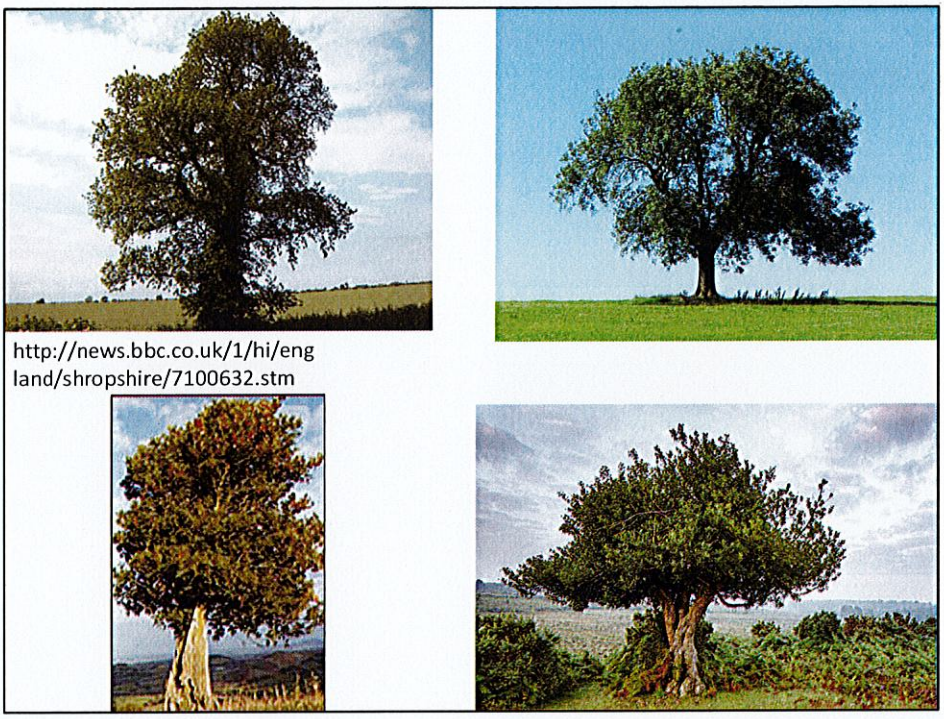
How animals have access to browse determines intake. Browsing directly from trees allows animals to eat what they want and went they want, although they are limited to what they can reach and seasonal availability.

This is an ancient oak woodland in Denmark that was used for coppice. Here, horses grazed and browsed on the oaks until the 19th century.

Trees in this mixed-species silvopastoral system, are felled and fed fresh on the pasture. Once the leaves and twigs have been browsed off, the wood is cut and stored for firewood.

Fresh tree fodder can be cut and carried to housed animals. Here, the branches are offered as environmental enrichment.

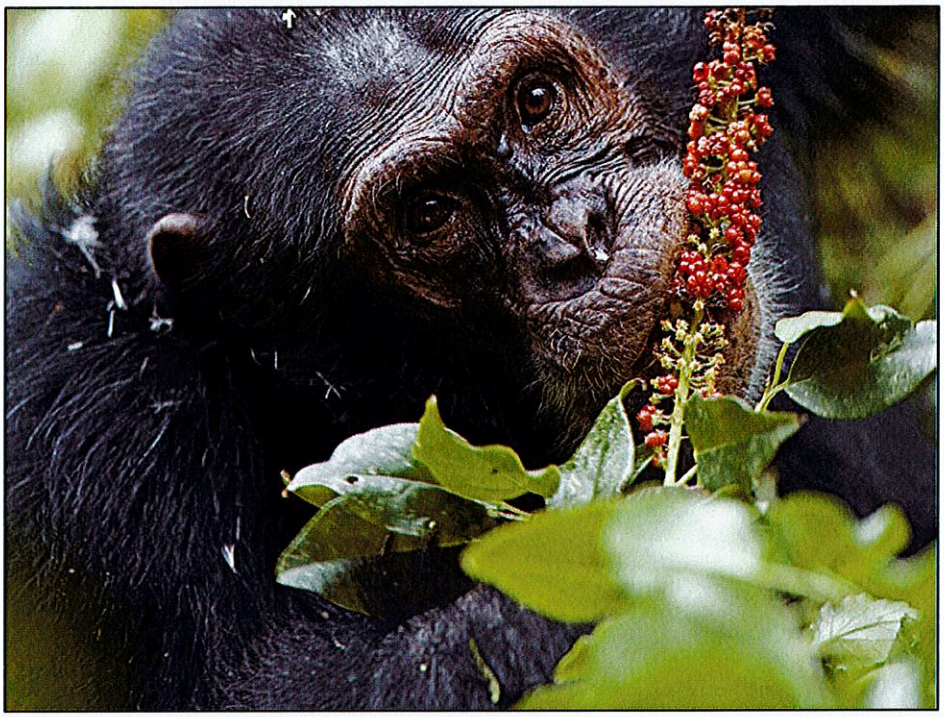
These old, pollarded ash trees in Sweden, were used for tree hay. Branches could be cut, leaving a big enough snag on the tree upon which the cut branch could be hung for drying.
Drying, or wilting, tree fodder reduces tannins thus increasing palatability.



http://news.bbc.co.uk/1/hi/england/shropshire/7100632.stm

In UK, the traditional fodder trees were ash and elm and holly for the winter. In Shropshire, on the Stiperstones nature reserve there are 200, 400-year-old pollarded holly trees that the miners used to feed their cattle in wintertime. The practice ceased in UK once turnip growing became popular.

So, tree fodder can be offered as browse at source, as cut and carried feed, or as dried or ensiled for later use. The species of tree will partly determine which is the best approach e.g., willow is too dry to ensile effectively on its own and is better mixed, fed fresh or dried for hay.



There is some evidence that animals are able to self medicate and that trees can play a role.
The strongest evidence of selection of plants for disease management or pain control comes from primates.
The chimpanzee in the image is ingesting phytolacca, a plant used in human medicine for many varied ailments. The berries are used for rheumatism, skin complaints and soreness linked with lactation.
We also know that primates can manage internal parasites and gastro-intestinal upsets by swallowing rolled-up hairy leaves, causing vomiting.

https://meridianjacobs.wordpress.com/tag/grazing/

For farms animals, there is increasing evidence that they are fully able to make associations between food and treatment for disease.
Broiler chickens grow rapidly and can suffer from leg problems as a result. When offered normal feed or their normal feed with added pain medicine, lame broilers consistently select the treated feed whilst the sound birds did not.
Salicylic acid in, e.g., willow, is the origin of the human pain killer aspirin. When offered a choice, sheep choose willow and poplar with high salicylic acid content, possibly due to the beneficial anti-inflammatory effects.

In a neat study, sheep were over-fed on either grains, tannins or oxalic acid, inducing illness. These animals were then offered access to three medicines (sodium bentonite, polyethylene glycol and di-calcium phosphate), only one of which would aid recovery. The sheep quickly learned to select the appropriate medicine to restore health.

Learning is a very important part in keeping the body in a state of balance so allowing animals to make connections is vital if they are to keep themselves healthy.

Animals are certainly capable of determining whether their diet is deficient in some way when there are defining features that reveal its presence in a food source such as a particular smell or taste.
Lambs deficient in phosphorus and calcium increase their preference for supplements that provide those minerals.
Where supplements are not offered, animals can find their own way to address the imbalance. These images show herbivores also deficient in phosphorus and calcium finding novel sources to redress the imbalance. The ingesting of 'abnormal' feedstuffs is known as pica.

The animal's ability to self-regulate its internal state is already being utilised (albeit on a small scale) in some animal management regimes. For these dairy cows in USA, bicarbonate of soda is offered ad-lib. Bicarbonate of soda acts as a pH buffer for the gut and intake is noticeably higher during the transition from fresh pasture to the more acidic, ensiled winter feed.

In this image, the goats have stripped every last bit of greenery and bark available to them, preferentially selecting browse over grazed plants.
Goats are well adapted to eating tannin-rich browse. Relative to body weight, they have larger livers than cattle or sheep so they can more effectively process the tannins. They are also equipped with salivary glands that produce a specific saliva, which binds the tannins.
Crucially, goats are resilient but not very resistant to parasites. Where sheep have developed a parasite-specific immunoglobulin (IgA) that can react to parasite burdens, goats have developed feeding habits that physically remove them from the risk zone which is up to approximately 15 cm (6") from soil level.
The elevated height of browse can be used as part of a parasite management programme for other species at risk of heavy parasite burdens, along with the tannins contained in browse species.
Studies of sheep and goats feeding on tannin-rich browse show up to 50 % reductions in faecal egg counts and a reduction in successfully hatching nematode eggs.
Importantly, if parasitised herbivores learn to self-medicate, given a variety of plants with a variety of plant secondary metabolites (PSMs), producers need not resort to giving fixed doses of chemicals to all animals in the herd, likely with different parasite burdens.

In conclusion, the more diverse the environment, the more likely animals can learn to look after themselves and to maintain their internal balance. In doing so, they can also express diverse behavioural repertoires at appropriate times, enabling them to lead more enriched lives that closer reflect the term 'positive welfare'.
Trees can play an important role in this process.

The end