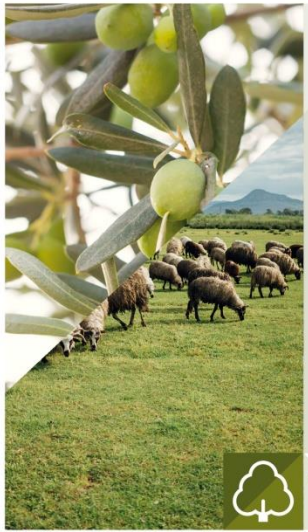


Module 2 for LL2, Agroforestry for Grazed Woodlands
Course 3 – Advantages of agroforestry for grazed woodlands

Chapter 2 - Animal Welfare in Grazed/Browsed Woodlands

By Samer Murr, Engineer
Lebanese Agriculture Research Institute

Animal welfare in grazed/browsed woodlands

Lesson 1: Livestock integration within agroforestry systems

A. Indoor livestock management : Pros & Cons

B. Livestock and the advancement of sustainability

C. Agroforestry definition

D. Different types of agroforestry with livestock

Course co-funded by the EU under the ENI CBC Med Programme and developed in the framework of LIVINGAGRO project activity 3.1.8

A. Indoor livestock management : Pros & Cons

Indoor housing advantages

- Reduces labor inputs
- Allows higher milk yield without increasing farm size
- Facilitates the provision of high-energy diets
- Improves protection against endoparasites & inclement weather
- Allows intensification in production to respond the growing global consumer demand

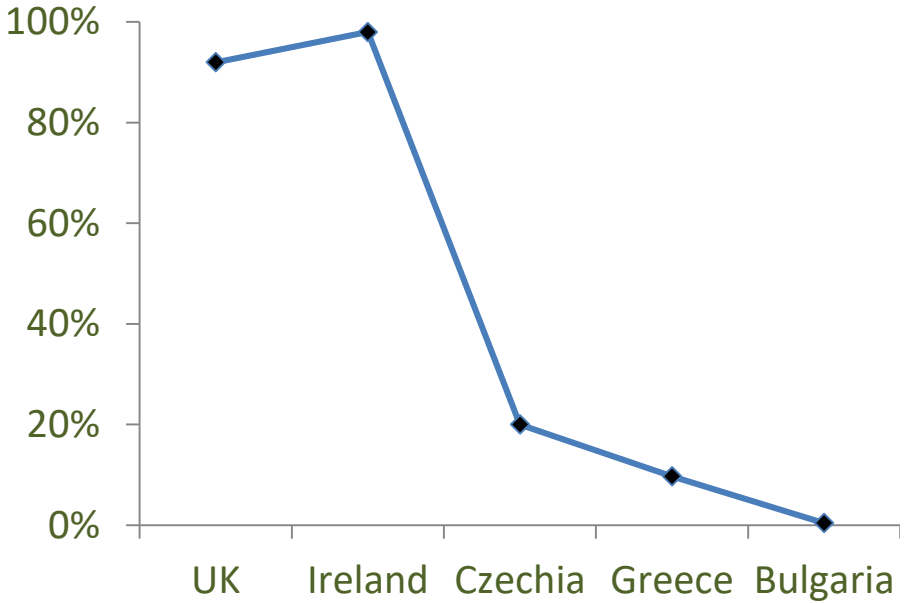
A. Indoor livestock management : Pros & Cons

Indoor housing disadvantages

Fewer dairy cattle with pasture access:

- Europe: Substantial variation in management
- North America : only 34% of dry cows, 20% of lactating cows on pasture (Crump et al, 2019)

Image 1: Percentage of pasture based systems* of dairy cattle across Europe. Data adapted from *Crump et al, 2019*



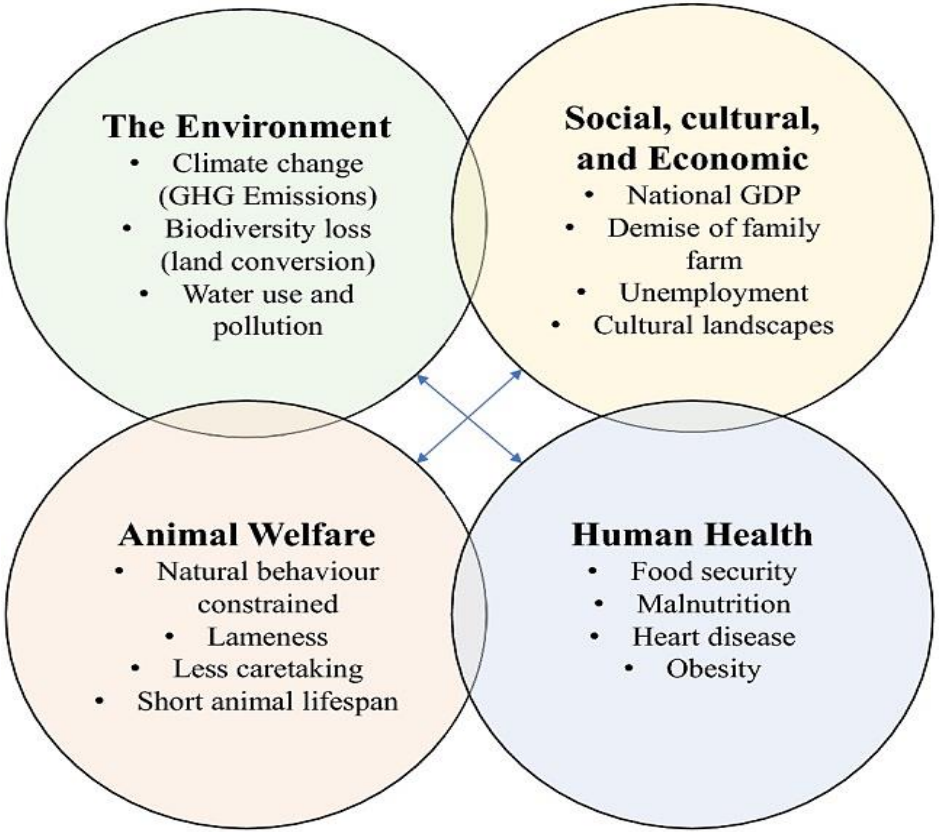
* usually includes indoor housing in winter and around calving

Lesson 1 **A. Indoor livestock management : Pros & Cons**

Indoor housing disadvantages

The strong connection between livestock and anthropogenic climate change can be no more denied and alternatives no more postponed

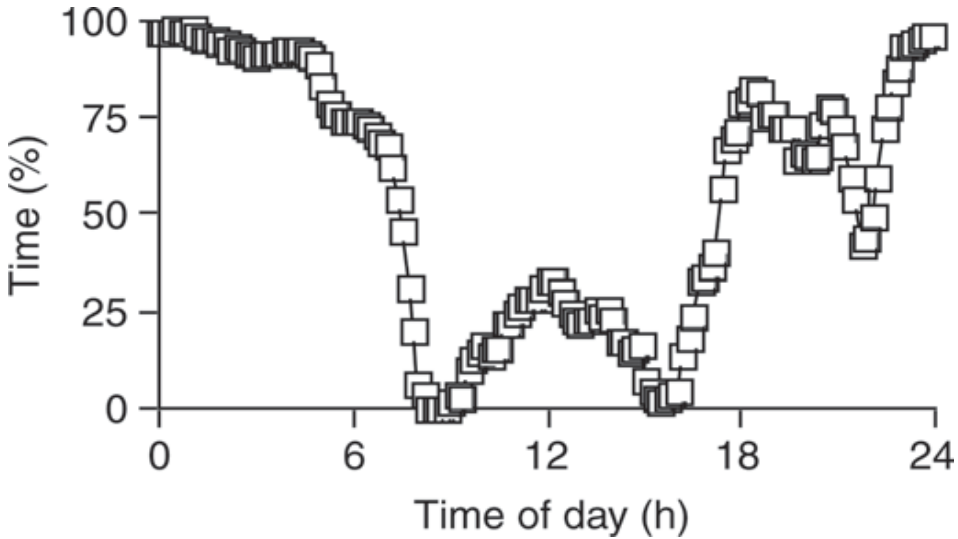
Image 2: Impacts of dairy intensification (Clay et al, 2020)



B. Livestock and the advancement of sustainability

What system would livestock choose based on natural behavior ?

Image 3: Percentage of time cows spent on pasture when allowed free access between a free-stall barn and adjacent pasture. Redrawn from Legrand , 2009.



=> Major overnight time spent on pasture

⇒ Day-time preference for barn conditions, probably due to shade availability

Is there a system that is both viable and sustainable?

B. Livestock and the advancement of sustainability

Eco-intensification of livestock-based systems

Ecological intensification systems could be defined as :

- using natural processes to replace human-produced inputs (pesticides, fertilizers) by provisioning of ecosystem services
- maintaining or increasing food production per unit area

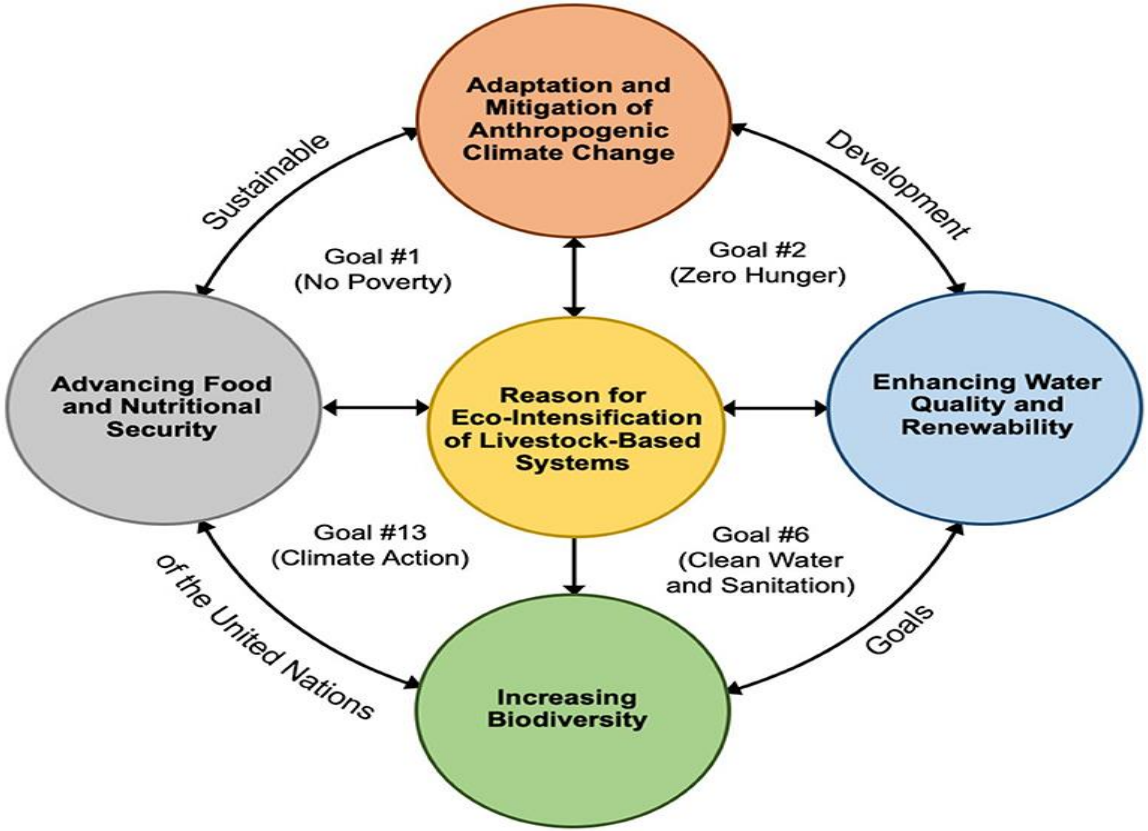
Bommarco et al (2013) Havstad et al (2007), Herrero et al (2009)

Eco-intensification system of livestock-based can be obtained by combining:

- sustainable management of crops and trees by integrating livestock within;
- controlling the positive effects of livestock-based farming systems ;
- reduction of the farming environmental footprint ;
- adoption of ecologically based principles for animal husbandry

B. Livestock and the advancement of sustainability

Image 4: Eco-intensification of livestock-based systems to advance SDGs (Sustainable Development Goals) of the United Nations (Lal, 2021)



- ✓SDG #1: improving income of small landholders as well as that of commercial farmers.
- ✓SDG #2: by judicious production and use of animal-based diet (FAO, 2017)
- ✓SDG #6: reducing the water footprint of livestock (Doreau *et al*., 2012)
- ✓SDG #13: reducing emissions of GHGs from the livestock sector (Gill *et al*., 2010)

C. Agroforestry definition

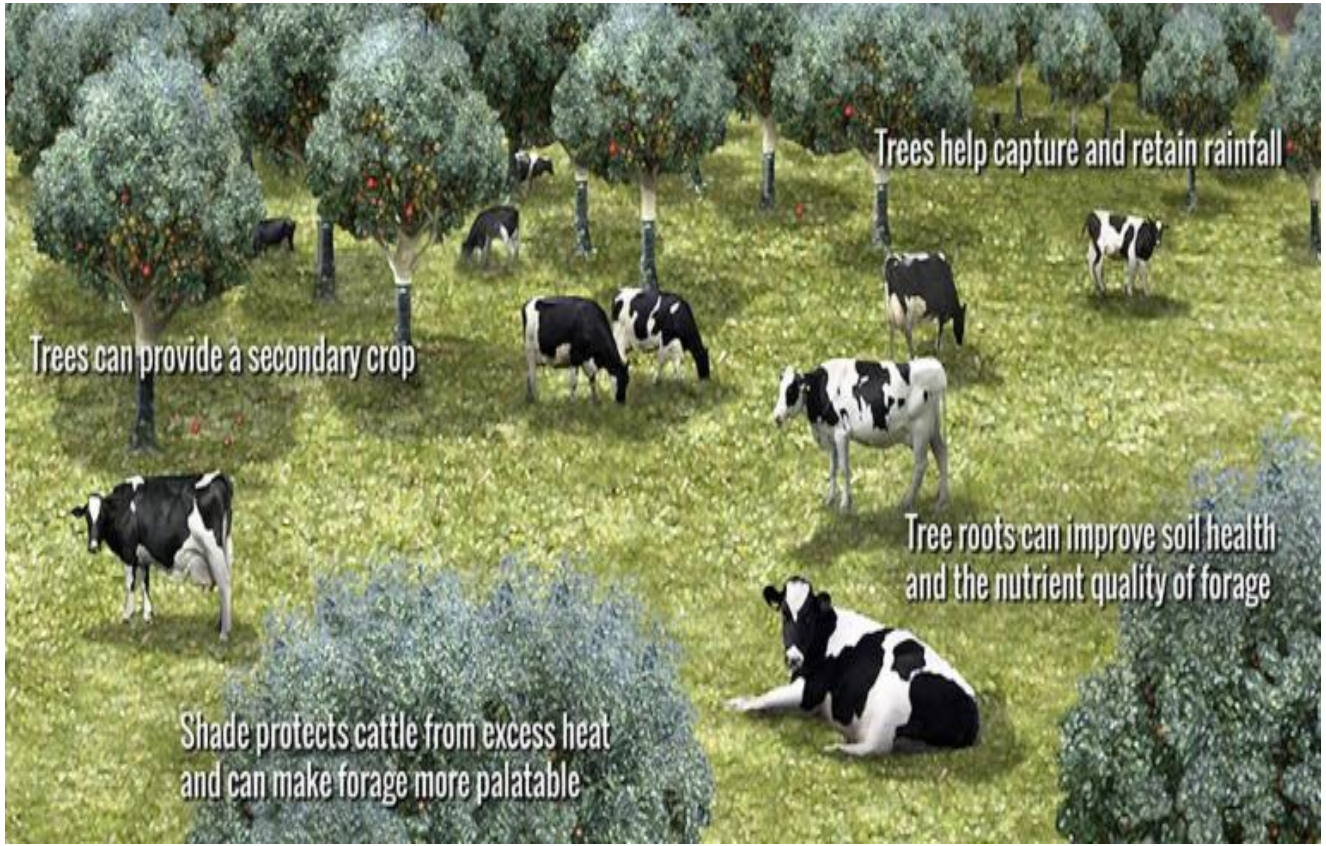
Agroforestry is the name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboo, etc.) are deliberately used on the same land-management units as agricultural crops and/or **animals**, in some form of spatial arrangement or temporal sequence.

In agroforestry systems there are both ecological and economical interactions between the different components (Lundgren and Raintree,1982).

D. Different types of agroforestry with livestock

➢ Silvopastoral systems

Image 5: agroforestry arrangements that purposely combine fodder plants with shrubs and trees for animal nutrition and complementary uses (citation 1)



D. Different types of agroforestry with livestock

➢ Silvopastoral systems (SPS)

SPS are implemented mainly in four types of systems:

1) Scattered trees in pasturelands
2) Timber plantations with livestock grazing areas
3) Pastures between tree alleys, windbreaks, live fences, or fodder banks with shrubs
4) Intensive silvopastoral systems (ISPS) combining high-density cultivation of fodder shrubs (4000–40,000 plants per ha) with improved grasses and tree or palm species at densities of 100–600 trees per ha (Murgueitio *et al.* 2015, Chará *et al.* 2017). These systems are managed under rotational grazing with occupation periods of 12 to 24 hours and 40 to 50-day rest periods, including *ad libitum* provision of clean water and mineralized salt in each paddock (Calle *et al.* 2012, Murgueitio *et al.* 2015).

D. Different types of agroforestry with livestock

➢ Silvopastoral systems

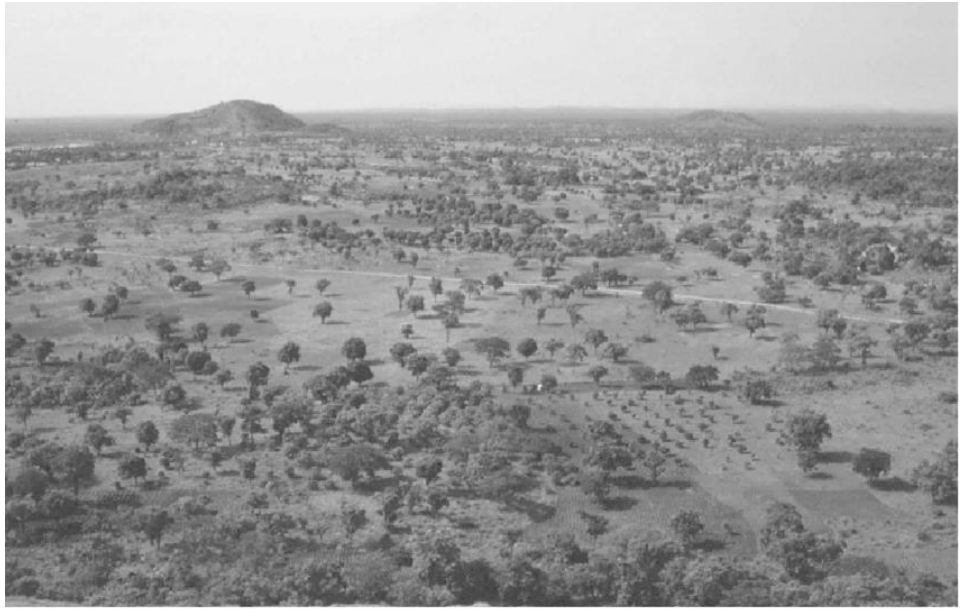


Image 6: Parklike landscape with scattered trees in pastures and crop fields in the northern Côte d'Ivoire, West Africa (Boffa, 1999)

Image 7: Pinus, bahiagrass and crimson clover; trees planted in double-row with pasture alleys between the double rows. Bahiagrass dominates the alleys during the summer and crimson clover does in the winter (citation 2)

D. Different types of agroforestry with livestock

➢ Silvopastoral systems

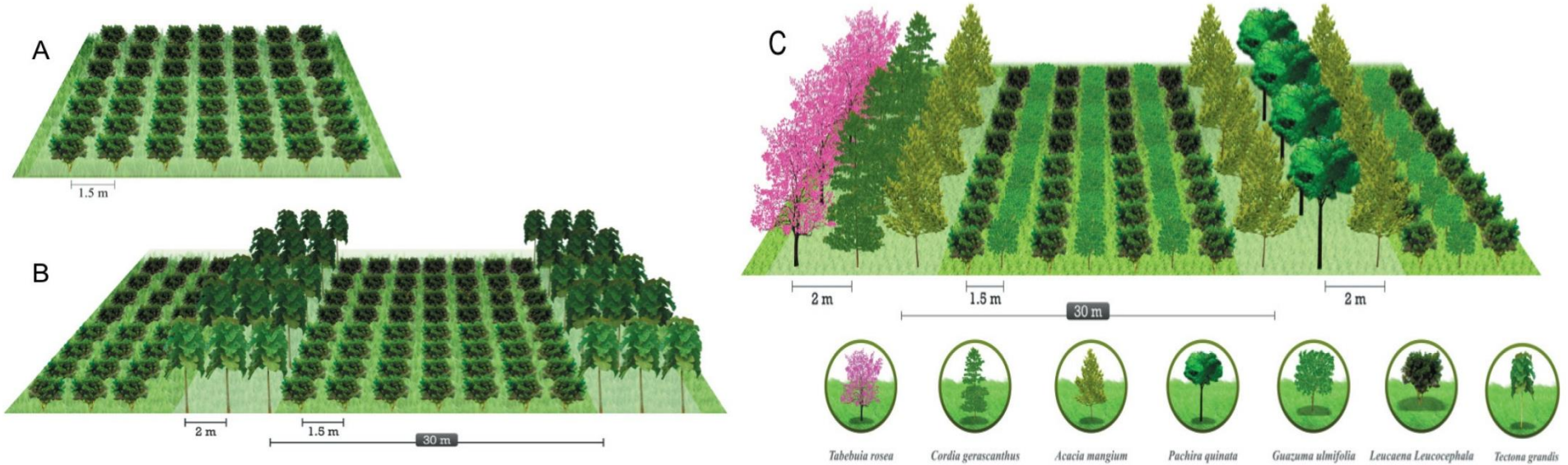
Image 8: Windbreaks in crop fields, Oklahoma state. (citation 3)

Image 9: Living fence of Gliricidia sepium to separate pastures, Dominican Republic. (citation3)

D. Different types of agroforestry with livestock

➢ Silvopastoral systems

Image 10: Illustration of the evaluated plant arrangements of three intensive silvopastoral systems (ISPS) (Morales et al., 2017)



A: ISPS1 - low plant diversity (*Leucaena leucocephala* for browsing and *Cynodon plectostachyus* and *Megathyrsus maximus* for grazing); B: ISPS2 - middle plant diversity (*Leucaena leucocephala* for browsing, *Cynodon plectostachyus* for grazing associated with *Azadirachta indica*, *Albizia guachapele*, and *Tectona grandis* as timber); and C: ISPS3 - high plant diversity (*Leucaena leucocephala* and *Guazuma ulmifolia* for browsing, *Cynodon plectostachyus* and *Megathyrsus maximus* for grazing and *Tabebuia rosea*, *Pachira quinata*, *Cordia gerascanthus*, and *Acacia mangium* as timber).

D. Different types of agroforestry with livestock

➢ Silvopastoral systems

Image 11: ISPS with *Leucaena leucocephala* (density of 10,000 ha-1) and *Eucalyptus tereticornis* as windbreaks, Colombia. The plot in the lower right was grazed the day before (citation 4)

Image 12: ISPS with *Tithonia diversifolia* and *Cynodon plectostachyus* and Braford (Brahman x Hereford) cattle, Argentina (citation 5)

D. Different types of agroforestry with livestock

➢ Silvopastoral systems (SPS) - Geographical distribution

SPS are found worldwide, in two circumstances.

1) Intentionally created, implemented by farmers in Europe, North America, Australia and Latin America

- Integrated systems: production of wood, fruit or nuts in alley cropping systems (as windbreaks): two-layer SPS
- Direct browsing or browsing after pruning or coppicing trees, which provides extra nutrients to livestock: two-layer SPS
- Grazing and feeding from grasses integrated with high density shrubs like Leucaena in a two-layer SPS system, as in Australia (Shelton and Dalzell 2007)
- Intensive three-layer SPS combining grasses with high density shrubs for a natural regeneration of native trees and introduction of timber trees, as in Latin America.

D. Different types of agroforestry with livestock

➢ Silvopastoral systems (SPS) - Geographical distribution

2) Adaptation and management of natural ecosystems to provide shelter and services, by using livestock grazing pressure assessment to keep a balance between silvopastural biomass production and convenient stocking rate (number of livestock units “LU” per unit area of defined biomass stocking rate): ie. 0.10–0.15 LU/ha at 1950, 0.15 LU/ha at 1982, 0.24–0.4 LU/ha at 2005 (Plieninger 2006; Mila´n et al. 2006), for example:

- La Dehesa and Montado ecosystems on the Iberian Peninsula (Ferraz-de-Oliveira, 2016)
- El Chaco in South America (Kunst *et al.* 2016)
- Several areas in Africa and Asia (Le Houerou, 1987)

D. Different types of agroforestry with livestock

➢ Silvoarable systems

Silvoarable systems contain trees or shrubs that can be distributed in alley cropping, copses, as isolated/scattered trees or in hedges or belts.

Image 13: Silvoarable agroforestry experiment with poplar and barley (citation 6)

Image 14: Combined production of olives and beef – Lebanon. Photo credit : M. El Riachi

D. Different types of agroforestry with livestock

➢ Forest farming

Having trees on farms has huge benefits: more income, a more buffered climate, shelter from wind and rain, and soil protection/fertigation with tree roots and leaf litter.

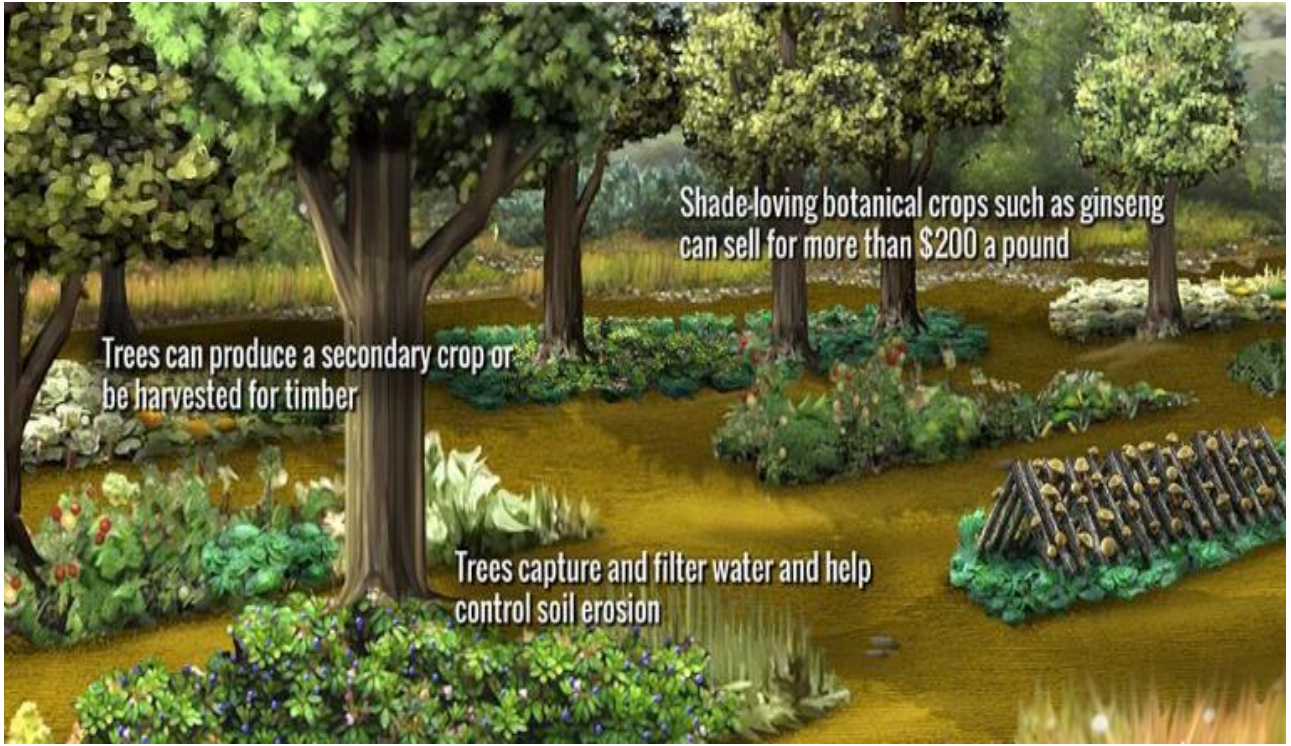


Image 15: Forest farming (citation 1)

Lesson 1 **D. Different types of agroforestry with livestock**

➢ Hedgerows

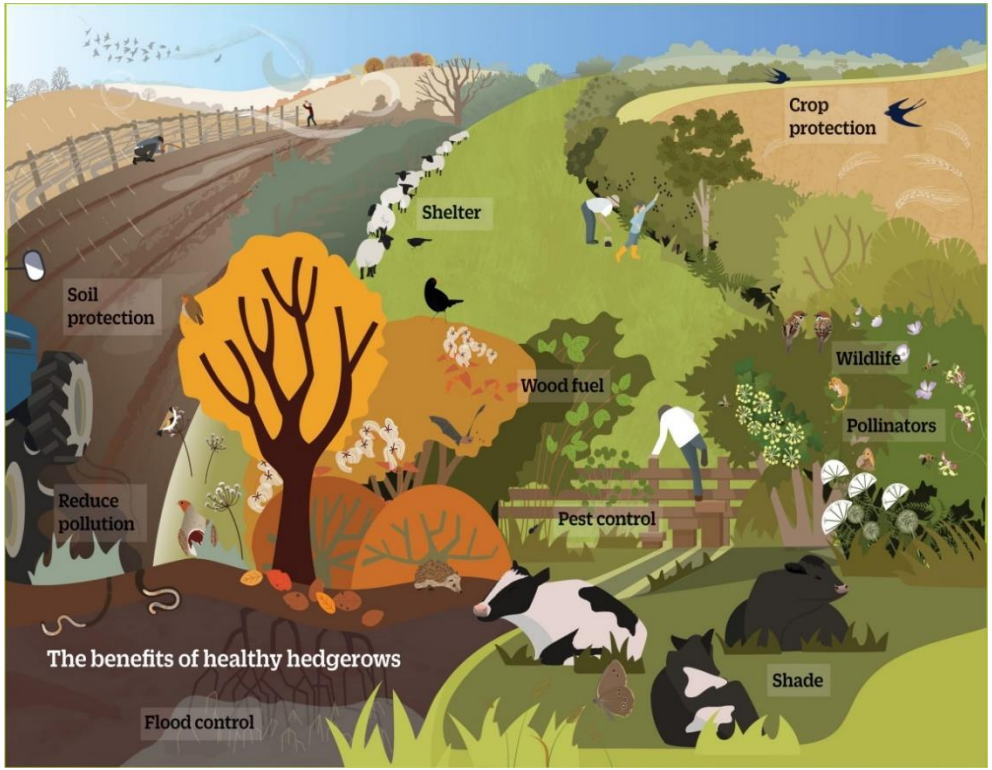


Image 15 : What have hedgerows ever done for us diagram. (citation 7)

Strips of woodland can border habitats, with shapes and sizes ranging from narrow strips of closely trimmed, scraggy hawthorn bushes sparse in wildlife, to thick bushes beneath mature trees.

Image 16: An example of Hedgerows (citation 8)

D. Different types of agroforestry with livestock

➢ Riparian buffer strips

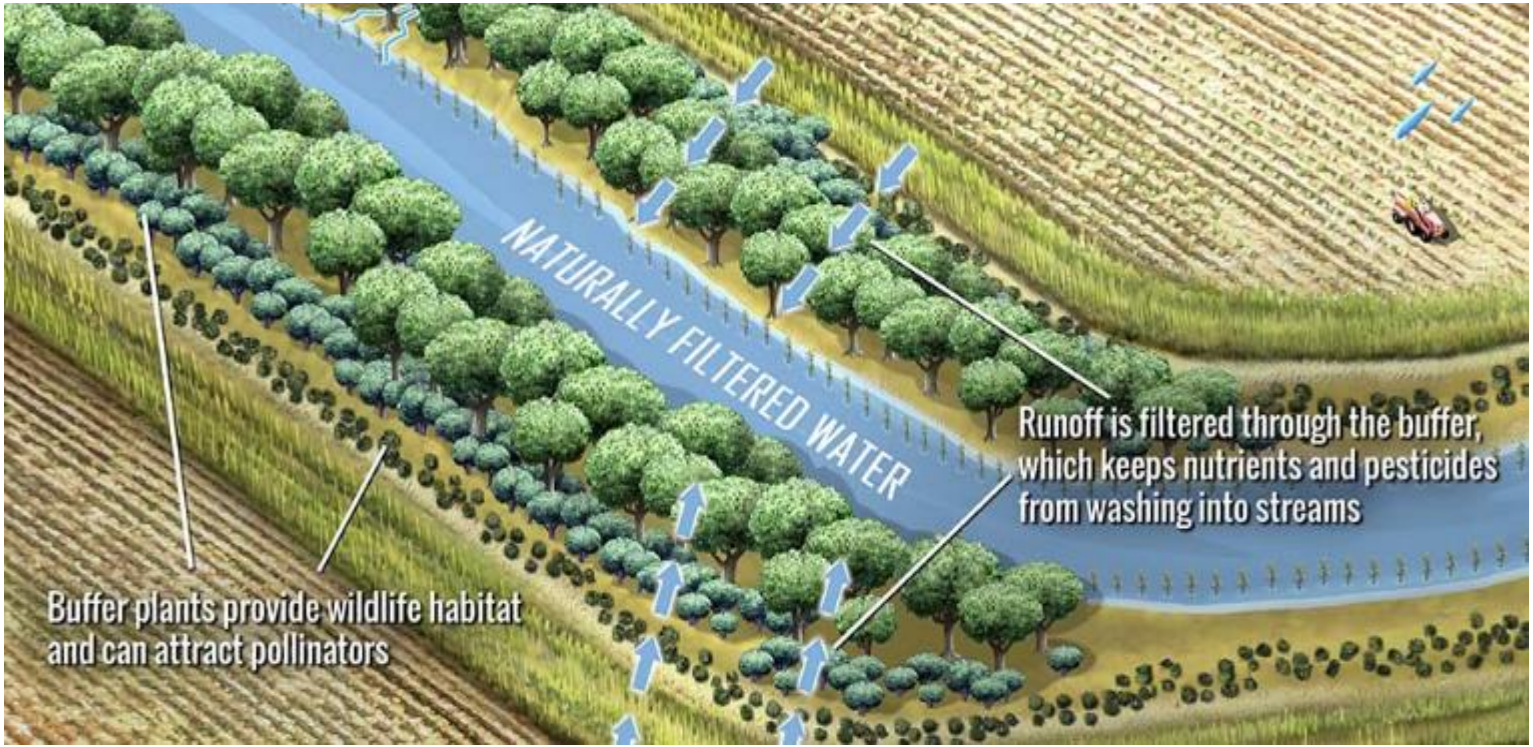


Image 17: Riparian buffer illustration. (citation 1)

D. Different types of agroforestry with livestock

➢ Kitchen gardens

Image 18: Homestead - a source of multiple products (trees, vegetables, cows, chicken) (citation 9)

Home gardens or kitchen gardens combine trees and/or shrubs with vegetable production.

Household gardens supply and supplement subsistence requirements and generate secondary direct or indirect income. They tend to be located close to permanent or semi-permanent dwellings for convenience and security.

Animal welfare in grazed/browsed woodlands

Lesson 2: Livestock welfare in agroforestry systems

A. What is animal welfare?

B. Areas of people concern toward animal welfare

C. Animal welfare based measures

D. Farm animal monitoring and management

A. What is animal welfare?

World Organization for Animal Health definition (2008)

ANIMAL WELFARE
IS RESPECTED WHEN THE ANIMAL IS

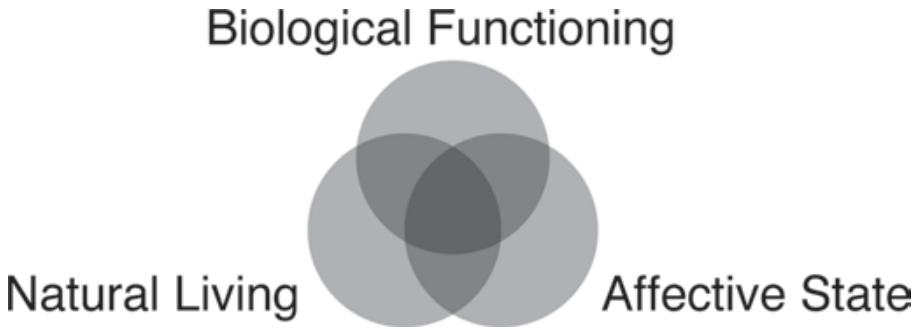
"healthy, comfortable, well nourished, safe, able to express innate behavior, and … not suffering from unpleasant states such as pain, fear, and distress"

State of the individual as regards its attempts to cope with its environment (Broom, 1986)

B. Areas of people concern toward animal welfare

People taking care of animals

Helping with disease, injury, poor growth rates, reproductive problems



Von keyserlingk et al (2009)

Consumers of organic products

Of livestock in pastures, expressing natural behavior

People's emotions

unpleasant feelings: pain, fear, hunger, …
or
positive states: pleasure / play

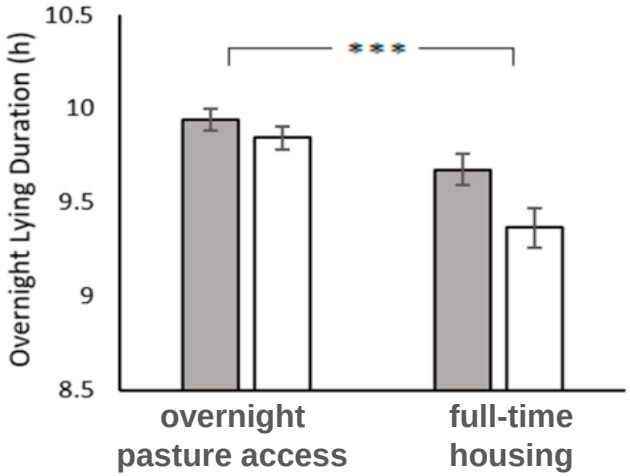
C. Animal welfare based measures

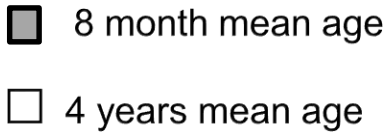
Comfort behavior principles:

Cattle Lying behavior in Pastures vs. indoors

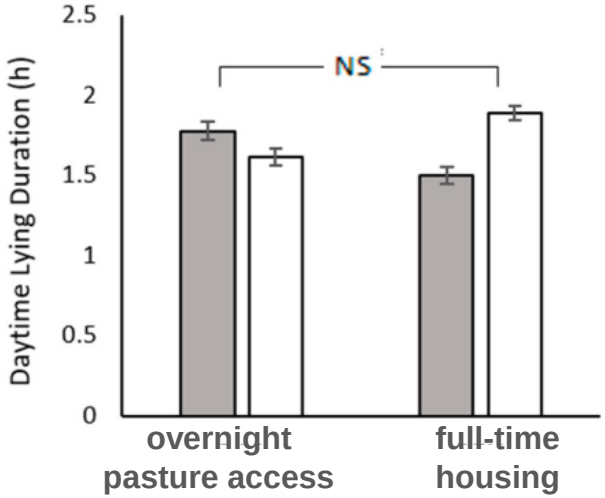
Whatever mean age is , overnight lying duration is longer in pastures.

- **Pastures** offer more comfortable surfaces to lie on than **indoor** cubicles, which include more abrasive surfaces.
- In **pastures**, there is less competition for space, and less restriction of movement.





Wagner et al, 2017



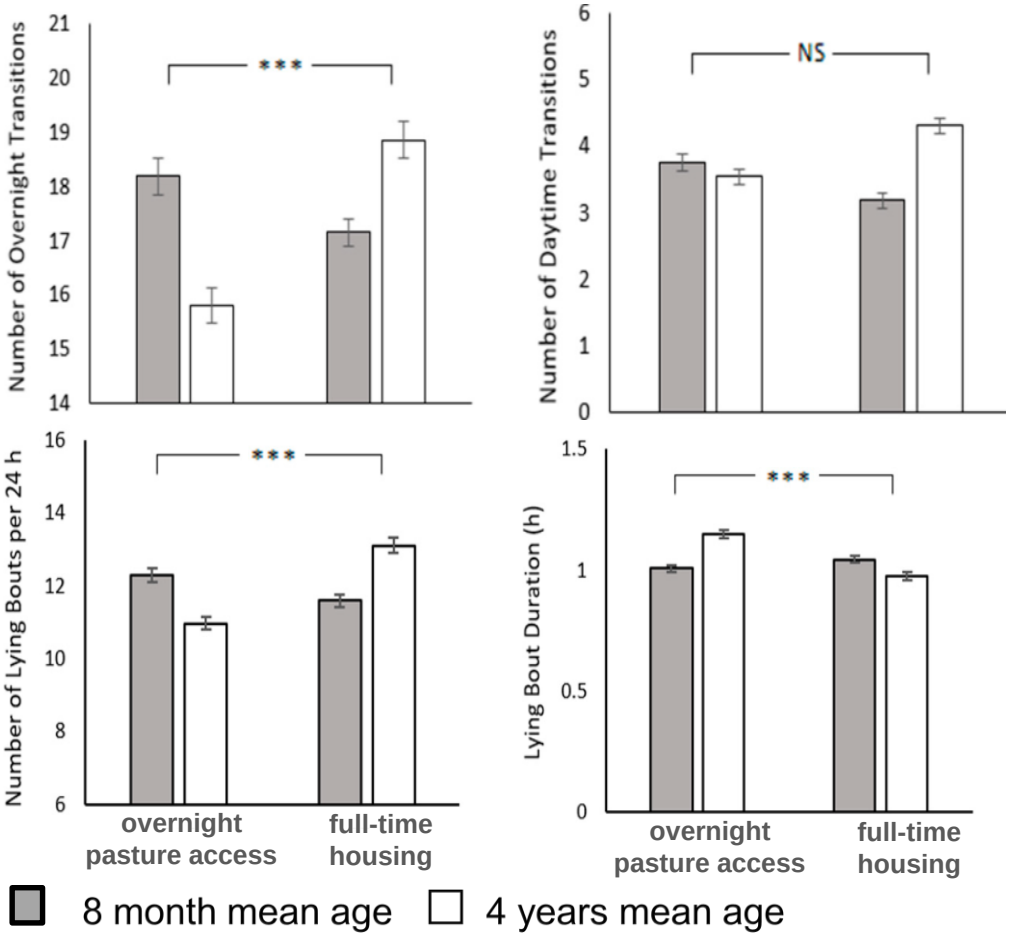
C. Animal welfare based measures

Comfort behavior principles:

Lying behavior: pastures vs. indoors

- In **pastures**, there is less lameness and fewer hock lesions; **indoors**, there is an elevated risk of injuries from slippage on slurry-covered concrete, and greater risk of the mastitis and enteritis associated with disrupted lying behavior (such as the augmented number and decreased duration of lying bouts).

- **Pastures** enable increased rumination and metabolic processes that are jeopardized **indoors.**



Wagner et al, 2017

C. Animal welfare based measures

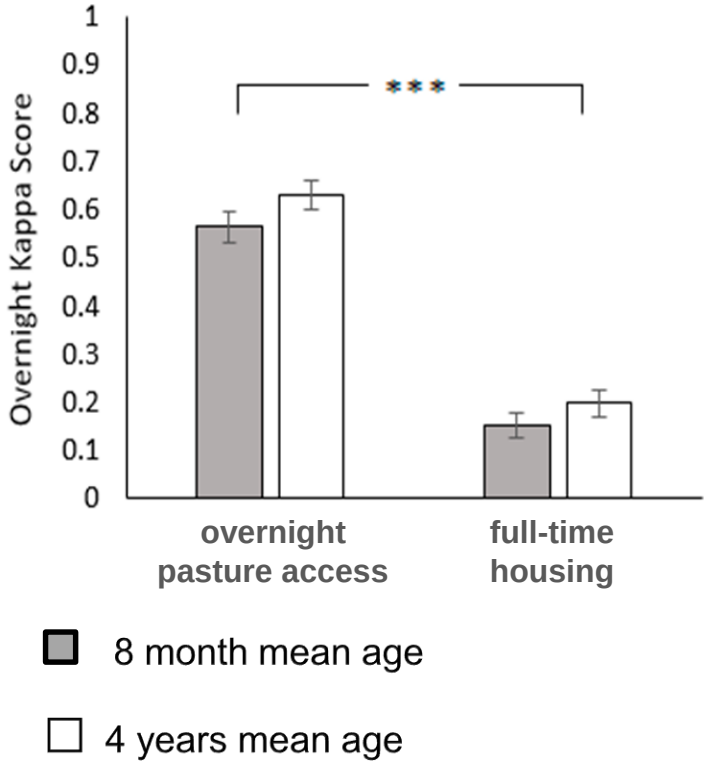
Comfort behavior principles:

Synchrony behavior in pastures vs. indoors

(the same behavior at the same time)

Synchrony behavior of dairy cows and bulls in pasture indicate substantial agreement with kappa score means between 0.61 and 0.8, while indoor values are too slight (less than 0.2).

These findings concur with the fact that in semi-natural pasture environments, cows generally compete less and demonstrate natural behavior patterns (due to the deactivation of the hypothalamic pituitary–adrenal axis).



Wagner et al, 2017

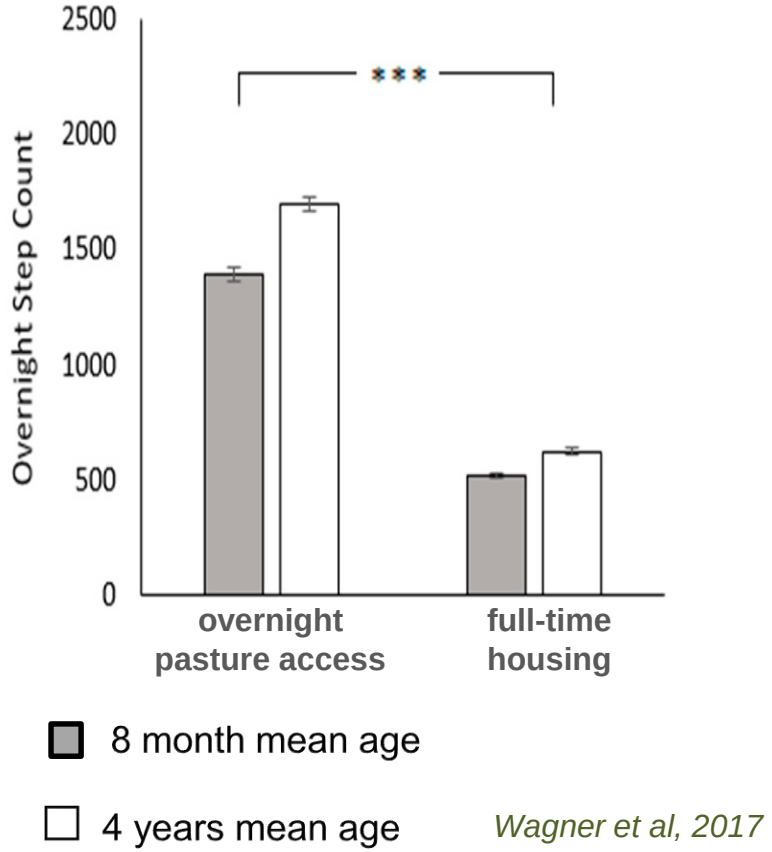
C. Animal welfare based measures

Comfort behavior principles:
Locomotion in pastures vs. indoors

Movement increases overnight during grazing with pasture access, even without external motivation (3 times difference of step counts with indoor).

This results in:

- more activity and welfare
- physical benefits (to legs, feet and hooves)
- reduced metabolic stress (lower heart rate and plasma lactate)



Wagner et al, 2017

C. Animal welfare based measures

Health principles

Good health is central to good welfare

Measures by veterinarians and producers focus on

- Crude indicators: illness or death
- Clinical indicators: disease, injury, and reproductive problems
- More sensitive indicators suitable for use before clinical illness:
  - ✓ assessment of an animal's condition
    (cleanliness, body condition, skin alteration, gait and lameness)
  - ✓ close monitoring of sensitive production phases such as cows' transition period (when they are more prone to disease)
  - ✓ animal productivity parameters

C. Animal welfare based measures

Health principles

Problems in biological functioning are clearly a welfare concern in many cases.

Example: **Poor welfare can lead to**

=> Illness

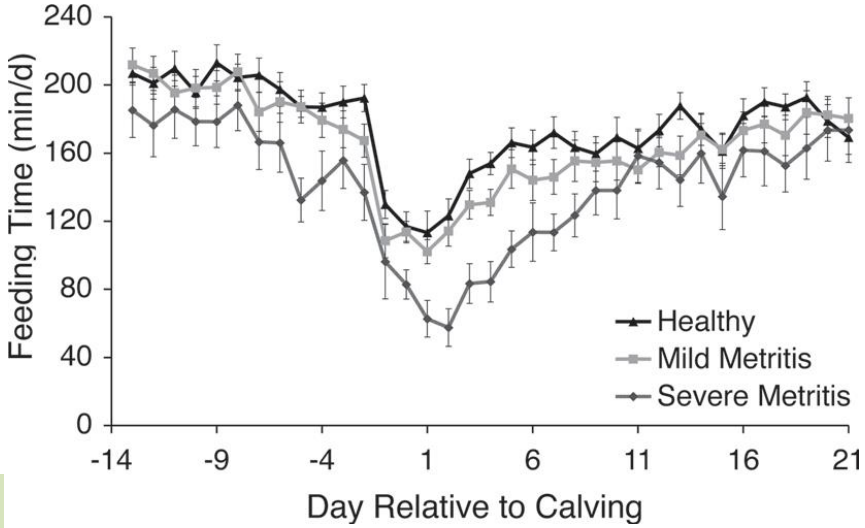
=> Activation of the immune system

=> Need for more metabolic energy

=> Reduced feed intake

=> Reduced milk production, growth, or reproduction

The challenge is to get **improved management procedures** onto livestock farms through a careful **assessment** of animal health to **reduce the risk** of suffering as a result of disease.



Average feeding time (min/d) of healthy, mildly metritic, and severely metritic Holstein dairy cows from 13 d before until 21 d after calving.

Von keyserlingk et al (2009)

C. Animal welfare based measures

Health principles

The welfare of animals in feedlots is often worse than that of animals on pasture.

However, the welfare of animals kept on pasture-only systems can also be poor due to heat stress, parasitic and other infectious disease, and low nutrient availability with associated competition.

C. Animal welfare based measures

Silvopastoral systems

In three-layer SilvoPastoral Systems (SPS), animal welfare is improved in several ways, when compared to pasture or indoor management systems:

- ✓ Nutritional improvement: shrub and tree intake
- ✓ Thermal comfort: availability of more shade
- ✓ Better social behavior: less fear caused by concealment; better human-animal interactions
- ✓ Better health: more predators reduce the number of ticks and flies;
  reduced risk of cancer;
  lower risk of excessive sunlight and related diseases
- ✓ Better body condition: due to increased availability of nutrients and shade, less disease, and improved food choice, food intake, and social behavior.

C. Animal welfare based measures

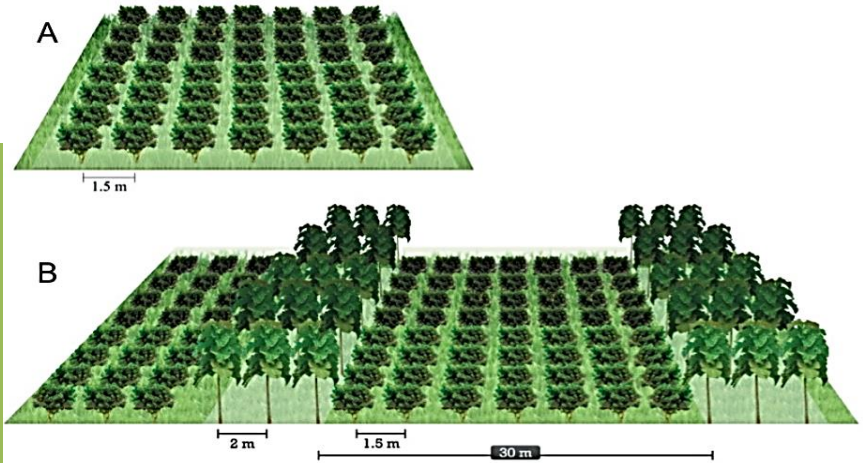
Silvopastoral systems

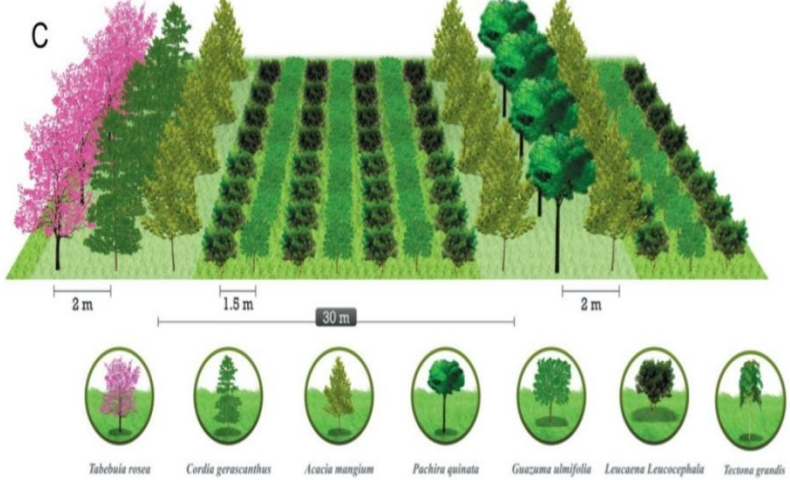
"Evaluation of Animal Welfare refers to biological measures of the animal as an individual at a given time on a scale ranging from very poor to very good and can be measured quantitatively using many criteria."

Broom, 2011

We'll show in the next slides Calculations adapted for animal welfare qualifications, used by Morales et al (2017), for different intensity levels of plant diversity in silvopastoral models

Silvo-pastoral models ambiantal, botanical and zoo-technical parameters





	Forest ecosystem	Altitude	Av. rainfall	Relative humidity	Av. temperature	Livestock	Animal load	Av. age	Av. weight	Area surface
ISPS1	sub humid tropical	960 m	1050 mm/year	75%	24 °C	Lucerna cattle	20	11- 14 month	289 kg	1200 m^2
ISPS2	tropical dry	605 m	1350 mm/year	71%	26 ºC	zebu	20	24 month	357 kg	600 m^2
ISPS3	tropical dry	134 m	1,000 mm/year	83.5%	27.1 °C	crossbred zebu males	16	10-12 month	252 kg	600 m^2

A: ISPS1 - low plant diversity (*Leucaena leucocephala* for browsing and *Cynodon plectostachyus* and *Megathyrsus maximus* for grazing); B: ISPS2 - middle plant diversity (*Leucaena leucocephala* for browsing, *Cynodon plectostachyus* for grazing associated with *Azadirachta indica*, *Albizia guachapele*, and *Tectona grandis* as timber); and C: ISPS3 - high plant diversity (*Leucaena leucocephala* and *Guazuma ulmifolia* for browsing, *Cynodon plectostachyus* and *Megathyrsus maximus* for grazing and *Tabebuia rosea*, *Pachira quinata*, *Cordia gerascanthus*, and *Acacia mangium* as timber).

Morales et al., 2017

C. Animal welfare based measures

Silvopastoral systems

Intensive silvopastoral systems

- ✓ beneficial to cattle welfare
- ✓ good for livestock farmers
- ✓ useful for sustainable livestock production

Principle	ISPS1	ISPS2	ISPS3
Food and water	99	100	97
Comfort	100	100	100
Health	40	36	25
Behaviour	88	89	82
Animal welfare status	Excellent	Excellent	Excellent

ISPS1 - low plant diversity
ISPS2 - middle plant diversity
ISPS3 - high plant diversity

Morales et al., 2017

Health score was low because the animals from all the intensive silvopastoral systems (ISPSs) faced problems with induced pain that resulted from castration, dehorning, and hot branding practices that were carried out without using anesthesia or analgesia. On the other hand, the other indicators of animal welfare in the ISPSs were very encouraging.

C. Animal welfare based measures

Silvopastoral systems

Calculations used for the integration of the qualifications within each welfare indicator of cattle in silvopastoral systems

Criterion	Sub-criterion	Measurement	Calculation
Food and water	Free of prolonged hunger	Body condition score (BS)	I = 100 − number of animals with BS <5
	Free of prolonged thirst	Water provision	Decision tree (Welfare Quality® 2009)
Comfort	Comfort for resting	Body dirtiness	I = 100 − % dirty animals
	Thermal comfort	Thermal stress (TS)	I = 100 − % animals with TS
	Ease of movement	Space	I = ((100 × De − 2)/7), in which De = density of animals
Health	Injuries	Lameness (L)	I = 100 − % animals with L
		Integument alterations (IA)	s = (100 − ((%M) + 5 (%S))/5), in which M = mild and S = severe
	Diseases	Cough (C)	I = 100(1− ((A) + 3 (Al))/3), in which A = alert, Al = alarm, in which: C (A = 4% Al = 8%), ND (A = 5% Al = 10%), OD (A = 3% Al = 6%), BD (A = 5% Al = 10%), D (A = 3% Al = 6%)
		Nasal discharge (ND)	
		Ocular discharge (OD)	
		Breathing difficult (BD)	
		Diarrhoea (D)	
	Induced pain	Surgical procedures (SP)	Decision tree (Welfare Quality® 2009)
		Castration (CT)	Decision tree (Welfare Quality® 2009)
		Dehorning (DH)	Decision tree (Welfare Quality® 2009)
		Hot branding (M)	Decision tree (Welfare Quality® 2009)
Behaviour	Expression of social behaviours	Cohesive and agonistic behaviours	$I = 100\left(\frac{y_1}{y_1 + y_2}\right)$, in which y_1 = frequency of agonistic behaviour; y_2 = frequency of cohesive behaviour

(Morales et al., 2017)

C. Animal welfare based measures

Silvopastoral systems

Qualifications used within each welfare indicator of cattle in ISPS

Criterion	Sub-criterion	Measurement	ISPS1	ISPS2	ISPS3
Food and water	Free of prolonged hunger and thirst	Food offer (kg DM/100 kg live weight)	9.24	8.46	6.9
		Body condition score (0 to 9)	6.7	7.0	6.5
Comfort	Ease of movement	Space m^2/animal	60	60	37.5
	Thermal comfort	Breathing rate	48.6	72.6	55.0
		Skin temperature (back) (°C)	37.3	37.5	40.0
		Skin temperature (abdomen) (°C)	35.5	35.8	36.0
Health	Injuries	Lameness (number of animals)	0.0	0.0	1.0
		% mild integument alterations	50.0	5.0	25.0
		% severe integument alterations	0.0	0.0	12.5
	Diseases	Cough, nasal discharge, ocular discharge, breathing difficulty, diarrhoea	0.0	1.0	3.0
		Ectoparasites (number of flies)	1.0	9.0	0,0
		Ectoparasites (number of ticks)	6.0	0.0	5.0
Behaviour	Human-animal relationship	Avoidance distance (m)	1.6	1.2	1.3
	Emotional state	QBA (score from 0 to 100 cm)	83.0	84.0	71.0

ISPS1 - low plant diversity ; ISPS2 - middle plant diversity ; ISPS3 - high plant diversity

Morales et al., 2017

C. Animal welfare based measures

Silvopastoral systems

Evaluated values obtained from the integration of indicators for animal welfare criteria

Criterion	Sub-criterion	ISPS1	ISPS2	ISPS3
Food and water	Free of prolonged hunger	98.8	98.8	98.8
	Free of prolonged thirst	100	100	80
Comfort	Comfort for resting	99.9	99.9	99.9
	Thermal comfort	100	100	100
	Lameness	99.9	99.9	99.9
	Space	100	100	100
Health	Injuries	76.4	91.2	61.4
	Diseases	100	81.0	54.6
	Induced pain	0	0	0
Behaviour	Expression of social behaviours	100	100	100
	Expression of other behaviours	100	100	100
	Human-animal relationship	94.97	96.58	98.18
	Emotional state	83	84	71

absence of anesthesia & analgesia for surgical procedures

Cough due to wet season

ISPS1 - low plant diversity ; ISPS2 - middle plant diversity ; ISPS3 - high plant diversity

Morales, et al. 2017

D. Farm animal monitoring and management

- It is essential to **regularly inspect animals' health and welfare** in pastures and silvopastures.
- **New technologies can help**
  - ✓ improve production efficiency
  - ✓ lower environmental impact
  - ✓ enhance animal welfare
- **Useful technology** includes sensors, automated responses, and new tools for the management of animals, such as animal welfare monitoring with the help of camera technologies, positioning technologies, drones and virtual fences.
- These applications must be **used without compromising animal welfare**.
- A combination of **automated digital monitoring and manual follow-up inspections** may prove to be a reasonable compromise.

D. Farm animal monitoring and management

Sensor Technologies

Product	Type & Features	Technology	Recorded Behaviour
RumiWatch System	Nose: Eating time, Rumination Leg: Activity	Accelerometer Pressure gauge	Eating time Rumination Lying time Movement Standing time
IceTag	Leg: Activity	Accelerometer	Lying time Step count Standing time
CowManager SensOor	Ear: Activity, Eating time, Rumination	Accelerometer	Activity Rumination Eating time
Heatime HR LD System	Neck: Activity, Eating time, Rumination	Accelerometer	Activity Eating time Rumination

The tables (edited from Herlin et al, 2021) show commercially available and scientifically validated animal-based sensors, the type of measurements taken, and the information they generate.

Type of Sensor	Measurement	Information
Activity	Activity, rumination, lying time, step count	Oestrus, calving, lameness, general health
pH sensor	Rumen pH	Rumen acidosis
Camera	Activity, feed intake, body shape	Ketosis, body condition, lameness, mastitis
Thermometer, thermography	Body temperature thermal body surface radiation	Water intake, calving, infection, lameness, general health
Microphone	Rumination time	Rumen function, general health, oestrus, calving

D. Farm animal monitoring and management

Drones

Image 19: Drones replacing cowboys to track cattle. (citation 10)

Image 20: Thermal camera arm drones for scouting. (citation 11)

D. Farm animal monitoring and management

Virtual fences

Image 21: Livestock kept in pasture without installing posts or wires (citation 12)

Image 22: Steer outfitted with a virtual fence collar. (citation 13)

Animal welfare in grazed/browsed woodlands

Lesson 3: Environmental aspects of agroforestry systems

A. Impact of livestock intensification on biodiversity, the ecosystem, & the environment

B. Agroforestry as a viable solution to environmental problems

Lesson 3

A. Impact of livestock intensification on biodiversity, the ecosystem, & the environment

The concept of **biodiversity** includes the extent of variation for three types of differences:

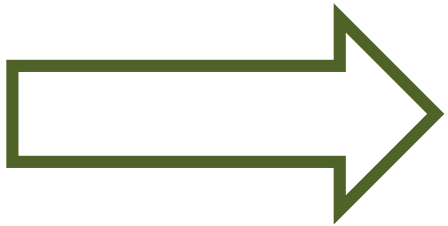
- Genetic
- Biologically functional
- Based on ecosystem type

Broom, 2018

Biodiversity is declining worldwide, mainly because of farming.
33% of the earth's total land surface is being used for livestock production.

Giraldo et al, 2011

Increasing demand for animal products worldwide



Reduced habitat for wild (and local) species of animals and plants

Lesson 3

A. Impact of livestock intensification on biodiversity, the ecosystem, & the environment

Reduced habitat extent for animals

The increased intensification of livestock farming has contributed to

- The formation of the Rare Breeds Survival Trust (RBST) of the remnant populations of purebred animals (the original population), as breeders are infusing genes from other breeds or modifying genes, such as Lincoln Red, Aberdeen Angus and Hereford
- The critical endangerment of several species, such as Gloucester cattle and Norfolk Horn sheep (Alderson, 1994)

Lesson 3

A. Impact of livestock intensification on biodiversity, the ecosystem, & the environment

Reduced habitat extent for plants

The increased intensification of livestock farming has contributed to

- The removal of trees and shrubs, first on land used for the construction of roads or buildings, and secondly in order to use herbaceous monoculture plants as livestock forage.
- Herbicides are widely used to maintain these monoculture plantations, greatly decreasing biodiversity.

Lesson 3

A. Impact of livestock intensification on biodiversity, the ecosystem, & the environment

Reduced habitat extent for wildlife species

The increased intensification of livestock farming has contributed to

- The decline and eradication of wild birds, mammals and reptiles as their natural habitat disappears, depriving them of shelter and protection.
- The disappearance of larger insects (natural predators of ticks, which are responsible for many insect-borne diseases) as well as earthworms and other soil invertebrates because of degradation of the structure of the soil.

Lesson 3

A. Impact of livestock intensification on biodiversity, the ecosystem, & the environment

Intensified farming operates at more drastic levels, influencing natural ecosystems and the global environment through

- **Contamination** of soil and waterways by agricultural chemicals
- The **carbon cost** resulting from CO2 production from vehicles and from the manufacture of materials used
- **Contamination** of water by animal excretions and sludge resulting from water treatment plants
- **Methane emissions** from the animals and their products

Lesson 3

A. Impact of livestock intensification on biodiversity, the ecosystem, & the environment

Therefore, although it can be profitable and can respond to great demand, **highly intensified livestock farming is unsustainable**, causing depletion of many resources and reasons for sustainability in any system, as summarized in the table below (adapted by Broom, 2018)

1.	resource depletion	to level that is unacceptable
		to level that prevents system function
2.	product accumulation	to level that people detect and find unacceptable
		to level that affects other systems in an unacceptable way
		to level that affects the system itself, perhaps blocking its function
3.	other effect	to level that is unacceptable
the consequences of acts or of system functioning (in 1, 2 and 3) could be unacceptable because of immediate or later:		
(a)	harm to the perpetrator	resource loss or poor welfare
(b)	harm to other humans	resource loss
(c)	harm to other humans	poor welfare
(d)	harm to other animals	poor welfare
(e)	harm to environment including that of other animals	

B. Agroforestry as a viable solution to environmental problems

- Agroforestry, especially silvopastoral systems, enhances conservation grazing conditions, which allows managers and breeders to select stock that thrive under conditions beneficial to wildlife and naturally occurring local plants.
- This is made possible by maintaining or enhancing the qualities of thrift and hardiness that are the main reasons for the selection of rare or traditional breeds.

Image 23: Waldschaf (forest sheep), an old endangered breed of the Bavarian Forest, Bohemian Forest and Waldviertel (Austria). (citation 14)

Image 24: Baladi *cow* Egypt, Palestine, Jordan, Lebanon Syria. (citation 15)

B. Agroforestry as a viable solution to environmental problems

- Shrubs & trees with edible leaves and shoots, in combination with pasture plants, produce more forage per unit area than pasture plants alone.
- The selection and management of plants can maximize positive, facilitative interactions among species and minimize competitive ones.
- Foraging ruminants can contribute to plant growth and plant survival.
- Shade under woody plants improves growth and nutrient accumulation for pasture plants.

Image 25: Cattle browsing Leucaena in a silvo-pastoral system, Caribe, Colombia. (citation 16).

B. Agroforestry as a viable solution to environmental problems

Shrubs and trees with edible leaves and small branches for farm animals such as “fodder trees” like *Leucaena leucocephala* shrubs that can offer **substantial benefits for farmers, animals, and the environment.**

variable (per year)	monoculture of *Cynodon plectostachyus*	silvopastoral system of *Leucaena leucocephala* (10 000 ha^{-1}) with *Cynodon plectostachyus*	difference (%)
nitrogen fertilizer ha^{-1}	184	0	−100
biomass tonne ha^{-1}	23.2	29.9	+29
crude protein tonne ha^{-1}	2.5	4.1	+64
metabolizable energy Mcal ha^{-1}	56.9	70.2	+23
calcium kg ha^{-1}	83.2	142.3	+71
phosphorus kg ha^{-1}	74.0	88.8	+20

Example: changes in nitrogen use and plant production in cattle farming after replacing *Cynodon plectostachyus* monoculture pasture plant with the pasture plant plus the leguminous shrub *L. leucocephala*

Murgueitio et al., 2008

Lesson 3

B. Agroforestry as a viable solution to environmental problems

Silvopastoral systems greatly increase wildlife and original ecosystem biodiversity, compared with pasture-only systems:

- The presence of shrubs and trees greatly increases the cover available for wild birds, mammals and reptiles.
- The wider range of plants results in more beneficial larger insects (such as dung beetles).
- More complex soil increases the number and variety of soil insects and other invertebrates.

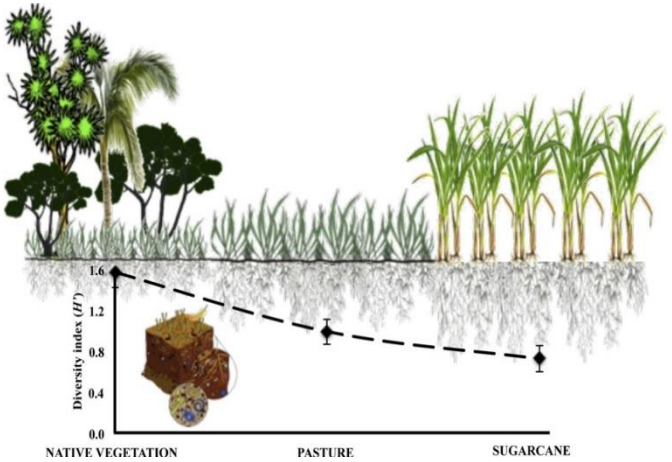


Image 26: Degradation of soil fauna due to sugarcane acreage. (citation 17)

Case studies

- The number of bird species in silvopastoral cultivated areas was three times the number in pasture areas without trees in the same region (Fajardo et al., 2008).
- The number of bird species was 24 species on pasture without trees, 51 species in woodland, and 75 species in silvopastoral systems (Múnera et al., 2008).

Image 27: Humming bird. (citation 18)

Animal welfare in grazed/browsed woodlands

Lesson 4: Livestock production in agroforestry systems

A. Beef Production

B. Dairy Production

C. Mixed Beef and Dairy Production

Livestock production in agroforestry systems

Shade is associated with

⇒ increased daily weight gain
⇒ increased milk production
⇒ increased fertility

- ✓ *Coffey et al., 1999*: Average weight gain: + 20%
- ✓ *Collier et al., 1981*: Dairy production: + 10 to 19%

  Shearer et al., 1999:
- ✓ *Collier et al., 2006*: Conception rates + 19.1%
- ✓ *Higgins et al., 2011*: Pregnancy rate + 37.5%

Livestock production in agroforestry systems

Research shows that increased tree presence in silvopastoral systems (SP) has the following effects:

Buergler et al., 2006:	increases forage mineral content increases fiber digestibility decreases cell wall components or NDF (neutral detergent fiber)
Orefice et al., 2016:	crude protein may be greater than in open pasture (OP) for example: orchard grass 12.9% in SP vs. 10.7% in OP
Costa et al., 2016 and Pent, 2017:	SP animal production is sometimes greater than in OP

A. Beef Production

Comparison of Beef Production: Treeless Systems and Intensive Silvopastoral System (ISPS) -- Colombia

Average	Conventional pasture	Improved pasture	ISPS
Stocking rate (large animals ha^{-1})	0.5	1.5	3
Daily weight gain $animal^{-1}$ (kg)	0.37	0.6	0.80
Daily weight gain ha^{-1} (kg)	0.185	0.9	2.4
Days of growth (from 250 to 440 kg)	514	317	238
Kg of meat produced ha^{-1} yr^{-1} (LW)	67.5	328.5	876.0
Consumption of DM (% of LW)	1.5	1.5	2
Consumption of DM (kg ha^{-1} yr^{-1})	958.1	2874.4	7665.0
Land surface required to produce 1 ton of beef yr^{-1} (ha)	14.8	3.0	1.1

DM stands for Dry Matter ; Conventional and Improved pasture data (Fedegan, 2012) ; Intensive Sylvopastoral System data (Mahecha et al., 2011)

ISPS model is superior for all the relevant studied parameters and daily weight gain / amount of meat produced are considerably higher

B. Dairy Production

Silvopastoral system on Lucerna Farm: Clear benefits for farmers and the environment

1990

Pastures

- Star grass *Cynodon plectostachyus* monocultures
- Animal load of 3.5 cows per hectare (ha^{-1})
- 9,000 L of milk per hectare per year ($ha^{-1}yr^{-1}$)
- Fertilization with 450 to 500 kg of urea per hectare per year

versus

Actual ISPS

- 10,000 L. leucocephala shrubs per hectare
- Animal load of 4.5 cows per hectare
- 15,000 L of milk per hectare per year
- No fertilizer

Calle Z et al, 2013

B. Dairy Production

Silvopastoral systems on El Hatico Reserve

1970

- Avg. tree cover <10 trees ha^{-1}
- Pasture management with herbicides
- Irrigation
- Chemical fertilizers

1996

- Pasture
- Milk production: 7436L ha^{-1}yr^{-1}
- Animal load: 3.35 cows ha^{-1}

2003

- ISPS
- **Milk production: 18,486L ha^{-1}yr^{-1}**
- Animal load: 5.04 cows ha^{-1}

2013

- 70 tree species in ISPS
- Sells certified organic milk

Molina et al., 2008; Murgueitio et al., 2011

Silvopastoral systems on El Hatico Reserve

The consequences of improvements: greater productivity resulting from the more complex vegetation structure and higher plant diversity

- Increased biomass production (27%)
- More raw protein (64%)
- More metabolizable energy (23%)
- More available calcium (71%)
- More phosphorus (20%)

Molina et al., 2008;
Murgueitio et al., 2011

C. Mixed Beef and Dairy Production

Silvopastoral systems of El Chaco: Tolima- Colombia

1990

- Extensive cattle grazing system
- Animal load: 0.55 head ha^{-1}

ISPS results: much better than average!

2010

- **Intensive Silvopastoral Systems (ISPS)**
- Rice cultivation, silvopastoral systems, and small forest remnants
- Animal load: beef: 2.5 head ha^{-1}
  dairy: 3.5 head ha^{-1}
- Daily dairy production: 9.5 L per cow.
- **Meat production: 1,036 kg ha^{-1} yr^{-1},**
  > average local productivity (74 kg ha^{-1} yr^{-1})
  > Latin American average (19.9 kg ha^{-1} yr^{-1})

Mahecha et al., 2011

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