9 Weed control

Section 9 describes the weeds' critical and positive characteristics. It introduces the pre-cautionary crop rotation and tillage approaches to reduce the risk of weed competition, as well as mechanical weed control options after the crops are established in the field.

9.1 Weeds from different perspectives

Weed is a main factor limiting crop yield. The delay of weed control leads to tremendous losses of crop yields (Table 32). Currently, the main technique for weed control is the hand hoe. Non-chemical mechanical management techniques are limited. Even if herbicides are applied (which are not allowed in organic farming (OF) systems), practices of weed control are weak, inefficient, and endangering for human health and the environment. That is because handling is often not compliant with safety rules, the spraying is not adapted to the growing stage of weeds, weed resistance, diaspores have accumulated in soils, etc.

Table 32. Estimated yield reductions due to delayed weeding

Crop	% yield reduction	Crop	% yield reduction
Maize	40	Sorghum	30
Wheat	35	Barley	18
Teff	30	Lentils	50
Chickpeas	30	Faba beans	20
Haricot beans	36	Field peas	15
Soya beans	50	Cotton	73
Peppers	30	Coffee	62

Source: Desta (2000)

Weeds compete with crops for water, nutrients, and light. In the early development stages crops are specifically vulnerable against weed competition. Competition for water is generally considered the most important factor under dry conditions, while with high rainfall weeds can completely cover the main crop if not regulated properly. Under high rainfall conditions weeds are growing fast and the risk of reducing the main crop yield is high. Weed yield can reach more than 1 t ha^{-1}, which is significant compared to crop yields with often less than 2 t ha^{-1}.

Weeds, or in this context herbs and grasses, also provide multiple positive functions in a cropping system, with positive impacts on soil fertility and crop yield, e.g.:

- Soil coverage, reducing risk of soil erosion.
- Mineral transfer from belowground and uptake of micro-nutrients.
- Host for mycorrhiza (increases the mineral and water uptake under dry conditions) as a source for the main crops.
- Host for beneficial insects, e.g. wild bees that are responsible for the efficient pollination of main crops.
- Feed source for bees.
- Feed source for animals.

Weeds can be tolerated to a certain amount, mostly when the main crop covers the soil approximately six weeks after sowing, without having a negative impact on the main crops' performance. Optimised weed management can lead to a yield increase of the main crop of up to 50-200%.

9.2 Crop characteristics and crop rotation-based weed control

Crop sensitivity to weeds starts with the size of crop seeds. Small seeds are sensitive (e.g. teff, forage legumes), due to the longer time period they need to reach a certain crop size, in comparison to large seeds. This fact can be explained by their faster germination and seed induced nutrient and water reserves (e.g. peas, beans) (Table 33). Furthermore, the dormancy of seeds can vary within different varieties and increase the risk of competition with weeds, as well as the germination rate of seeds, if not regarded in the seed density. Higher distances in and between crop rows can lead to an increase of weed competition. On the other hand, it allows for better mechanical weed control, specifically between the crop rows. Cereals with a short straw type (e.g. finger millet) are more vulnerable against weed, as well as pea varieties with half-leaves, or lentils and chickpeas. Generally, after approx. six weeks, crops cover the soil sufficiently to compete successfully with weeds. Before, an efficient weed control is of high priority.

Based on crop specific vulnerabilities and their capacity to suppress weeds, defined rules exist for the follow-up of crops in crop rotations to limit weed development and competition with the main crops (see also section 7.4). The main rule for controlling weeds via a crop rotation is to alternate between weed-sensitive and weed-suppressing crops, and to integrate forage crops with more than one cut per year.

Table 33. Crop characteristics and mechanical weed control

Crop	Vulnerability in the early stage	Weed suppressing capacity	Potential for mechanical/ mechanised control	Potential techniques
Wheat	+ to ++	++	++	Hand hoe / mechanical weed control*
Barley, oat	++	+	++	Hand hoe / mechanical weed control*
Maize	+	++	+++	Hand hoe / mechanical weed control*
Finger millet, teff	+++	+	+	Hand hoe / mechanical weed control*
Faba bean	+	++	++	Hand hoe / mechanical weed control*
Peas	+++	+	+	Highly sensitive and mechanical weed control limited; mainly hand hoe
Lablab	+	+++	+++	Hand hoe / mechanical weed control*
Cowpea	+	+++	+++	Hand hoe / mechanical weed control*
Forage legumes	+ to ++	+++	+++	Cutting/mulching the crop after growth of approx. 10 cm to kill the annual weeds in between
Vegetables	+ to +++	+	+++	Hand hoe / mechanical weed control*
Potato	+	++	+++	Hand hoe / mechanical weed control*
Sweet potato	+	+++	+++	Hand hoe / mechanical weed control*
Tuber crops	+	+++	+++	To add e.g. clover in between the crops

Source: Own compilation
* curry comb and weeding cultivator

9.3 Tillage based weed control

As chemical herbicides are prohibited in OF, tilling plays an important role in mechanical weed control.

9.3.1 Tillage techniques for weed control

We distinguish eight main tillage systems for weed regulation (see also section 8). They are used in practice, partly combined with a crop rotation sequence, and often with diverse instruments, different sizes, working depth, driving speed of tractors, or drawn by animals. The tillage systems differ in their impact on soil, water, weed, pests and diseases. This diversity poses limits to offering general recommendations. Following procedures are always to be adapted to the field specific circumstances:

- Deep plow (up to 35 cm): burrowing of weeds to a deeper soil depth can hinder their germination, but on the other hand conserve the seeds with possible germination during the following season(s).
- Inter-row cultivation with oxen-plow (*Shilshaloat*): Breaking the soil crust in between the crop rows, such as maize or sorghum.
- Shallow plow (up to 15 cm): loosening of weeds and covering them with soil.
- Wing share cultivator (up to 30 cm): loosening specifically deep rooting weeds.
- Double-heart coulter cultivator (up to 15 cm): shallow mixing the soils, de-rooting weeds and transferring them to the surface.
- Chissel plow (up to 10 cm): cutting weeds via rotating discs.
- Rotavator (up to 8 cm): rotating knives, loosening of weeds, mixing with soil.
- No-tillage: no intervention in the soil; seeding via a stick, or if mechanized via slit drill seeding.

Under OF conditions, where herbicides are excluded, reduced tillage as a stand-alone measure can be critical and mostly leads to stronger weed growth. This approach can be established only if combined with regulative strategies in the cropping system with 20-25 % of forage legumes, mulching, and additional technical interventions.

9.3.2 Times of tillage interventions for weed control

To reduce weed pressure effectively, timely weed control before planting is essential. Technical measures, following specific time windows, are:

- After harvesting the pre-crop: Soil should be loosened and weed seed germination facilitated via harrowing to induce seed germination – this can be conducted twice or more times.
- In between harvest and establishment of the following crop: In case perennial weeds dominate, they can be reduced by using catch crops and their cuttings (see above), and / or mouldboard ploughing to bury the weeds; disking perennial root weeds can lead to weed multiplication via parts of roots.
- Before sowing: High seed bed quality is of high importance in order to provide best germination conditions and growing advantages for the main crop.

The weed control can be significantly improved by applying such interventions properly and in time. The specific actions depend on several aspects such as the pre- and following crop, soil conditions (soil type, water), crop residues, or the availability of a certain technique.

9.4 Mechanical weed control after establishing the crops

Mechanical weed control provides multiple functions. Besides reducing weed pressure, loosening the soil to increase water and oxygen infiltration serve for optimising the overall growth conditions for the crops, the micro-fauna and microorganism activity of the soil, while increasing the mineralisation of (soil) nutrients.

Equal to tillage techniques, several options for weeding, such as horse and currycomb harrow, wheel hoe, or finger harrow exist. Five degrees of technological intensities can be differentiated:

1. Hand hoes in different versions and instruments.
2. Instruments with or without wheels that can be moved via oxen or horses.
3. Instruments with wheels, but without motorisation.
4. Instruments that are moving by a rotovator (walking tractor).
5. Instruments for tractors.

The selection of technologies depends on the soil, soil structure, size of the land, rainfall, crop, and financial capacities. Currently, most of these technologies are not available in Ethiopia or not affordable for the single farmer, which is a challenge for the weed control management.

Hand hoe / mechanical weed control should be applied according to three phases:

- Phase 1 – Before germination of crops: loosening the soil and disturbing weeds in the germination phase.
- Phase 2 – Early stage of crops: 4-6 or 6-8 leave stadium of crops; loosening the soil and disturbing weeds in the germination phase, as well as small already rooting weeds.
- Phase 3 – Before the crop is closing its canopy: disturbing bigger weeds.

Mulching is also an efficient strategy for suppressing weeds. Furthermore, mulching reduces evapotranspiration, provides nutrients, and hinders erosion processes. However, the challenge is to produce sufficient mulching material. Weeds can serve as mulching material, but mulching with weed biomass containing weed seeds should be avoided.

An appropriate amount for the suppression of weeds are approx. 5 t DM ha^{-1} a^{-1}. To produce this amount, alleys in between the field crops, or in the surrounding of the fields, can provide the needed biomass. In some cases, compost can also be used for covering the surface around single crops or crop rows.

9.5 Further information

Limited research on weeds in OF systems in the tropics exists. Some of the existing literature includes the use of herbicides which is prohibited in certified OF. Such research needs a reflection on how the recommendations beyond the herbicide use can be relevant for OF systems.

- Iyagba (2010)
- Marambe & Sangakkara (1996)
- A. K. Watson (1992)
- Liebman & Davis (2009)

10 Crop pest and disease control

Section 1 introduces to why the conventional pest and disease management does not provide a sustainable solution for smallholder farmers. Instead, a series of alternative technical and crop production methods for regulating pests and diseases are introduced, including nature-based products.

10.1 The critical situation of pest and disease control

The Ethiopian climate in the highlands provides both, humid conditions that are predestined for the development of crop fungi, and more dry periods that are favoured by insects. The latest developments in cropping systems indicate less crop diversity, which provokes an increase of soil-borne diseases, i.e. crop rotation pests and diseases.

Crop production strategies to reduce pest and disease pressure via crop rotations with more than six crops are rarely implemented in farms. As a result of one-sided crop rotations, the humus content of soils is low, which is often an additional indicator for low microbial biomass and diversity, as well as low mycorrhiza growth. This is weakening the soil's potential to reduce diseases, but also reducing the uptake of available nutrients.

Technical measures, such as the low cutting of maize stubbles, are often missing and hence allowing for the survival of e.g. stemborer larvae, if not pastured by animals. Strategies to increase the anti-phytopathogenic potential of soils, via the addition of compost or farmyard manure, are often lacking, too.

A strategy to implement pest and disease resistant varieties is not established. In general, a broader spectrum of varieties with specific characteristics is missing in the market. Biotopes in the farms and overall biodiversity decreased over time and today living spaces for beneficial organisms are limited or absent.

In summary, at most farms relevant cropping systems and natural based mechanisms for pest and disease control are excluded or lost their functionality. Current doses and application techniques of pesticides are critical, spraying is often not timed correctly and can lead to environmental pollution and human health problems. Integrated pest management systems are weakly developed and information thereof is rare.

The following section focusses mainly on the farms' internal potential and natural based interventions to regulate pests and diseases, as it is the strategy in organic farming (OF) systems. This introduction informs about a range of innovations for reducing the risk of pest and disease infections, with an estimated yield potential of 50 to 100 %.

10.2 Alternative pest management

Alternative pest management strategies can be classified into agronomic, plant production and biotope specific measures in the farm, and technical strategies offered by industries. Table 34 provides an overview of the general strategies which are only in some cases crop specific. The strategies help to increase the resilience of farming systems against pests and diseases. Obviously, many strategies need to be optimised for crop protection against pests and diseases.

Table 34. Alternative pest management

Approaches	Description
	Farm internal
	Agronomic
Sowing technique	To offer best growing conditions through optimal spacing and deposition of seeds in a well-prepared seedbed.
Sowing date	To sow early or late to avoid pest and disease damages in certain plant growth periods.
Seed protection	To protect seeds through application of liquids or specific soils; pre-germination of seeds in (warm/hot) water.
Seed development	To initiate fast development of plants through pre-germination in water.
Soil tillage	To disturb the living space of pests; to transfer pests into deeper layers where they are not able to survive or develop and finally die off.
Harvest	To cut and transfer parts of plants that host pests and diseases.
Irrigation	To establish water saving methods in order to regulate climatic conditions to avoid fungi.
Manure, compost	Well prepared compost with temperatures above 60°C.
Slurry	To control pests.
Plant based liquids	To control pests and to strengthen plant health.
	Plant production
Crop rotation	To reduce the survival of soil borne diseases.
Catch crops	Pest distraction.
Intercropping	To offer beneficial living space and to reduce pest pressure.
Crop spacing in an area	To optimise general plant growth conditions.
Companion planting	To integrate "enemy" plants to keep pests in distance or to hinder their development.
Cover cropping	To reduce the spreading of diseases.
Guard crops	Strong smelling plants to discourage pests.
Push and pull	To regulate pests, diseases and weeds through the combination of maize, desmodium, Napier, and other grasses.
Alley cropping	To regulate micro-climatic conditions; to provide living space for beneficial organisms.
	Biotopes
Single trees	To provide living space for beneficial organisms.
Hedges	To provide living space for beneficial organisms.
Woodlots	To provide living space for beneficial organisms.
	Farm external
	Seeds
Varieties	To provide resistant or tolerant varieties against pests and diseases.
Seed protection	To protect seeds against pests and diseases through the application of industrial produced liquids.
	Products
Natural based pesticides	To protect / reduce pests and diseases through the application of industrial produced liquids.
Pheromones	To hinder the multiplication of pests.
Yellow tables / Glue	To collect pests.
Lime	To block pest pathways.

Source: Own compilation

10.3 Crop combinations to reduce risk of pest and disease development

Many different allelopathic interactions between plants or plant families are known (see also section 7.3). The principle of companion planting is a strategy in gardening to use these positive physical or chemical interactions between plants for more effective planting schemes (Table 35).

Table 35. List of useful plant combinations / companion planting to reduce pest and disease pressure

Crops	Companion plants	Remark
Allium		Allium species may inhibit nitrogen fixation of legumes, but assist with pest control.
Chives	Leaf crops	Repels aphids, disease resistant.
Garlic	Leaf crops	Pest control reduces potato and tomato blight.
Leek	Celery, carrots, onion	
Onion	Beet, lettuce, carrots	
	Asteraceae	
Lettuce	Strawberry, carrots, legumes	
	Brassicaceae	
Broccoli, cauliflower, brussel sprouts, cabbage, savoy, chinese cabbage	Beet, tomatoes, herbs (celery, mint, parsley, rosemary, sage, thyme, wormwood)	
Choumoellier, covo, rape, kohlrabi, turnip	Beet, lettuce, peas, herbs (chervil, celery, mint, parsley, rosemary, sage, thyme, wormwood)	
	Cereals	
Maize, corn	Legumes, cucurbita, rice	
Sorghum, millet, rapoko	Legumes, bushy plants, ground creepers	
	Cucurbita	
Butternut, courgette, cucumber, pumpkin, gem squash, melon, gherkin	Maize, sorghum, millet, peas, runner beans	In general: combine with tall, shade providing crops.
	Fruits	
Apple	Herbs (lavender, rosemary, hyssop, rue)	
Citrus	Nasturtium, guava	
Gooseberry	Tomatoes	
Grapevine	Mulberry, legumes	
Strawberry	Bush beans, lettuce, spinach	
	Herbs Often contain strong smelling essential oils	
Celery	Leeks, bush beans, runner beans, tomatoes	
Dill, caraway	Maize, cabbage, onion, lettuce	Flowers help to attract predatory wasps.
Fennel	Do not combine with tomatoes, beans, caraway	Fennel is a poor companion plant, works moderately with dill.
Hyssop	Grapevine	Can be a decoy plant for cabbage butterfly.
Lemon balm	Tomatoes, cabbage family, fruits, onions	Can help to prevent bees from swarming.
Lemon grass	Herbs	Repels mosquitoes and flies.
Mint	Kale, cabbage, radish	Mint repels moths.
Parsley	Tomatoes	
Wormwood	Carrots	
	Legumes Fix nitrogen for subsequent seasons	
Broad beans	Dill	
Groundnut	Maize, soybean	
Kidney beans, dwarf beans, runner beans	Carrots, beet, cauliflower, maize, celery	

Pea	Beet, radish, carrots, cucurbita, potatoes	
Pigeon pea	Sunflower, millet, other legumes	
Soybean	Groundnut	
Diverse		
Spinach	Strawberries	
Chard	Legumes	
Chicory	Radish, carrots, beet, turnips	
Sunflower	Lettuce, legumes, herbs	Do not combine with potatoes.
Root crops		
Beet	Lettuce, cabbage, onion, dwarf beans	
Carrots	Lettuce, radish, chives, onions, leek	Leek repels carrot fly.
Cassava	Tapioca	
Parsnip	Onions, legumes	
Radish	Legumes, onions, lettuce	Radish is a good companion plant to most plants.
Solanaceae		
Eggplant	Green beans, potatoes	
Potato	Legumes, sweet corn, cabbage, eggplant, flax, parsley, garlic	Flax repels potato bug.
Tomato	Parsley, garlic	
Tobacco	Tomatoes	Compost made with tobacco roots is rich in potassium.
Capsicum, pepper (sweet and hot)	Parsley, garlic, legumes	

Sources: Own compilation; Vukasin, Roos, Spicer & Davies (1995)

The maintenance of an ecological diversity via the before-mentioned agronomic methods should be the main focus in preventing pests and diseases. Besides these measures, herb teas, oils and other liquids, and household remedies can be applied for combatting pests, especially as they are cheap to produce (Table 36).

Table 36. Plant based liquids and household materials for pest control

Ingredients	Description	Method
Basil *(Ocimum sp.)*	Treatment of seedbeds against soil borne diseases and pests.	Crush leaves and soak for 24 h, drench soil with infusion before planting.
Blackjack *(Bidens pilosa)*	Insecticidal and antifungal properties.	Collect and crush seeds, boil for 10 minutes to make a tee before spraying.
Garlic / Onions *(Allium sp.)*	Natural pesticide against insects and slugs.	Soak 1-3 crushed bulbs in 1 l of water before spraying; bit of soap can be added.
Khakibush /Marigold *(Tagetes sp.)*	Can be used against aphids, soft bodied insects, and nematodes.	Soak 10-15 mature, chopped plants in 20 l boiled water; add some sieved wood ash and spray affected plants. The remaining course material from the solution can be used as good mulch.
Chili *(Capsicum sp.)*	Used against insects. Best in a mixture with garlic/onion and marigold.	Crush 1 garlic bulb, 1 onion and 1 tablespoon of chili, mix with 1 l of water, add 1 tablespoon of soap after 1 h, then spray.
Tephrosia *(Tephrosia vogelii)*	Powerful repellent and insecticide. Contains rotenone which kills fish, should not be used near streams or water!	Crush 50 fresh leaflets and soak in 1 l water for 24h; train and spray, do not add soap.

Tobacco	Nicotine contained in tobacco is very poisonous, should only be used with extreme caution and as a last resort! Never harvest plants treated with tobacco within 3 days after spraying. Do not use tobacco on the potato family.	Soak 1 kg of bruised tobacco leaves in 15 l water for 24 hours, then spray. Addition of slaked lime will increase the effectiveness of the spray.
Mineral oils	Light mineral oils may be used against pests and eggs. Do not spray often and not on hot days since the oil affects plant growth.	Mix 20 ml of oil in 1 l water, then apply.
Pyrethrum	An effective insecticide derived from the *Chrysanthemum* family or *Tanacetum parthenium.* Spray can be used against many insect pests, it is non-toxic to mammals.	Pour 1 l of boiling water over 50 g pyrethrum powder / 250 g *Tanacetum* flowers, let it soak for several hours, then filter and add 1 l soapy water, then spray.
Flour	Household flour can be used to control mites, aphids, and caterpillars.	Dilute 1 tablespoon of flour in 1 l water, splash or wipe on infested leaves; the solution should be put on the plants in the morning on a sunny day. Flour can also be dusted on caterpillar-infested plants.
Milk	Milk can be used against many fungal diseases and some viral diseases, as well as spider mites and the eggs of several caterpillar species. Sour milk mixed with water and wood ashes can be effective in controlling mildew.	Dilute 1 l of milk in 10-10 l water, then spray. Spraying has to be repeated after 10 days for diseases and after 3 weeks for insects.
Insects	Remedies made from a pest species itself often discourages others from eating.	Crush 10-20 grasshoppers and mix with 5 l water; sprinkle over crops affected by this specific pest.
Compost	A tea made from well decayed, fermented compost can be used as a tonic to strengthen plants and treat a variety of fungal and bacterial diseases.	Mix a shovel full of compost with 10 l water and let it stand for 3-11 days, then apply on plants directly, using a watering can. After sieving, it can be used to spray on diseased leaves.

Source: Vukasin et al. (1995)

10.4 Further information

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11 Hedge and alley systems

Section 11 introduces the role and function of hedge and alley systems and their integration into smallholder farms. An example is given that explains the economic relevance of alley trees.

11.1 Role and functions of hedge and alley systems

From an ecological point of view, there is no stability of the Kafa Zones ecosystems without trees. As a result, strategies are necessary that integrate elements of forestry into the farming system. Hedges and alleys are elements of agroforestry systems and are important contributors for farm productivity increases and sustainability. When hedgerows and alleys are systematically implemented, farm productivity can be raised by about 50 to 200%.

Advantages of hedge and alley systems:

- Provide fuel wood, timber, shade, fruit, medicine, fodder for livestock, and green manure for improving soil fertility.
- Benefits for crops through improved soil fertility, soil structure, soil moisture and micro-climatic conditions, transfer of nutrients to crop field from hedges/alleys, possibly habitat generation for pest predators (increased farm biodiversity), soil erosion protection from wind and water.
- Extended cropping period and higher intensity of land use possible.
- Trees and shrubs deliver highly demanded fuel wood and construction material, and can thus be used to generate additional value and income (as well as additional fodder for animals).
- A farmer can produce a higher yield per unit of land compared to monoculture cropping.

Challenges for the establishment of hedge and alley systems:

- Establishment needs some time, thus benefits will come with a time gap.
- Capital for investment in trees is necessary.
- Higher demand for labour and management – planting, watering, and pruning schedules need to be carried out in time, otherwise the result will be poor; however, the labour demand can be reduced by proper planning.
- Alley crops can compete with crops for water and nutrients; therefore, you need to plant trees/shrubs with deeper rooting systems than the crop plants.

11.2 Species characteristics

The diversity of alley and hedge crop species is enormous. Species perform differently in terms of biomass production, nitrogen fixation, phenotype, root biomass, wood quality, drought and frost resistance, forage quality, contour planting potential, pH demand, and yield (Table 37).

Table 37. Alley and hedge crop characteristics

Species	Site conditions pH; T°C; NN; M.a.s.l.	Drought resistance	Biomass production* t ha^{-1} a^{-1}	Nitrogen fixation kg N ha-1 a^{-1}	Feeding cha-racteristics	Source
Acacia spp. (*Acacia nilotica*)	5-9 pH 18-28 °C (tolerates 4-47°C) 300-2,200 mm 0-1,340 m	+++	n/a	n/a	++ (leaves: 14-20% crude protein, leaves and pods generally well accepted by animals)	www.tropicalforages.info http://apps.worldagroforestry.org/treedb/index.php
Crotalaria spp. (*Crotalaria juncea*)	6-7 pH (tolerating 5 – 8) 20-30 °C (tolerates 4-40) 500-1,500 mm (tolerates 200-4,300 mm) up to 1,500 m	+++ (when est.)	Total green matter yields 18-27 t/ha, forage yield 5-19 t/ha	10-90 kg/ha	+ (some compounds cause unpalatability)	www.pfaf.org Samba et al. (2002)
Calliandra spp. (*Calliandra calothyrsus*)	5-6.5 pH 22-28 °C 700-4,000 mm 250-1,800 m	++ (can tolerate drought)	++ 7-10 t DM/ha/a	n/a	++ Leaves and pods rich in protein (22% DM), non-toxic, but contain tannins (can reduce protein digestibility)	www.pfaf.org http://apps.worldagroforestry.org/treedb/index.php
Faidherbia spp. (*Faidherbia albida*)	5,5-7 pH (tolerating 5-7.5) 18-30 °C 250-1,200 mm 270-2,700 m	+++	n/a	n/a	Pod and leaves high quality feed forage	www.infonet-biovision.org http://tropical.theferns.info
Gliricidia (*Gliricidia sepium*)	4.5-6.2 pH >15 °C 900-1,500 mm 0 - 1600 m	+++	++ 9 to 16 t/ha of DM in fodder plots	+	+++ High nutritive value. CP content 18-30% and in vitro digestibility of 60-65%	www.tropicalforages.info
Grevillea spp. (*Grevillea robusta*)	5-7 pH 15-20 °C (tolerates down to -8) 0-3,000 m 700-2,000 mm	+++	n/a	n/a		www.infonet-biovision.org http://apps.worldagroforestry.org/treedb/index.php
Leucaena leucocephala	5-8 pH 25-30 °C 500-2,000 mm 0-1,000 m	+++	++	n/a	+++	http://www.newforestsproject.org/ www.pfaf.org

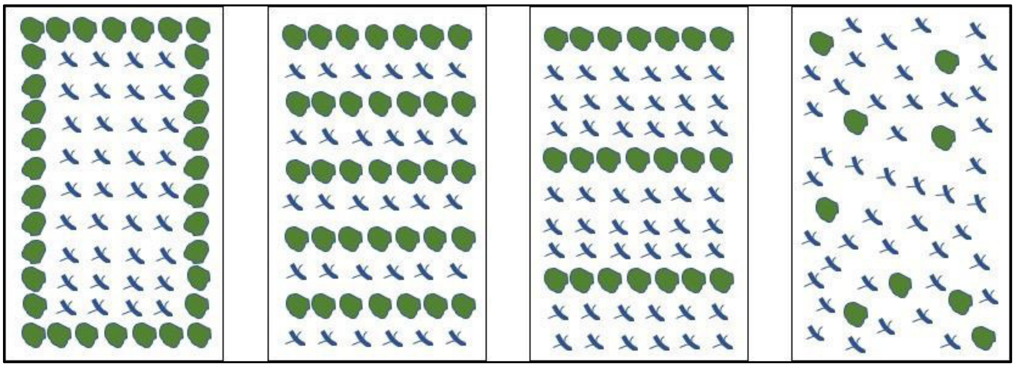
Pigeon pea (*Cajanus cajan*)	5.5-6.5 pH 18-38 °C 500-1,000 mm Up to 1,500 m	+++ (when established)	+++ 1-5 t/ha/a green matter	n/a	+++ Leaves up to 9% protein	www.pfaf.org www.infonet-biovision.org
Sesbania sesban	5-7,5 18-24 °C 100-2,300 m 500-2,000 mm	+++	+ Average 4-12 t DM/ha/a, but up to 20 t/ha DM	n/a	+++ Protein rich (20-30% of DM), good digestibility	www.infonet-biovision.org www.feedipedia.org
Stylosantes spp. (*Stylosantes fruticosa*)	4-8 pH 25-30 °C 350-1,500 mm Up to 2,000 m	+++	+ 3-6 t DM/ha/a	n/a	++ About 8% protein in DM	www.feedipedia.org
Tree lucerne (*Chamaecytisus palmensis*)	5-7 pH -15-40°C (tolerates a wide range) 350-1,600 mm 0-1,000 m (but survives up to 3,000 m)	+++	+++	+++	+++ (foliage 17-22% protein (DM))	http://apps.worldagroforestry.org/treedb/index.php

Sources: Own compilation, various sources
* Depends on the size/age of the bush or tree
+ (lower) to +++ (high) = Level of drought resistance / ability to fixate nitrogen/ fodder quality

11.1 Integration of hedges and alleys into farming systems

There are different ways of adopting hedge and alley systems (Figure 10). In the first three examples (from left to right), trees and shrubs are grown in alleys or hedgerows. In the example on the right, where trees are dispersed, they should be grown in a distance of 8 to 10 m. The alleys need to get pruned regularly to avoid shading of crops, with the biomass providing a valuable resource.

Figure 10. Alley system designs



Source: Own illustration, according to Kang (1996)

11.2 Economy of alley crops

The economy of alley crops needs a site-specific calculation, as many factors influence the performance. Table 38 provides an exemplary calculation of labour input, investment costs, and profit based on a case study on *Grevillea robusta*, which is suitable for the midlands and highlands of Kafa. *Grevillea robusta* has high potential as it is a hardwood with a high market demand, low water needs, beneficial to the soil, and yields significant returns if kept for at least six years. It can be planted as a barrier crop around the fields and hence, having a high adoption potential for limited land sizes. However, seedling supply, investment costs, and difficult germination of *Grevillea robusta* are challenges to face.

Table 38. Exemplary economic calculation *of Grevillea robusta* cultivation with 200 trees using a space of 10 x 5 m on 1 ha

Indicator	Unit	Planting							Total
		Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	
Labour	Days	40	30	20	15	15	15	15	**150**
Seed and material costs	Birr	1,000	400	0	0	0	0	0	**1,400**
Labour costs	Birr	2,350	1,700	1,200	900	900	900	900	**8,850**
Costs	Birr	3,350	2,100	1,200	900	900	900	900	**10,250**
Sale value per tree	Birr tree $^{-1}$	-	14	60	140	300	440	600	**600**
Sale value 200 trees	Birr*	-	2,800	12,000	28,000	60,000	88,000	120,000	**120,000**
Net primary value	Birr								**109,750**

Source: Adapted from OneAcreFund (2014)
*The trees do not provide a cash flow per year, but rather provide income when the trees are harvested. The sale values are conservative estimates.

11.3 Further information

- Bishaw (2001)
- B. Kang & Mulongoy (1992)
- B. Kang, Van der Kruijs & Atta-Krah (1989)
- Jabbar, Reynolds, Larbi & Smith (1997)
- Sumberg, McIntire, Okali & Atta-Krah (1987)

12 Coffee

Section 1 describes the diverse coffee systems, seedlings, planting, and coffee plant education, planting schemes, organic manure, and fertiliser demands that are relevant for an optimal coffee yield, and specifically to adapt to and mitigate to climate change.

12.1 Coffee systems

As the origin of wild coffee, *Coffea arabica*, Ethiopia produces premium quality coffee, as the highland area is suitable for Arabica production. Ethiopia has the potential to be a leading producer in both, quality and quantity. Ethiopian coffees are traded worldwide as conventional or speciality products. Speciality coffee is certified by organic (Ndambi, Pelster, Owino, De Buisonje & Vellinga, 2019) standards, Rainforest Alliance, Fairtrade, or combinations of programs.

Arabica coffee grows over a wide range of agroecological zones and geographical regions. A high share of coffee produced in Ethiopia is shade grown (40-60% canopy cover), except for some homegarden systems in the east.

Ethiopian coffee regions can be classified into four production systems, of which the first three can be considered as traditional (Table 39). Coffee production systems differ according to accompanying vegetation, structural complexity, management, and agronomic practices.

Table 39. Coffee production systems in Ethiopia

Production system	Data	Description	Propagation
Forest coffee (FC)	5% of total production Yield: 200-250 kg/ha	Close to natural forest condition, almost no intervention.	Natural regeneration.
Semi-forest coffee (SFC)	50-55% of total production Yield: 300-400 kg/ha	Forest is manipulated mainly for coffee production, low management intensity.	Natural regeneration, planting of local coffee varieties.
Garden coffee (GC)	40% of total production Yield: 400-500 kg/ha	A lot of variations within the coffee system, intensive management needed, hoeing and fertilization; planted shade trees, mainly intercropping with enset.	Planting of selected coffee varieties; seedling selection and raising in nurseries.
Plantation coffee (PC)	<5% of total production Yield: 1,000-1,200 kg/ha	Coffee grown by the state enterprise or private companies, under planted shade trees.	Planting of selected coffee varieties; seedling selection and raising in nurseries.

Sources: Gole, Itana, Tsegaye & Senbeta (2015); Hirons et al. (2018)

Forest coffee production displays the highest biodiversity of all coffee production systems (Table 40) and, therefore, fits naturally well for an organic approach.

Table 40. Vegetation characteristics of different production systems (Yayu area)

Coffee systems	Canopy cover	Trees	Canopy tree species	Coffee plants
	%	ha^{-1}	n	ha^{-1}
Forest	84	460	32	3,600
Semi-forest	40-60	155	19	5,800
Garden	30-40	75	5-10	1,000-3,500
Plantation	30-40	75	5-10	3,300

Source: Gole et al. (2015)

In the following we focus on the garden coffee system, which asks for several organic farming (OF) practices that can also be applied in the plantation system.

12.2 Garden coffee management

While in forest and semi-forest coffee systems the intervention via management is limited, garden coffee needs several activities to make the coffee productive and capable to cope with climate change, i.e. increasing temperatures. To maintain and increase biodiversity is of high relevance in terms of climate regulation, wood use for different purposes, apiculture, and other options for second income generation.

Garden coffee is a combination of coffee plants, crops that deliver humus and nitrogen or other nutrients (fertiliser trees), shadow and cooling function, eventually other fruit crops, green manure, and value trees for diverse purposes. In the early stage of planting, also food crops, e.g. maize with beans, can be integrated without competing the coffee shrubs (Table 41, Table 42).

Coffee seedlings are prepared in shaded nurseries. Seedlings are to be raised 6-12 months before the planting season. For that, a seedling bed needs to be prepared, with best compost quality from cow dung. Under reduced rainfall patterns seedlings are dependent on a water supply.

The young coffee plants need to establish under shade trees (see section 12.2.1). Most of the certifiers of organic coffee ask for more than 12 different tree species. For planting coffee, compost must be added to the planting hole (see Table 41) and mulch to the surrounding of the coffee plant. After planting the seedlings, it takes 2.5-3 years before the first coffee is produced.

Weed control should be done continuously around the coffee plants. The main reduction of weeds under Kafa rainfall conditions is through under-sown legumes. Whenever possible, mulch material is to add to the coffee plants directly from banana/enset (leaves), or branches from the shadow trees.

Pruning is an essential management practice in coffee production. It helps to achieve the desired plant shape and leads to sustainable higher yields, while contributing to disease and pest control. Current practice involves capping the main branches at 1.8 m toward a stumping at 30 cm above ground (Gole et al., 2015). The cutting should be done with an angle, allowing the water to drop down, so the cutting can dry fast to avoid the development of fungi. As important is the cleaning of the shrub in the inner part of the coffee plant, which supports air circulation and thereby reduces the risk of increased humidity and thus favourable conditions for fungi. Complete stumping is recommended at an 8-12 years interval.

Not only under the organic label, but also in traditional coffee farming, plant health is regulated by shading and pruning. Pest and disease pressure are higher in the more intensively managed systems, like plantations and home gardens. The major coffee diseases in Ethiopia are coffee berry disease (CBD) and coffee wilt disease (CWD). Coffee leaf rust (CLR) is regulated by high genetic diversity and the existence of tolerant genes, disinfected cutter for pruning, and the burning of infected material. The major coffee pests are nematodes, the coffee berry borer, leaf minor, stem borer, and scale insects.

Table 41. Steps to set up a garden coffee system

Steps	Activity	Remarks
		Year 1
1	**Selecting the site**	There are no specific limitations.
2	**Assessing soil quality**	Min. pH measurement.
3	**Tillage**	Keep the fertile soil on top.
4	**Measuring the field**	See figure below; keep the distances in the rows and in between the rows.
5	**Planting coffee**	See section 12.2.1.
6	**Planting shadow trees**	Shadow trees: mix of *Sesbania* and other legume trees; high value trees; trees for apiculture.
7	**Planting banana or enset**	For humus production and soil erosion control.*
8	**Apply manure**	One bin per coffee plant mixed with surface soil.
9	**Apply water**	One bin per coffee plant.
10	**Mulch the coffee**	Approx. a layer of 50 cm green manure around the plants.
11	**Sowing green manure**	Desmodium, alfalfa, clover, or mucuna.
12	**Pruning coffee and trees (ongoing)**	Use a clean cutter, protect the cut stem with wax or other substances; keep the inside of trees free of branches.
13	**Mulching prunings**	Cover the soil in between the crops with the prunings; infected material must be sorted out from the coffee site and used as mulch in other fields.
		Year 2-3
1	**Sowing green manure and mulching**	Keep soil around coffee crops free. Weed control only very shallow, to avoid damage of the shallow coffee root system.
2	**Sowing maize and beans**	Avoid narrow planting to the coffee reducing competition.
3	**Green manure seeds**	Harvest the seeds, dry and store for the next year, or let them fall down to the soil directly.
		Year 4-ongoing
1	**Composting coffee husks**	Recycle the compost to the crops.
2	**Animal manure and slurry**	Small amounts directly to the coffee plants.
3	**Green manure**	Use the seeds from the former years.
4	**Pruning coffee and trees (ongoing)**	See above; balance the shadow effect of trees.
5	**Banana / enset leaves**	Use the leaves for mulching directly around the coffee plants.

Source: Own compilation

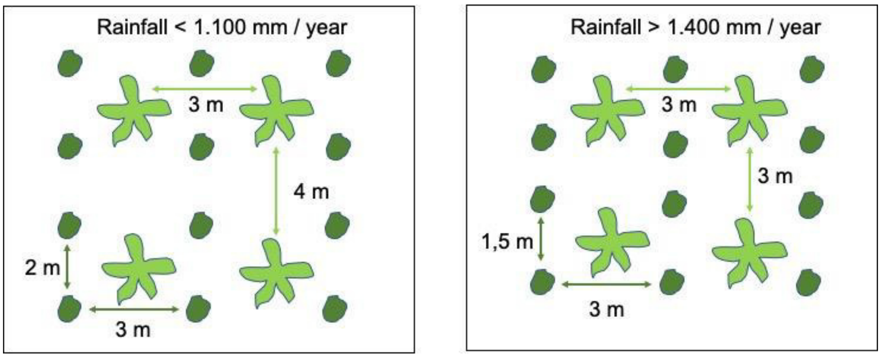
* after harvest of fruits stems can be positioned in the field as soil erosion barriers above the single coffee plant

12.2.1 Coffee planting schemes

Coffee crop density, the implementation of banana or enset, of leguminous or shadow trees, and other plants like herbs (see the example) is a site-specific decision, based on experience, the soil quality, the rainfall pattern, and the amount and characteristics of the chosen coffee varieties. With decreasing rainfall, the density of all crops has to be reduced as well (Figure 11).

Due to an ongoing increase in temperature, professional shading to reduce the temperature is becoming more and more relevant for organising healthy coffee systems. Temperatures of 30°C and more lead to stress and challenge the survival of the plant itself. Shade trees can moderate extreme temperatures by at least 5°C.

Figure 11. Structure of banana-coffee intercropping under different rainfall regimes



Source: Own illustration, according to CIALCA (2010)

The planting scheme in Table 42 provides an example for a rainfall regime higher than 1,400 mm a^{-1}, added by Table 43 summarising the number of plants.

Table 42. Planting scheme for coffee with trees, cash crops, herbs and green manure crops

Hedge 3 m		Horizontal																Total
		Row		No.	1	2	3	4	5	6	7	8	9	10	11	12	13	m
		No.	cm	200	100	300	100	200	100	200	100	200	100	200	100	200	100	22
		1	**200**		UL													**200**
		2	100		BT		C	R	C	R	ST		C		C		BT	100
	V	3	200		ST		BE	R	ST	R	C		BE		ST		C	200
	e	4	100		C		C	R	C	R	C		C		C		C	100
	r	5	200		BE		ST	R	BE	R	C		ST		C		BE	200
	t	6	100		C		C	R	C	R	C		C		C		C	100
	i	7	200		C		BE	R	C	R	ST		C		BE		ST	200
	c	8	100	MB	C	MB	C	R	C	R	C	O	C	MB	C	O	C	100
	a	9	200		ST		C	R	ST	R	C		BE		ST		C	200
	l	10	100		C		C	R	C	R	C		C		C		C	100
		11	200		BE		ST	R	BE	R	C		ST		C		BE	200
		12	100		C		C	R	C	R	C		C		C		C	100
		13	200		C		BE	R	C	R	ST		C		BE		ST	200
		14	100		BT		C	R	C	R	C		C		C		BT	100
Total		**m**	**21**															**21**
			No of trees (seeds) row -1															
BT			**4**		**2**												**2**	
ST			**15**		**2**		**2**		**2**		**3**		**2**		**2**		**2**	
C		**No.**	**58**		**6**		**8**		**9**		**10**		**9**		**9**		**7**	
BE			**13**		**2**		**3**		**2**		**0**		**2**		**2**		**2**	
R			**26**		**0**			**13**		**13**								
MB (seeds)			**1.880**	**416**	**0**	**1,248**								**416**				
UL (seeds)			**2.275**		**325**		**325**		**325**		**325**		**325**		**325**		**325**	
O			**Open space for further crops**															
Trees*			**32**		**6**		**5**		**4**		**3**		**4**		**4**		**6**	

Source: Own illustration
* incl. banana / enset
For shortcuts see Table 43

Table 43. Number of plants

Plot +15%	Plant type	Short cut (comp. Table 42)
4	Big tree	BT
15	Small (Legume) tree	ST
67	Coffee	C
13	Banana/enset	BE
30	Rosemary	R
1,914	Maize + beans	MB
2,616	Under-sown legumes	UL
0	**Open space for further crops**	O

Source: Own illustration

12.3 Economic considerations

The question arises how far the implementation of e.g. banana into the coffee system is economically advantageous. One example from Uganda (CIALCA, 2010) introduces a banana-coffee intercropping comparison of revenues per ha a^{-1}, which shows an economic advantage of banana and coffee intercropped (4,450 USD ha^{-1}) in comparison to coffee mono-cropped (2,400 USD ha^{-1}) or banana mono-cropped (1,700 USD ha^{-1}). The same is reported from agroforestry home gardens in Ethiopia when compared to non-agroforestry gardens (Linger, 2014). Furthermore, climate resilient strategies, such as the integration of shading trees, are economically of high relevance to keep coffee production resilient in terms of plant health and productivity.

An often posed question is whether certification guarantees higher income for the farmers through better prices (see Jena, Chichaibelu, Stellmacher & Grote, 2012). Insignificant premium prices, as well as poor access to credit and information from the cooperative is discussed. As a consequence, farmers and cooperatives need a monitoring scheme and advise on how to manage the coffee in a proper way and make the OF approach also economically competitive.

12.4 Further information

- Hirons et al. (2018)
- Tsegaye (2017)
- The Consortium for Improving Agriculture-based Livelihoods in Central Africa (CIALCA): www.cialca.org, https://www.youtube.com/watch?v=YYlQYmC1CiU

13 Grassland

Section 13 introduces the diverse pasture types, cut and carry systems for fresh fodder, hay and silage production, and species characteristics to optimise grassland performance.

13.1 Pasture types

Currently, pasture productivity is often below 1 t DM ha^{-1} a^{-1}. The oftentimes unregulated, free grazing practices hinder a production of high quality feed. Overgrazing, a lack of additional seeding and pasture management lead to erosion, landslides, and low productivity. However, there are diverse pasturing types that allow an environmental sound and efficient use of grassland (Table 44), to increase animal productivity and income.

Table 44. Animal pasturing types

Type	Description	Advantages	Disadvantages
Free grazing	Animals are moving with a cowboy anywhere.	Diversity of feed.	Low energy and protein density, labour demand.
Continuous grazing	Animals are moving free in a fenced pasture.	Low workload.	Quality of pasture might be low, risk of overgrazing.
Rotational grazing	Fenced areas, animals move from area to area, all the same size.	High forage quality.	High management demand.
Strip grazing	Animals get stepwise a new share of pasture.	High forage quality.	High management demand.
Arable land after harvest	Animals are moving with a cowboy.	Additional feed at the end of the season.	Soil compaction risk.

Source: Own compilation

13.2 Cut and carry systems

There is a saying that grassland is the mother of arable land due to the manure that is produced through animal feeding and manure collected, at least overnight, in stables, and finally distributed on arable land.

However, currently grassland management is of low quality, and far away to do this saying justice. Seeding with adapted plants, adapted cutting, and fertiliser systems are missing. The amount of animal manure is low or mostly lost, i.e. nutrients washed out or transferred to arable fields. As a consequence, grassland productivity is low. In the next years, cut and carry with the classical pasture systems will be an exception. In the meantime, hybrid grass species for a monocrop production of grass, like Napier grass or *Brachiaria spp*., could provide a relevant amount of forage specifically in the Kafa Zone, with its relatively high rainfall. If space is limited due to competition with cash crops, every piece of land where erosion control measures are obviously necessary, hybrid grass stripes for cut and carry purposes should be established.

13.3 Grassland vegetation

Pastures are often poor in species and overused, and therefore ask for a re-seeding of the sward. For refreshing the sward, a mixture of grass and leguminous species is recommended (Table 45).

Before sowing during the first half of the rainy season, the soil has to be slightly opened with a harrow. After sowing, the pasture should not be used for six weeks to not threaten the establishment of the new plants. Fencing is a must and should be regulated and protected by the community. Additional manure is not a must, however small amounts of farmyard manure compost have a positive effect on plant growth. Refreshing the pasture with new plants leads to a potential biomass yield increase of 100-300%, which will have a similar impact on animal performance.

Table 45. Species for optimising pastures / grassland use

Species	Soil characteristics	Altitude M.a.s.l.	Rainfall mm	Utilisation	Yield t DM ha^{-1} a^{-1}	Plant characteristics
			Grasses			
Brachiaria brizantha	Loamy soils	Up to 2,000 m	1,500-3,500	Pasture, cut & carry, soil conservation	8- 20	Can be heavily grazed.
Panicum coloratum	Fertile sandy to clay soils	Up to 2,100 m	400 – 2,000	Pasture or hay	4-23	Hardy species but should not be grazed during establishment, good with legumes.
Pennisetum purpureum	Well drained soils	Up to 2,000 m	200-4,000	Mainly cut & carry	20-80 (+ fertiliser) 2-10 (- fertiliser)	One of the highest yielding tropical grasses! Grazing at six to nine week intervals at a height of about 90 cm gives good utilisation.
Cynodon dactylon	Thrives best on heavier silt	Up to 2,600 m	625-1,750	Pasture, hay, cut & carry	5 - 15	Very resistant and robust grass, should be grazed heavily; potential weed!
Setaria sphacelata	Thrives on fertile loamy soils	Up to 2,600 m	>750	Pasture, cut & carry, soil conservation	10 - 15 (Up to 25 when fertilized)	Can be sown with companion legumes, only light grazing until establishment.
Cenchrus ciliaris	Light, sandy, rocky soils	Up to 2,000 m	375-750	Mainly pasture	2 - 18	Needs time to establish (up to six months), good in combination with *Chloris* or *Megathyrsus.*
Paspalum dilatatum	Heavy clay soils	Up to 2,300 m	900-1,300	Mainly pasture	3- 15	Resistant to heavy grazing, good in combination with *Cynodon* or *Trifolium.*
Avena sativa	Best in loam soils	Best above 2,000 m	>800	Pasture, cut& carry, hay	4- 15	Often sown in mixture with legumes; light and continuous grazing is recommended, should not be grazed when the soil is very wet.
Chloris gayana	Wide range	Up to 2,400 m	310-4,030	Pasture, hay, cover crop	10-16	Drought resistant, grazing should not be too heavy; grows well with legumes, *Setaria, Avrna, Chenchrus, Megathyrsus.*
Megathyrsus maximus	Well drained, moist and fertile soils	Well adapted to sloping, cleared land in rainforest areas	>1,000	Pasture, cut & carry, hay, silage	25- 30 (+ fertiliser) 5-7 (- fertiliser)	Should not be grazed under 35 cm height; helps to prevent soil erosion, but can become a weed in not grazed areas.

			Legumes			
Arachis pintoi	Wide range, well drained	Up to 1,400 m	>1,100	Pasture	1-5	Tolerant to heavy grazing and compatible with aggressive grasses such as *Brachiaria*.
Vicia sativa	Wide range	Originated in southern Europe	310-1,630	Pasture	1-6	Susceptible to drought in first phases of development; overconsumption can lead to gastrointestinal problems in livestock.
Medicago sativa	Best on deep, well drained, sandy to fertile loamy soils	Up to 2,400 m	600-1,200	Pasture, cut & carry, hay, silage	15-25	One of the most important forage legumes; does not tolerate close grazing well, and some form of rotational grazing is necessary to maintain the persistence and production of plants.
Lablab purpureus	Wide range	Up to 2,400 m, but prefers lower altitudes	2,500-3,000	Pasture, cut & carry, hay, silage	2-9	The crop should be first grazed about 10 weeks after sowing, does not withstand heavy grazing; may cause bloat; a well-managed stand can provide three grazing periods per season.
Desmodium spp.	Wide range (pH above 4,5)	Up to 2,500 m	900 -3,000	Pasture, cut & carry, hay, silage	12-19	Can be grazed as a long-term pasture, requires a well-prepared seed-bed for establishment; grows well with a wide variety of grasses; initial grazing should be very light to permit establishment, rest periods minimum 3-12 weeks.
Trifolium pratense	Wide range; prefers well drained loams	Can be grown at high altitudes	310- 1,920	Pasture, cut & carry, hay, silage	4- 20 (Pure stands, very region-dependent)	Red clover can replace alfalfa in areas too wet or too acidic for it; can be major source of honey; rotational grazing is best suited for persistence; during the year of establishment, light grazing is recommended.

Sources: feedipedia.org; Indian Grassland and Fodder Research Institute; INRA; CIRAD; AFZ; FAO

13.4 Pasture management

Uncontrolled, free grazing, which is commonly practiced in the area, leads to many problems. Animals eat the most palatable plants first and with a short recovery time, they will eventually die off. At the same time, weeds and plants of lower palatability will spread. In the practice of rotational grazing, a high stocking rate is kept on a smaller paddock for a short period of time, followed by a period of rest. Although paddock construction and moving the animals requires more labour demand and fertiliser input (manure), the advantages of rotational grazing are manifold (Table 46). Pastures are grazed more efficiently, grass nutritional value is higher, and weeds are better suppressed. Strip grazing follows the same principle. To reduce weed pressure, pasturing with different animals contributes to the control of grassland weeds and the regrowth of a diverse plant family.

Table 46. Rotational grazing: effect of the herbage growth rate on number of paddocks

Herbage accumulation rate*		Stocking rate	Return to the plant***	Period of		Paddocks
kg DM ha^{-1} day^{-1}	cm day^{-1}	AU ha-^{1}**	days	Occupation (days)****	Resting (days)	n
20	0.5	1	30	30	30	2
44	1	2	15	15	30	3
60	1.5	3	10	10	30	4
80	2	4	7.5	7.5	30	5
100	2.5	5	6	6	30	6
120	3	6	5	5	30	7
200	5	10	3	3	30	11

Source: Adapted from Corsi, Martha , Nascimento & Balsalobre (2001)
AU = animal unit (500 kg = 2 TLU, Table 49); DM = dry matter; * = herbage density of 40 kg DM cm^{-1} ha^{-1}; ** = Intake of 10 kg DM AU^{-1} day^{-1}; *** = Assuming the animal returns to the same patch grassland when regrowth is about 15 cm high; **** = Assuming the animal must not return to a given patch faster than the established period of time.

13.5 Silvo-pastoral systems

Pastures can be improved by additional seeding of suitable grass and legume species (Table 45) and/or the inclusion of trees (silvo-pastoral system). In such systems valuable fodder trees and shrubs (Table 37) are interplanted in a pasture. Silvo-pastoral systems provide several benefits (Table 47):

- No need for fertiliser due to nitrogen fixing trees.
- Higher fodder yield per m^2 and fodder trees with high palatability.
- Reduced disease risk for animals, additional habitats attract beneficial organisms which naturally control tick populations.
- Less land for producing more meat.
- Less methane emissions.

Rotational grazing is recommended to avoid continuous tree damages.

Table 47: Effects of different pasturing systems on meat production and methane emissions

Measure	Unit	Conventional extensive pasture	Improved pasture without trees	Intensive silvo-pastoral system*
Animal load	Large animals ha^{-1}	0.5	1	3
Per animal weight gain	kg day^{-1}	0.37	0.5	0.75
Per hectare weight gain	kg ha^{-1}	0.185	0.5	2.25
Annual meat production	kg ha^{-1} yr^{-1}	67.5	182.5	821.3
Methane emissions of 1 t meat	kg CH_4 ton^{-1}	229.5	208.2	127.9
Land area to produce 1 t meat	ha ton^{-1} a^{-1}	14.8	5.5	1.2

Source: Broom, Galindo & Murgueitio (2013)
* in this example, a very high density (10,000 shrubs ha-^{1}) of *L. leucocephala* has been planted

13.6 Further information

- http://www.igfri.res.in/pdf/old_bulletins/tropical_pasture.pdf
- https://idl-bnc-idrc.dspacedirect.org/bitstream/handle/10625/21121/IDL-21121.pdf?sequence=1
- http://www.fao.org/3/i2433e/i2433e07.pdf

- http://www.fao.org/agriculture/crops/thematic-sitemap/theme/compendium/tools-guidelines/how-to-management-grassland-and-pasture-areas/en/
- http://www.fao.org/agriculture/crops/thematic-sitemap/theme/spi/scpi-home/managing-ecosystems/management-of-grasslands-and-rangelands/en/
- http://www.fao.org/ag/againfo/themes/documents/PUB6/P614.htm

14 Livestock

Section 14 gives general information about animal husbandry, including the specific rules for housing in organic farming, the demand for land, feed, forage per animal and forage balances.

14.1 Animal husbandry in organic agriculture

Animal husbandry is a traditional part of smallholder farmer activities. Animal husbandry, and specifically cow milk production, is of importance for the integration of forage legumes into the cropping system and their efficient use. Animals are mostly kept outside, e.g. in a kraal, or living in the house, together with the people, or in small stables.

Three important IFOAM norms guide the establishment of animal housing in organic agriculture (OA):

1. "The operator shall ensure the following animal welfare conditions:
   a) Sufficient free movement and opportunity to express normal patterns of behaviour, such as space to stand naturally, lie down easily, turn around, groom themselves and assume all-natural postures and movements such as stretching, perching and wing flapping;
   b) Sufficient fresh air, water, feed and natural daylight to satisfy the needs of the animals;
   c) Access to resting areas, shelter and protection from sunlight, temperature, rain, mud and wind adequate to reduce animal stress."

   (IFOAM norm 2021, point 5.1.3)

2. "All animals shall have unrestricted and daily access to pasture or a soil-based open-air exercise area or run, with vegetation, whenever the physiological condition of the animal, the weather and the state of the ground permit. Such areas may be partially covered. Animals may temporarily be kept indoors because of inclement weather, health condition, reproduction, specific handling requirements or at night. Lactation shall not be considered a valid condition for keeping animals indoor."
   (IFOAM norm 2012, point 5.1.8)

The last point is often difficult to apply in tropical smallholder systems, but there are many ways that try to solve this. Therefore, the newest version of IFOAM norms also adds that:

3. "On holdings where, due to their geographical location and structural constraints, it is not possible to allow free movement of animals, tethering of animals may be allowed for a limited period of the year or of the day. In such cases, animals may not be able to turn around freely but other requirements of 5.1.3 must be fulfilled."

IFOAM norms (Table 48) also note that herd animals may not be kept in isolation from other members of the species. In special cases (keeping males from females, diseases) or if smallholders can only afford one animal, isolation is acceptable. If the farm only has one animal of a species, close human contact or contact with other animal species is recommended.

Dependent on the feed source, i.e. the size of the grazing area, additional land is necessary to cover the feed demand. To collect animal manure, separate units for animals are necessary. Straw that could be used for the uptake of urine is limited and often used as forage. Under high rainfall conditions, slurry and water management is a must, organised via roofing, channelling, and collecting the slurry. A combination with biogas production is always advantageous (see section 20).

Table 48. Animal indoor spacing and feeding area (stable / pasture / arable land / alleys)

Animal	Unit	Min. indoor space animal	Min. outdoor space	Pasture	Forage	Alley	Water consump-tion per animal	Remarks
	No.	m^2 animal^{-1}*	m^2 animal^{-1}	ha	ha	m	l day-^{1}	
Cow (300-400 kg)	1	6	4.5	0.3	0.3	10	30-80	0.4 ha fodder crops per cow in zero grazing systems; 1 ha per cow if 100% pasture.
Cattle	1	5	4	0.3	0.1	8	30-80	
Steer	1	10	30	0.3	0.2	2	30-80	If together with herd, run out 9 m^2.
Sheep	1	1.5	2.5	0.05	0.05	2	5-20	0.5 m^2 space per lamb.
Goat	1	1.5	2.5	0.03	0.05	2	5-20	0.5 m^2 space per fawn.
Pigs (>40 kg)	1	1.5	1.2				15-25	
Sow + piglet	1	7.5	2.5				10-25	
Broiler	6	1	60	5 m^2		0.5	0.5-0.75	
Chicken	6	1	60	5 m^2		0.5	0.5-0.75	
Donkey/ horse	1	6	12	0.1	0.1	5	10-25, twice a day	
Rabbit	1	1.6	1.2	10 m^2	10 m^2	1	50-150 ml kg^{-1} LW	

Sources: Own compilation; (EG) Nr. 834/2007; * Kraal (see Excel for own calculations); www. infonet-biovision.org

Furthermore, sufficient water is a must for healthy animals. Ideally, they should have access at all times. Roughly calculated, the water demand per cow is 1 l per 10 kg live weight, plus 1.5 l per 1 l of milk produced (see Table 48). For example, a cow with 300 kg live weight and a milk yield of 10 kg a day needs 30+15 = 45 l of water every day.

14.2 Forage balances

Animal feed in organic farming (OF) is mainly based on farm own roughage. Feed deficits lead to a loss of animal performance, and the recreation time to become productive again is increasing and economically critical. To maintain and increase animal performance, forage supply and demand should be planned in advance.

Forage balances are an instrument to approximately estimate the demand and supply of forage. Yields of forage crops can vary according to seed quality, rainfall, and overall crop management. Forage demand has to be adapted to the breed, age and, in case of cows, to their milk productivity. For planning, the tropical livestock unit is defined with 250 kg (Table 49), which is of relevance for the rough estimation of forage, approximately 2.2 kg DM 100 kg-1 LW (Table 51).

For rough planning, a forage balance based on DM quantity is enough. However, specifically for the milk production, a more detailed energy and protein calculation is necessary. Depending on the source, the following DM intake requirements for animals may vary, and care has to be taken to observe livestock response to adapt requirements to farm-specific conditions!

Feeding cereals to ruminants is not an economic option, if the potential for roughage production is high, which is the case for the Kafa Zone. An exception are residues from cereals and grain legumes. The main forage mix is based on forage legumes and Napier grass or similar grasses, stover and crop residues (Table 51), pasture, alley trees and shrub branches (see also Table 115 for other feed). Three feeding intensities provide a general overview on the amount of forage per year (Table 50).

Table 49. Tropical livestock unit

Animal	kg LW	TLU
Cattle in herd	175	0.7
Cow	250	1
Sheep	25	0.1
Goat	20	0.08
Donkey	125	0.5
Camel	313	1.25

Sources: Diverse sources; own data (Excel)

Table 50. Approximate feed requirements per herd TLU / animal in low to high technology input systems

Livestock system	**Input level per herd TLU kg day^{-1} DM**			**Input level per animal kg day^{-1} DM**		
***Non-pastoral (>120 days LGP)**	**Low**	**Intermediate**	**High**	**Low**	**Intermediate**	**High**
Cattle	7.8	8.5	8.9	7.8	8.5	8.9
Goat	10.0	11.5	16.1	0.8	0.9	1.3
Sheep	9.1	11.3	11.6	0.9	1.1	1.2

Source: FAO
LGP = Length of growth period, DM = dry matter
*non-pastoral systems: feed intake from crop residues restricted to 30% (low), 20% (intermediate), and 10% (high) of diet

There are several commonly available options for making effective use of shrub and tree foliage. Trees and shrubs provide green biomass of moderate to high digestibility and protein content when other feed reserves are scarce and low in nutrient quality. One of the most successful methods is the cultivation of *Leucaena leucocephala* as a palatable, high-protein browse, or cut and carry feed component, often used with crop residues or native grasses as the basal roughage (for more information see Renard, 1997).

Forage balances give important information, e.g. if animals are undernourished, when the current system does not provide enough forage for the given animal density in smallholder farms (Table 51**)**. Following the feeding ratio definition of animal feed demand, 1 ha is necessary additionally, or approx. 2 t of concentrates, assuming their nutrient and protein content is two times higher than of the mostly pure overgrazed grasslands.

Table 51. Forage balance (roughage) for an average animal husbandry group in a smallholder farm per year

Forage supply Crops	Yield DM kg ha-1	Area ha		Margin DM t ha-1	Total yield DM kg ha-1
Forage legume	8,000	0.1		5-1	800
Napier grass	10,000	0.1		7-15	1,000
Alley branches	2,000	0.1		1-4	200
Pasture	1,500	0.1		0.5-3	150
Maize stover	1,000	0.1		0.5-2	100
Teff straw	500	0.1		0.25-2	50
Free grazing for covering the feed deficit	1,000			0.5-2	
Total forage supply		**0.6**			**2,300**
Forage demand Animal	**Animal weight kg LG**	**Demand** DM kg day-1**	**Animals No.**	**Days No,**	**Total demand DM kg a-1**
Cow	300	6.6	1	365	2,409
Calve	65	1.43	1	200	286
Cattle	300	6.6	1	365	2,409
Oxen	400	8.8	1	365	3212
Sheep	25	0.55	1	365	201
Goat	15	0.33	1	365	120
Donkey	200	4.4	1	365	1,606
Rabbit	2	0.044	10	365	161
Total forage demand					**10,404**
Forage balance					**-8,104**
Covering via free grazing					**Approx. 8 ha**

Sources: Own compilation, different sources
Remark: Excel B2; ** 2.2 kg DM 100 kg-1 LW; * Desmodium, clover, alfalfa or mucuna; calculation of dry matter (Broom et al., 2013): Fresh matter (FM) x 0.8 directly after harvest.
Forage balances have to be positive or at least neutral. In this case, the provided crops and area would be barely enough to feed one cow. The given forage balance is negative due to the exemplary housing of every kind of farm animal and thereby acts only as draft. It can be found and modified in the additional materials provided together in this handbook.

Dependent on the lactation period and milk performance, feeding demand as well as specifically protein differs (Table 52). The diverse digestibility of the forage sources is of relevance, as the feed demand of animals for milk production increases accordingly.

Table 52. Quantities and qualities of feed fed to different species within household premises

Animal category	Feed types				Nutrients	
	Green fodder*	Dry fodder	Concentrates	Dry matter***	Total digestible nutrients (TDN)	Digestible crude protein (DCP)
Unit	kg DM	kg DM	kg DM	kg DM	TDN	DCP
Cattle						
In milk	4.75	5.50	0.64	6.71	3.44	0.27
Dry	3.40	4.02	0.40	4.83	2.46	0.18
Adult male	4.06	6.03	0.33	6.74	3.36	0.21
Young stock	2.18	2.13	0.18	2.62	1.33	0.10
In milk	5.96	6.34	1.05	8.14	4.25	0.37
Dry	5.44	4.95	0.52	6.28	3.21	0.25
Adult male	4.04	7.47	0.36	8.06	3.99	0.24
Young stock	2.29	2.22	0.19	2.74	1.39	0.10
Goat	1.04	0.20	0.06	0.49	0.27	0.03
Sheep	1.01	0.20	0.04	0.46	0.24	0.03
Others**	2.35	6.72	0.49	7.08	3.54	0.22

Source: NATP project database
* Includes cultivated fodder, and the fodder gleaned and gathered from cultivated and uncultivated lands
** Includes camel, horse, donkey, and mule; *** Broom et al. (2013)

14.3 Further information

- http://www.fao.org/3/t0828e/T0828E12.htm
- http://www.fao.org/3/t0828e/T0828E00.htm#TOC

15 Dairy cattle

Section 15 provides the most relevant key data for dairy cattle, including herd size, dairy breeds, feeding strategies dependent on the expected / planned milk production, minimum hygienic standards, and examples for housing.

15.1 Herd composition and stocking rate

Herd composition is important to ensure the annual replacement of old and milked-out cows. The ratio of cows to followers (heifers, calves) should be around 2:1, which allows the selection of the best breeds. The overall stocking rate will depend on the available grassland, forage legumes, and grasses like Napier grass or *Brachiaria spp*. and other high value grasses (see also demand for land, Table 51).

The quality and amount of produced feed influences the stocking rate (
Table 53). Grazing systems generally need more land than cutting systems (zero grazing), due to the often low quality of the grassland. In general, the aim should be to feed with optimised pastures, where management is on a high level, and grassland for cutting, forage legumes, high yielding grass, alley shrubs and tree branches is provided.

Table 53. Stocking rates of cattle under different production intensities

Feeding quality	TLU* ha^{-1}	Roughage	Concentrates
High	3-4	Forage legumes, high yielding grasses, optimised pasture systems, etc.	++
Medium	1,5-3	Lower yielding grasses, interspersed shrubs.	+
Low	1	Overgrazed pastures, residues from arable lands, weeds.	-

Source: Own compilation
* 1 TLU (tropical livestock unit) is defined with 250 kg live weight (see Table 49)
-, +, ++: low to high addition of concentrates

15.2 Dairy breeds

The right breed of cattle depends on environmental and management factors. In organic systems, the choice of locally adapted, hardy animals that show a long productivity is generally advised over high-yielding, susceptible breeds (Table 54). These breeds should only be chosen if adequate care and feeding can be guaranteed.

Table 54. List of potential indigenous and exotic dairy/ dual purpose cattle breeds

Name of breed	Purpose In order	Milk yield Ø l /day^{-1}	Lactation period Ø days	Average body weight kg	Remark
Abergele	Drought, meat, milk	1-1.5l	150	140 – 170	Tolerant to heat, parasites and diseases, ability to cope with feed shortages. Low yields.
Afar	Milk, drought	5	250-290		Resistant and adapted to harsh conditions. Low yields.
Ayrshire	Milk	10	300	450	High yield potential, good milk composition. Relatively adaptable and resistant. High feed and water requirements.
Begait	Milk, drought	5	250-300	250-300	Adapted to hot climate and water shortage. Low yields.
Boran	Dual purpose	2.5-10	250-300	250-300	Heat and drought tolerant, well developed herd instinct, excellent mothering ability, docile, long-lived. Difficult to breed, low yields.
East African Zebu	Dual purpose	5	250-300	250-300	Very hardy and resistant. Low milk yields, late maturing.
Friesian/ Holstein	Milk	Up to 50	300	550- 650	Highest potential milk yield of all breeds, frequent calving. Need high level of management for high yields, heavy feeder, susceptible to diseases and high temperatures.
Fogera	Drought, meat, milk	2	250-300	250-300	Adapted to swampy conditions, tolerate flies and ticks.
Guernsey	Milk	Up to 25	300	475	High milk yield potential, good feed converter, minimum calving complications. Need plenty of clean water.
Horro	Drought, meat, milk	4-5	100-240	320-480	Adapted to humid conditions.

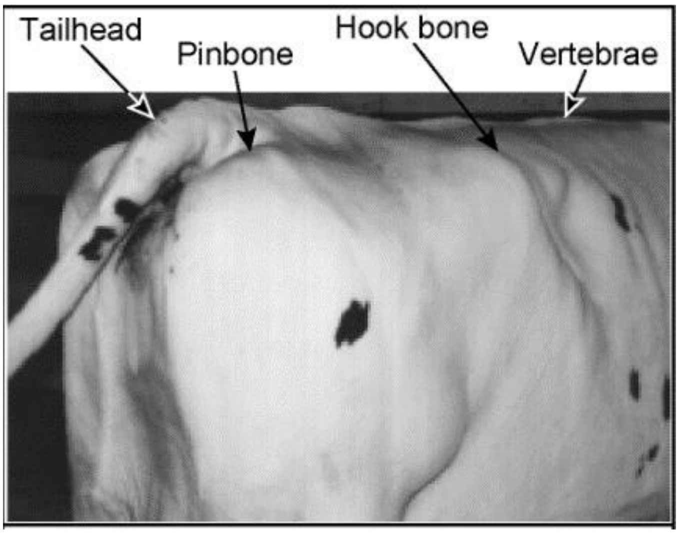
Jersey	Milk	22	300	350	High yield with small bodyweight, milk with high butter fat content (5.2%), relatively hardy, high fertility, suitable for crossbreeding, longevity. Susceptible to milk fever and tick-borne diseases.
Raya	Drought, meat, milk	3	210	210-230	Adapted to local conditions (Tigray) and as drought animals.
Sahiwal	Dual purpose	5-10	250-300	350-400	Docile, adapted to harsh conditions, milk with high butter fat content (4.8%). Difficult to breed.
Sheko	Milk, meat, drought	2	250-300	200	Adapted to humid areas in south-western Ethiopia.

Sources: https://www.infonet-biovision.org/; Hailu (2018)

15.3 Dairy health

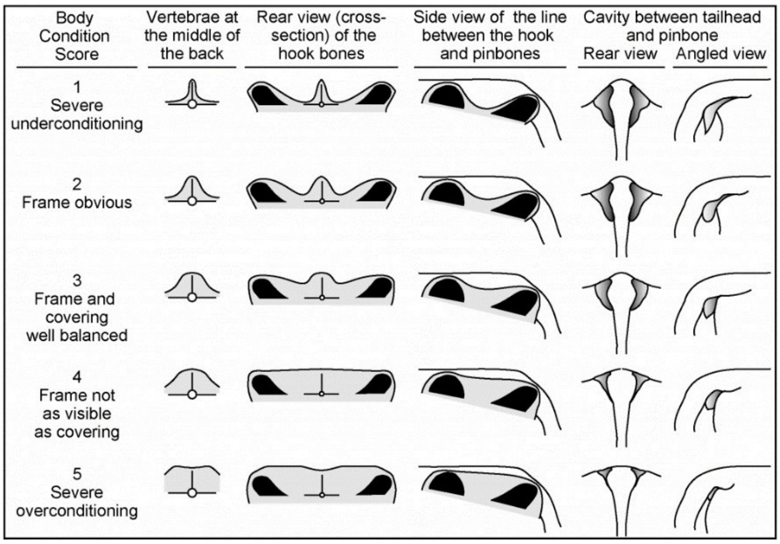
Increased production of milk is demanding the cows, therefore animals should be surveyed closely on their health and feeding status. The body condition score (BCS) for cows tells much about the health and feeding status of an animal and is determined by observing the animal's rump area (Figure 12 and Figure 13). Cows are ranked on a scale from 1 (severe under-conditioning) to 5 (severe over-conditioning). A low score indicates a lack of adequate nutrition, a high score indicates an imbalance in nutrition (not enough protein). A BCS of 2.5 - 3 indicates a healthy animal.

Figure 12: Identification of body parts used for the BCS



Source: Babcock institute, adapted after Edmonson, Lean, Weaver, Farver & Webster (1989)

Figure 13: Body condition scores (BSC)



Source: Babcock institute, adapted after Edmonson et al. (1989)

15.4 Feed ratios for cows

Feed ratios depend on the breed and the performance potential of cows (see also section 15.2). The higher the targeted milk yield, the more relevant is feed amount and quality. Currently, milk yield per lactation period is often around 1,000 kg or even below, although most dairy breeds would be capable of producing 3 – 4,000kg! This is most often the result of poor feeding and watering. When feeding dairy, some general aspects have to be considered (Table 55).

Table 55. Topics to be considered when producing dairy

Topic	Description	Remark
Water	See Table 48	Restricted access to enough fresh water is oftentimes the most restricting factor for milk yield in tropical countries.
Roughage	At least 60% of diet should be forage-based roughage to allow for adequate fibre levels; with increasing milk yield, forage has to be increasingly supported with supplements/ legumes/ concen-trates.	Inadequate levels of effective fibre lead to tumen acidosis.
Supplements/ concentrates	Supplement rations should be at a maximum of 40%.	It is advised to use supplementary feeds that can be produced on-farm!
Legumes & leguminous trees	Good source of protein and nutrients. Can easily be produced on-farm.	Do not feed more than 30% legumes in total diet, to avoid bloating issues.
Minerals & vitamins	Minerals, especially salt, should be provided daily.	1-2% of diet, e.g. Maclick super.
Temperature	Provide enough shading structures for the animals.	Heat stress induced feed uptake reduction and resulting lower milk yields are a common problem in the tropics.
Forage management practices	Cut/ graze forage at the right time, processing can be applied for better uptake (e.g. chopping, silage).	For example, Napier grass: Cut at the right time, after 35-40 days, wilting for one day before feeding increases DM %, chop before feeding for easier uptake.

Sources: FAO, various sources

For calculating dairy cattle feed requirements, several steps have to be followed (Table 56).

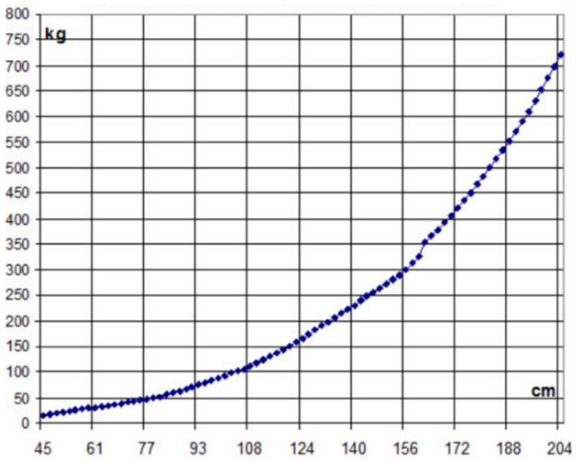
Table 56. Steps for dairy feed formulation

Step	Description	Example
1: Estimate live weight	Use chest girth measurement (Figure 14).	Cow with girth of 160 cm weighs approx. 300 kg.
2: Calculate maximum DM intake	Max DM/cow/day = 0.025*live weight + 0.1*kg milk (or see Table 57).	Cow with 350 kg and 5 l milk production: 0.025*350 + 0.1*5 = 9,25 kg / or around 10 kg. max. DM intake (Table 57).
3: Daily nutrient requirements per cow?	See Table 57	350 kg cow, 5 l milk per day = 72 MJ ME, 800 g CP, 27 g Ca, 27 g P.
4: Is the energy need being met?	Calculate weather available feedstuff meets energy requirements. Divide the ME requirement of the cow by the ME content of the available feedstuff (Table 58).	350 kg cow, 5 l milk, fed only Napier grass: 72 / 7.9 = 9.11 kg DM → this is below the max. DM intake of the cow, therefore possible! 450 kg cow, 20 l milk, fed only Napier grass: 161 / 7.9 = 20.4 kg DM of Napier grass → this is far above the max. DM intake capacity of the cow (17 kg), more diverse feedstuff needed!

5: Are nutrient requirements being met?	Estimate nutrients supplied by the feedstuffs (Table 58) and nutrient requirements (Table 57).	350 kg cow, 5 l milk, fed only Napier grass: Napier grass: (CP: 98, Ca: 3.6, P: 2.9) * max DM intake of 10: CP = 980 g (806 g required) Ca = 36 g (27 g required) P = 29 g (27 g required).
6: Estimate the amount of feed	Calculate amount of fresh feed from % DM (Table 58), include some margin for wasted food (e.g. 5%).	350 kg cow, 5 l milk, fed Napier grass: Napier grass has 20% DM (or 200 g/kg), Max. DM intake is 9.25 kg, 9.25 * (1000/200) = 46.24 kg fresh grass With 5% wasted feed: 46.24 * 1.05 = 48.5 kg fresh Napier grass per cow.

Source: https://www.infonet-biovision.org/
DM = dry matter, CP = crude protein, Ca = calcium, P = phosphorus

Figure 14. Live weight estimation using chest girth circumference



Source: Kenya Agricultural Research Institute (KARI)

Chest girth can be measured using a simple measuring band. The band is placed around the chest, a hand's breadth behind the front legs (not too tight). E.g. a cow with a girth of 172 cm will weigh approximately 400 kg. Nutrient requirements per animal vary greatly depending on live weight and milk yield, an approximation of these requirements can be found in Table 57.

Table 57. Daily nutrient requirements of dairy cows

Live weight kg	Milk yield kg (4% fat)	DMI kg	Metabolisable Energy (ME) MJ	Crude protein (CP) g	Calcium g	Phosphorus g
350	0	10	45.5	294	14	10
	5	10	72	806	27	27
	10	11	97	1,093	42	36
	15	13	123	1,393	57	45
400	0	10	50.3	318	16	11
	5	11	78	874	29	29
	10	12	103	1,161	44	39
	15	14	129	1,448	58	48
450	0	11	54.9	341	18	13
	5	11	84	946	31	32
	10	13	110	1,234	45	41
	15	15	135	1,521	60	50
	20	17	161	1,826	75	59

500	0	12	59.4	364	20	14
	10	14	113	1,275	46	43
	15	16	138	1,560	59	51
	20	18	162	1,823	74	59
550	0	13	63.8	386	22	16
	10	15	121	1,359	48	46
	15	17	145	1,635	61	53
	20	17	168	1,892	75	62
	25	21	194	2,179	90	71
600	0	13	68.1	406	24	17
	10	16	129	1,431	50	49
	15	18	152	1,710	63	55
	20	20	174	1,984	77	65
	25	22	201	2,262	91	75

Source: https://www.infonet-biovision.org/
DMI = Maximum dry matter intake

There is a long list of possible available feedstuffs (Table 58), which provides a rough and general estimation of the feed values of different roughage and concentrate sources.

Table 58. Nutritional aspects of some commonly available roughages and concentrates

Roughage	DM %	CP g	ME MJ	Ca g	P g
Acacia, husk	92	110	12.5	3.8	1.6
Acacia, leaves	38	151	10.6	17	1.8
African locust bean, pod husks	93	47	12.5		
African locust bean, pod pulp	35	49	12.4	13.2	17.6
Banana, leaves	94	146	8.7	7.5	2.4
Banana, stalks	7	51	7.5	7.5	2.9
Barley, straw	90	38	6.5	4.9	0.8
Calliandra	15	220	7.7	2	1.5
Camel's foot, leaves	90	153	11.3	8.2	3.9
Cassava, fresh foliage	22	249	9.9	11.9	3.7
Cassava, foliage silage	24	238	9.8	25.1	3.3
Cassava, foliage wilted	36	263	10.2	14	3
Coco hulls	88	178	5.4	3.7	4.4
Coffee hulls	88	94	7.2	4.5	1.4
Coffee leaves, dried	92	167	3.6	6.2	1.2
Columbus grass, fresh	17	100	8.7	4.5	4.1
Cotton seed hulls	91	60	7	1.7	1.4
Cowpea, aerial parts, fresh	20	181	9.8	13.2	2.4
Cowpea, husk	25	110	8.1	13	2.5
Desmodium	25	151	7.4	8.5	2.2
Grey love grass	23	153	9.7	9.3	2
Groundnut, forage	26	175	10.4	9.3	2
Guinea grass	22	112	8	4.9	2.4
Guinea grass, hay	92	43	7.6	4.7	2.6
Guinea grass, straw	89	91	7.7	4.6	3
Jackfruit, leaves	40	156	7.5	14.7	3.2
Kenya sheep grass	25	82	7.6	3.9	2.3
Kikuyu grass, aerial parts, fresh	20	151	9.7	3.1	3.7
Kikuyu grass, hay	90	113	8	3	3.9
Leucaena	29	233	11	10.7	2.1
Lucerne, fresh	19	205	9.3	19.5	2.5
Lucerne, medium fresh	20	180	9	14.1	2.2

Lucerne, hay	89	182	8.4	16.8	2.6
Maize, stover	28	69	9.3	3.7	2
Maize, silage	32	70	10.8	1.9	1.8
Mango, leaves	33	94	11.7	16.9	1.5
Mango, peels	15	62	11.9		
Napier grass, 40cm	20	98	7.9	3.6	2.9
Napier grass, 80cm	20	90	7	3.6	2.9
Napier grass, early bloom	25	72	6.2	3.6	2.9
Napier grass, hay	93	107	8	2.8	2.3
Napier grass, silage	27	66	7.2	2.5	3.6
Neem tree, leaves	34	166	7.7	20	2.5
Nile grass, aerial part, fresh	21	140	9.1		
Nile grass, aerial parts, hay	90	85	5.9		
Nile grass, leaves, fresh	21	213	10.3		
Oat, straw	87	102	8.3	4.7	2
Pawpaw, leaves	20	240	9.9	34.6	3.5
Pineapple, leaves	20	91	11.5		
Pumpkin, hulls	89	190	4.2		
Pyrethrum marc (extracted)	90	130	8.7		
Rhodes grass, hay	25	89	8.4	3.8	2.9
Rhodes grass, medium maturity	86	94	8	3.1	2.6
Rib grass, fresh	92	204	10	18.2	2.8
Rice straw	92	42	5.8	2.9	0.9
Sesbania	26	244	11.5	15.9	3.3
Sorghum, aerial parts, fresh	25	173	8.6	3.5	2.8
Sorghum, straw	93	37	7.3	3.1	0.7
Soybean, aerial parts	25	137	9.1	15.3	2.8
Star grass	30	228	6.2	1.8	1.6
Sugarcane forage, fresh	22	41	9.3	1.9	1.1
Sugarcane leaves, fresh	42	52	2.4		
Sunflower, stover	75	57	6.2	11.2	0.8
Wheat, straw	91	42	6.8	4.8	0.7

Feedstuff	DM	CP	ME	Ca	P
	%	g	MJ	g	g
Acacia, seeds	92	284	14.2	2.8	4.2
African locust bean, seeds	90	318	15.9	0.8	3.9
Barley, grain	87	118	12.4	0.8	3.9
Brewers grain, fresh	25	259	6.6	3	5.7
Brewers grain, silage	25	276	10.2	3	5
Cassava peels, dry	87	52	11.5	4.5	0.8
Cassava tubers, fresh	37	26	12.4	1.6	1.2
Cotton seed meal, high oil, high fibre	92	374	11.9	2.2	11.9
Cotton seed meal, high oil, low fibre	92	450	13.2	2	12.4
Cowpea, seeds	89	249	13.4	1.1	4.1
Maize bran	88	120	11.3	4.8	3.4
Maize grain and cobs	87	88	11.9	0.5	2.8
Mango, pulp	17	42	13.7	1.9	1.1
Millet, grain	90	142	12.2	0.4	3
Millet, husk	92	24	5.4		0.5
Pineapple, by-product	88	45	10.8	4.9	1.2
Rice bran	91	88	6.7	4.7	7.4
Sorghum grain, ground	87	108	13.5	0.3	3.3
Sorghum bran and milling offal	89	117	13.2	0.9	4.9
Soybean, cake (expeller)	90	493	14.7	4.6	7.2
Sugarcane molasses	73	55	9.6	9.2	0.7
Sunflower, cake	91	279	10.9	3.9	9.2

Sweet potato vines	15	132	8.8	12.4	3.1
Wheat, bran	87	173	11	1.4	11.1
Wheat, grain	87	126	13.1	0.7	3.6
Wheat, pollard	90	150	11.5	1	7

DM = dry matter, CP = crude protein, ME = metabolizable energy, Ca = calcium, P = phosphorus
Sources: www.infonet-biovision.org; www.feedipedia.org

The following tables provide some information for exemplary feed ratios for animals with different weight and milk yield using widely available feedstuff. Energy and nutrient demands are easily met in the first diet (Table 59). At the indicated level of milk production, feeding only with Napier grass would be sufficient, but more diverse feedstuff is recommendable to fully provide for protein, vitamin, and micronutrient needs of the animals.

Table 59. Example feed ratio cow, 350 kg weight, 2,000 kg milk a^{-1}

Feed	kg DM day^{-1}	ME	CP	Ca	P	kg FM day^{-1}	kg FM a^{-1}
Napier grass	9	71.1	882	32.4	26.1	45	16,425
Lucerne, fresh	0.5	4.5	102.5	1.25	6.5	2.5	960
***Gliricidia* leaves**	0.5	5.5	27.5	5.5	1.15	2	730
Sum	10	81.1	1,012	39.15	33.75	49.5	18,115
Requirement*	10	72	806	27	27		

Source: Own data, see Excel
DM = dry matter, CP = crude protein, ME = metabolizable energy, Ca = Calcium, P = Phosphorus; FM = fresh material; * see (Table 57)

The second example (Table 60) describes a situation, where the energy demand is just slightly met, while there is a surplus in protein. The addition of another feed source, with higher energy and lower protein levels, like residues from cereals, would be beneficial.

Table 60. Feed ratio cow, 400 kg weight, 3,000 kg milk a^{-1}

Feed	kg DM day^{-1}	ME	CP	Ca	P	kg FM day^{-1}	kg FM a^{-1}
Napier grass	7.2	56.88	705.6	25.92	20.88	36	13,140
Lucerne, fresh	2.4	21.6	492	6	31.2	12.6	4,610.5
***Gliricidia* leaves**	1.2	10.56	158.4	14.88	3.72	8	2,920
Sweet potato vines	1.2	13.2	66	13.2	2.76	4.8	1,752
Sum	12	102.24	1,422	60	58.56	61.4	22,422.5
Requirement*	12	103	1,161	44	39		

Source: Own data, see Excel
DM = dry matter, CP = crude protein, ME = metabolizable energy, Ca = calcium, P = phosphorus; FM = Fresh material; * see (Table 57)

The third example (Table 61) uses the same diet but adapted to higher yielding and higher animal weight. As before, fresh lucerne is included in the diet. As protein levels become lower in older plants, the diet can still be maintained with lucerne of medium hay quality.

Table 61. Feed ratio cow, 450 kg weight, 4,000 kg milk a^{-1}

Feed	kg DM day-1	ME	CP	Ca	P	kg FM day-1	kg FM a-1
Napier grass	7.8	61.62	764.4	28.08	22.62	39	14,235
Lucerne, fresh	2.6	23.4	533	6.5	33.8	13.7	4,994.7
***Gliricidia* leaves**	1.3	11.44	171.6	16.12	4.03	8.7	3,163.3
Sweet potato vines	1.3	14.3	71.5	14.3	2.99	5.2	1,898
Sum	13	110.76	1,5405	65	63.44	66.6	2,4291
Requirement*	13	110	1,234	45	41		

Source: Own data, see Excel
DM = dry matter, CP = crude protein, ME = metabolizable energy, Ca = calcium, P = phosphorus; FM = fresh material; * see (Table 57)

Currently, 4,000 kg per cow is an exception and if so, mostly concentrates or residues from industries are added in a serious amount, while feed like lucerne or *Gliricidia* is hardly used. Kafa Zone has a relatively short period without rainfall, enabling farmers to prepare silage from lucerne and still having enough Napier grass.

15.5 Cattle housing

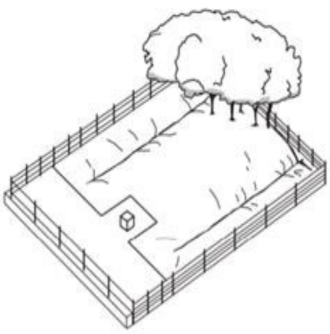
To ensure animal welfare, as well as efficiency in production and reproduction, cattle has to be kept safe from heat stress, particularly direct sunshine. Thus, some kind of shading structure is essential. A structure allowing 2.5–3 m^2 per animal will give the minimum desirable protection for cattle, whether for one animal belonging to a smallholder or many animals in a commercial herd. A 3 x 3 m roof will provide adequate shade for up to three cows. The roof should be min. 3 m high to allow air circulation. Roof water should me collected to reduce the mud in the yard. More adapted to the climate and economic circumstances are silvo-pastoral systems where shadow is provided by trees. These IFOAM guidelines, however, will not always fit available space and financial circumstances of all farmers.

15.5.1 Earth mounds

If housing structures are unaffordable for smallholders, the construction of a yard with an earth mound and draining ditches (Figure 15, Figure 16) can be an alternative. 15 to 25 m^2 per cow should be considered. The soil in the mounds can be stabilized with chopped straw or straw and manure. The yard has to include trees for sufficient shading. However, if these measures are realistic for a smallholder farm must critically be discussed.

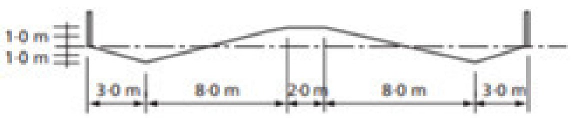
Latest before the rainy season, the mound will be used as manure and transferred to the crops. Management of manure depends on amount, ensuring that the animals stay clean and losses of nutrients are minimised.

Figure 15. Fenced earth mound with paved feeding area



Source: Mrema, Gumbe, Chepete & Agullo (2012)

Figure 16. Dimensions for an earth mound

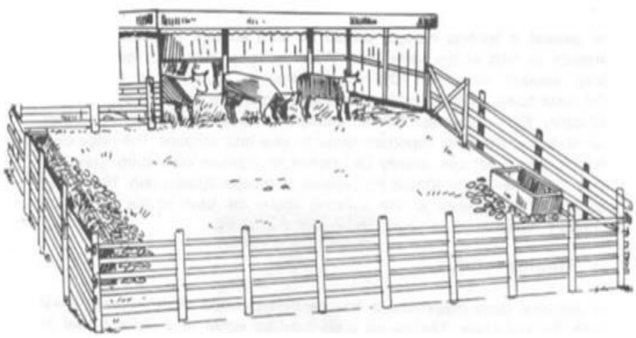


Source: Mrema et al. (2012)

15.5.2 Loose housing

Loose housing describes a system in which animals move freely, except for milking or treatment. It consists of an open paddock and a partially covered house. Such systems are cheap to construct and easy to expand (Table 62, Figure 17). Feeding and watering is comfortable and the free movement is good for animal welfare. Dung collection is more time consuming than in closed housing systems and care has to be taken to keep the stalls clean. This type of housing system is suitable for all kinds of livestock.

Figure 17. Typical loose housing system



Source: Felleke, Woldearegay & Haile (2010)

Table 62. Floor and trough space requirement of dairy cattle in loose housing

Type of animal	Floor space per animal		Trough length per animal in cm
	Covered area m²	Open area m²	
Cows	6 - 9	24 - 30	51 - 61
Young stock	4.5 - 6	15 - 18	38 - 51
Pregnant cows	12	55 - 61	61 - 76
Bulls	12	61 - 120	61 - 76

Sources: Own compilation, modified after SNV (2017); Mbindyo, Gitao & Peter (2018)

15.5.3 Closed housing

The construction of a cattle shed offers many advantages. It can be used for feeding and milking and makes the collection of dung and urine possible. The availability and cost of building materials will ultimately decide what can be used in construction. It does not matter which kind of timber is used for support, or which sheets or tiles are used for the roof, but at least a partly cemented floor is of highest priority, to allow for the collection of animal excretions and to facilitate cleaning.

15.5.4 Zero-grazing system

When faced with limited, overgrazed or degraded pasture land, the establishment of a half zero-grazing (hours outside the stable are limited) establishment is recommended (Table 63).

Table 63. Advantages and disadvantages of a zero / half zero-grazing system

Advantages	Disadvantages
Controlled handling, observation, feeding, herd management	Investment costs might be high
Higher milk production	Higher workload for feed collection
Easy manure collection, higher crop yields	Animal movement is limited

Sources: Own compilation, FAO

A zero-grazing system consists of some essential and optional parts (Table 64). Two examples of feasible zero-grazing systems are given in While the following illustrations show an idealised situation, many farmers may have two cows on average and stables must be reduced according to the building elements introduced in the examples.

The zero-grazing unit in Figure 19 shows an example of a smallholder farmer with a minimal land of 3 ha and a considerable number of animals, but the principle of the zero-grazing unit can be up- or downscaled, dependent on need and livestock numbers.

Figure 18 and Figure 19.

Table 64. Essential and optional parts of a zero-grazing system

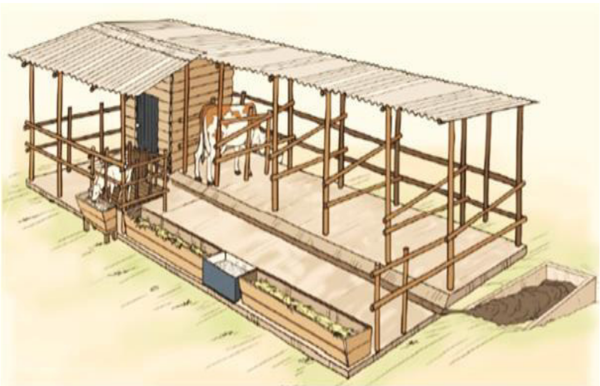
Essential parts	Optional parts
Cubicles (resting area)	A store
Walking area	Manure storage
Feed and water troughs	Fodder cutter
Milking place	Roof water catchment
Calf pen	Water tank
Fodder chopping area	Holding crush

Source: SNV (2017)

While the following illustrations show an idealised situation, many farmers may have two cows on average and stables must be reduced according to the building elements introduced in the examples.

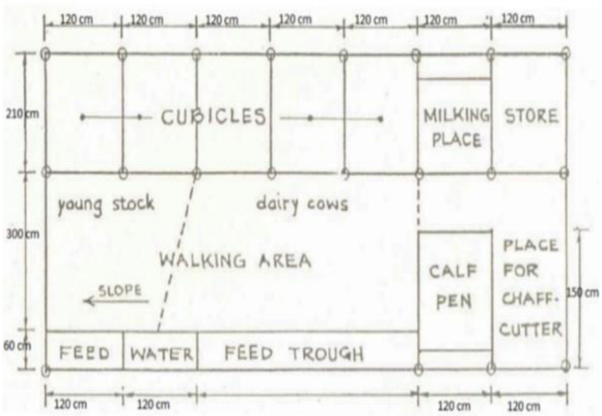
The zero-grazing unit in Figure 19 shows an example of a smallholder farmer with a minimal land of 3 ha and a considerable number of animals, but the principle of the zero-grazing unit can be up- or downscaled, dependent on need and livestock numbers.

Figure 18. Illustration of a basic zero grazing unit cubicles



Source: Felleke et al. (2010)

Figure 19. Plan view of a zero-grazing unit with five



Source: SNV (2017)

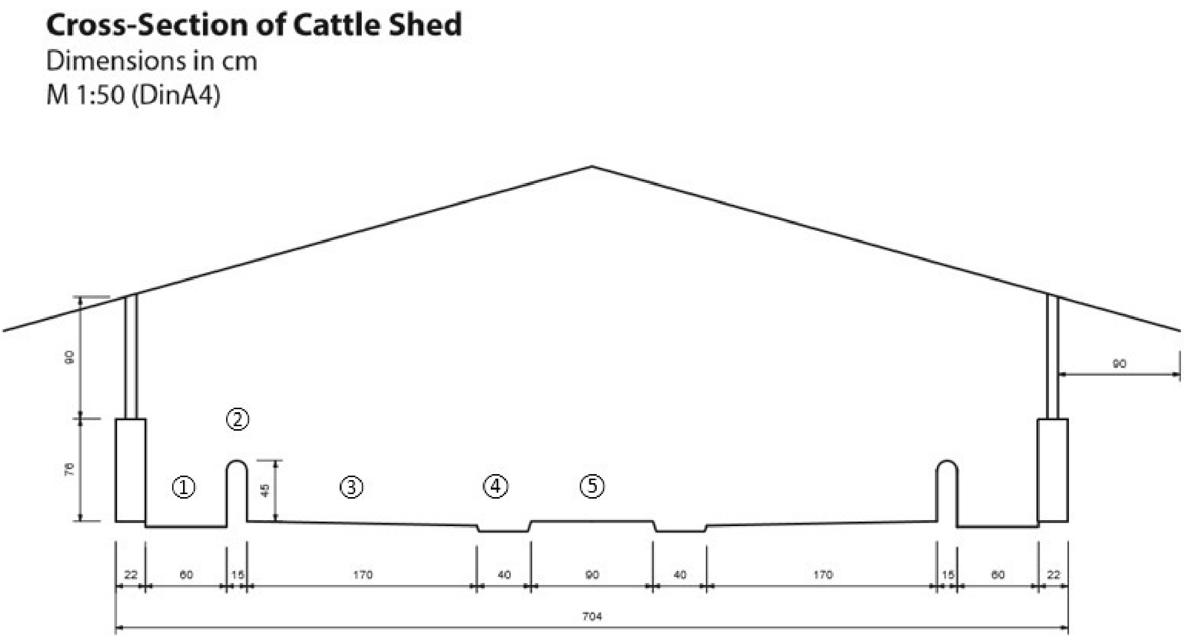
While the kind of wood used in the construction is less important, any wood within 50 cm of the ground should be well treated with some kind of wood preservative or mechanically protected. The floor of the raised cubicles can be made from wood, or plain soil with a high share of clay. Soft bedding needs to be provided for the animals. A concrete pit or sloping slab, in which the manure from the slightly sloping walking area can be collected, is essential to keep hygienic standards and thus milk quality.

The floor of the walking area should be paved, as it allows for the collection of urine as well as dung. If the floor is made of concrete, it is important to roughen the surface to prevent slipping. In case that concrete floor is unaffordable, the distance between the free stalls (cubicles) and the feed trough should be doubled or tripled. In case pasture is unavailable, an adjacent exercise paddock, where the animals can move freely for four to five hours each day, is strongly advised, as animal welfare is a key concern in organic agriculture (OA).

15.5.5 Cattle shed

The construction of a cattle shed is an option for bigger herds in combination with pasture. The openness of the shed offers plenty of light and ventilation. The floor should be cemented to facilitate regular washing and cleaning. A feasible option is a tail to tail shed with a double-slope roof (cross section Figure 20).

Figure 20. Cross section of a cattle shed



Source: Own illustration
(1) Feeding trough, (2) Inside wall, (3) Stall, (4) Drain, (5) Central alley

The dimensions of the stall (③ depend on the used breed, but on average at least 1.7 x 1.3 m per animal. The stall floor should be sloped downward by 3% and covered by sufficient bedding. The animals can be tethered to tie-points at the inner wall (② Manure from the drains (④ should be collected in an adjacent concrete tank.

15.6 Further information

- http://targetethiopia.com/wp-content/uploads/2018/01/DVC-Dairy-Policy-Inventory-2009.pdf
- https://snv.org/cms/sites/default/files/explore/download/dairy_housing_and_manure_management_training_manual_and_guide.pdf
- https://www.infonet-biovision.org/AnimalHealth/Cattle

- http://www.fao.org/3/i2433e/i2433e07.pdf
- http://www.fao.org/3/a-y4176e.pdf

16 Sheep & Goats

Section 16 introduces housing requirements of sheep and goats, feeding strategies, breeds, and health issues.

16.1 Housing

Housing requirements for sheep and goats need less consideration than for cattle or poultry (Table 65).

Table 65. Housing requirement for sheep and goats

Housing part	Sheep	Goats	Remark
Floor	Elevated, sloped (droppings), rammed earth or partly slatted.	Elevated, sloped (droppings), rammed earth, platforms for climbing.	Needs to be dry, especially goats are susceptible to diseases caused by damp floors.
Feed	Trough outside of shed.	Hay racks, elevated troughs.	Elevated feedstuff for goats, add mineral licks. Min. 50 cm per animal.
Water	Troughs best outside.	Troughs best outside.	Outside troughs are easier to fill and to keep clean. Min. 50 cm per animal.
Roofing	Minimum height 2.5 m.	Minimum height 3 m.	
Shed orientation	East-west orientation recommended.	East-west orientation recommended.	Take care with wind direction, good ventilation but also wind protection.
Separation	Own shed for rams/ sick animals.	Own shed for bucks/ sick animal.	Do not rear goats together with cattle! Risk of diseases.

Sources: Modified after Jayewardene (1977), Vukasin et al. (1995)

16.2 Feeding

When feeding sheep and goats, optimal pasture management is the foundation of feed supply in many farms. As frugal animals they need no additional concentrates/feedstuffs, if pasture quality is high. Whereas sheep are grazers, goats as browsers should be offered a more diverse diet of tree and shrub branches and foliage. The additional feeding with cut and carry forage legumes covers the protein needs. Overfeeding on lush and damp feeds, like alfalfa or clover, can lead to life threatening bloat. As a rule of thumb, no more than 2/3 of the diet should contain forage legumes. Introduced feeding examples represent an ideal situation, but with certain challenges. Currently, compared to the following numbers, max. 50% of feed energy and protein supply is reached in practice. But if seeds and seedlings for forage production are available, food supply can boost towards what is calculated in the tables below.

16.2.1 Feeding strategies in different life stages

Feeding ratios should consider the different life stages of the animal (Table 66). Especially during late pregnancy and milking period, when the animals need twice as much energy and protein as normal.

Table 66. Sheep/goat feeding during different life stages

Stage	Sheep Animal day^{-1}	Goats Animal day^{-1}	Remark
Before breeding season	Watch for over-fattening in ewes 1-3 months before breeding season.		Over-fattening in sheep can lead to reduced fertility.
Breeding season	Good pasture, grass and legumes mix.	Good pasture.	
Early and mid-pregnancy	Pasture + 1 kg legume hay / animal /day.	4-5 hours pasture + 5 kg green fodder.	
Late pregnancy	Good Pasture + 7 kg green fodder.	Good pasture + 7 kg green fodder.	
Lactation	Good pasture or 8 hours of grazing + 10 kg green fodder / 1 kg legume hay*.	6-8 hours pasture + 10 kg green fodder / 1 kg legume hay.	
After weaning	Pasture.	Pasture.	The least critical period with respect to nutrient require-ments.
Young animals	See Table 70.	See Table 70.	

Source: http://agritech.tnau.ac.in/
* alternatively pasture and silage

16.2.2 Feed demand

For high yielding goats, a detailed calculation of feed demands is recommended (Table 67,

Table 68). A rough estimation of the feed value of different fodder, that might be available for small ruminants, is given in Table 69.

Table 67. Steps for calculating feed rations for goats

Step	Description	Example Goat with 10 kg, should grow 100 g per day Available fodder: old grass & cowpea grains
1	Check for protein and energy requirements.	6 MJ ME and 33 g DP day^{-1}
2	Check the values of the available feedstuff.	Old grass: 1.9 MJ ME / 0 g DP Cowpea: 12.6 MJ ME /190 g DCP
3	Calculate the ratio to ensure protein needs are covered (protein need / g DP in fodder). How much energy does this provide? (kg feed * MJ ME)	33/ 190 = 0.18 kg cowpea 0.18 * 12.6 = 2,3 MJ ME
4	How much of my other feed source is necessary? Remaining ME need / MJ ME of fodder.	6 MJ ME – 2.3 MJ ME = 3.7 MJ ME 3.7/ 1.9 = 1.9 kg
5	Does it match maximum DM intake day^{-1}?	Maximum DM day-1 for 10 kg goat = 0.4 kg DM! With old grass, it would need to eat 1.9 kg, which is too high.
5	If energy needs are not met: - Accept slower growth rate. - Search for different feed sources.	 E.g. sorghum: 3.7/ 13.3 = 0.27 kg

Source: Modified after Jansen & van den Burg (2004)

Table 68. Total energy and protein requirement and feed intake of goats of different ages and weights

Weight kg	Growth g day^{-1}	Energy need MJ day^{-1}	Protein need g DP day^{-1}	DM intake g day^{-1}	DM intake as % of weight
10	50	4	23	400	4
	100	6	33	600	6
20	50	6	32	600	3
	100	7	42	800	4
	150	9	52	1,000	5
30	50	7	40	700	2
	100	9	50	1,000	3
	150	10	60	1,000	4

Source: Modified after Jansen & van den Burg (2004)

Table 69: Dry matter content and feed value of several feeds

Type of feed	DM (%)	CF (%)	DCP (g)	ME *	Quality
Young grass	18	4	25	1.9	Reasonable
Old grass	54	20	0	1.9	Poor
Good hay	85	32	50	5.8	Reasonable
Cereals					
Maize	87	3	65	14.6	Good
Millet	88	9	80	11.7	Good
Wheat straw	91	41	42	6.8	Good
Sorghum	87	2	55	13.3	Good
Pulses					
Field beans	87	9	205	11.8	Good
Chickpea	91	11	150	12.5	Good
Cowpea	88	5	190	12.6	Good
Groundnut (with shell)	94	18	240	20	Good
Soya bean	89	6	300	17.3	Good
Root crops					
Cassava root	87	3	725	12.8	Good
By-products					
Barley draff	89	15	600	10.8	Good

Source: Modified after Jansen & van den Burg (2004)
DM = dry matter in the feed; DCP = Digestible Crude Protein; CF = Crude Fibre, ME = metabolisable energy, MJ = Megajoule
* Giller, Beare, Lavelle, Izac & Swift (1997)

16.2.3 Lamb nutrition

Lambs are weaned around three months. Especially in the first three to four days, they should be kept with their dam to allow suckling. In the first few days, access to colostrum is important for the health of young animals. A feeding plan for the time until weaning is given in Table 70.

Table 70. Feeding plan for lambs

Age days	Mothers milk or cow milk ml	Creep feed g	Forage per day
1-3 days	Colostrum 300 ml, 3 feedings	-	-
4-14days	350 ml, 3 feedings	-	-
15-30 days	350 ml, 3 feedings	A little	A little
31-60 days	400 ml, 2 feedings	100-150	Free choice
61-90 days	200 ml, 2 feedings	200-250	Free choice

Source: http://agritech.tnau.ac.in/

16.3 Sheep and goat breeding

The productivity of local sheep and goat breeds in Ethiopia is low and efforts to improve productivity are currently limited. One of the major constraints to increase output is that purebred exotics, or crossbreeds of exotics with local breeds, are not adequately adapted to tropical management requirements and often do not survive. To better use the available genetic resources, selective breeding practices can help to produce good stock. If a farmer wishes to control breeding, some precautions have to be taken (

Table 71).

Table 71. Management practices for controlled sheep and goat breeding

Steps	Description
First pairing	Female goats are often still growing when being in heat for the first time; if serviced, the pregnancy will put a lot of stress on the animal resulting in a smaller and weaker goat and kids. Let only young goats/sheep be serviced when they have reached 3/4 of the normal, mature weight for that breed.
Planning of delivery date	Servicing at the right time ensures that there is sufficient feed available during the gestation and suckling period; correct planning of the servicing / delivery date (five months after servicing) helps to raise healthy animals.
Heat	If the farmer wishes to control breeding, he has to search for signs of heat: - Mounting of other animals. - Restless behaviour. - Slightly red and swollen labia (vulva).
Male animals	From 4 months on, raise male animals separately until breeding; if this is not possible, an animating apron can be used. Male animals that are not suited for breeding should be castrated before fourth month
Feeding (flushing for ewes)	Provide extra food for the last month before breeding

Source: IRACC (1997)

For goats, a guideline to select productive animals can be used (Table 72). The selection of productive animals, and the culling of unproductive ones, is a major step in controlling stocking rates and prevent the many common negative consequences of overgrazing.

Table 72. Traits of productive and unproductive dairy goats

Body part	Productive milking goat	Unproductive milking goat
Head and neck	Long and lean neck and head.	Short head and neck.
Back, ribs	Strong, muscular back. Deep, wide-sprung ribs.	Shallow, straight ribs.
Rump	Long, sloping.	Short, steep.
Udder and teats	Large, elastic.	Small, tough-skinned.
Milk veins	Large, knobby, easy to feel.	Hard to discern.
Hocks and legs	Straight, well placed apart.	Hocks nearly knock together.

Source: IRACC (1997)

16.4 Sheep and goat health

The "organic understanding" of animal health and welfare concentrates on health promotion through proper management practices and "prevention before curing", which is of special importance in areas where mainstream medicine is expensive and hard to come by (Table 73).

Table 73. Practical measures to ensure health through preventative animal husbandry practices

Prevention steps	Description
1: Breeds and strains	Appropriate breeding; choose robust breeds adapted to the climate and available fodder.
2a: Animal husbandry practices	Hygiene, regular exercise, as much access to pasture as possible to strengthen the immune system of the animals, appropriate housing, diversified feedstuff of good quality.
2b: Stock densities	Overstocking and overgrazing is a common problem in the zone, resulting in many weak animals prone to diseases.
2c: Grazing rotation and management	Changing pastures helps to prevent infestation with parasites.
3: Alternative treatments	Usage of plant based and traditional medicine.
4: As a last resort	Usage of antibiotics, other chemical remedies.

Source: Eyhorn, Heeb & Weidmann (2003)

A list of common tropical diseases for sheep/goats is given in Table 74. But remember that this handbook does not substitute any veterinary advice if animals show symptoms. Treatment with antibiotics should always be seen as last option.

Table 74. Common goat / sheep diseases and parasites in the tropics

Disease	Symptoms	Treatment	Control
Sheep pox	High fever, small red pimples around mouth and tail.	None.	Vaccination.
Blackleg	Swelling limbs, lameness, fever.	None.	Vaccination, careful disposing of carcasses to prevent spread of infections.
Enzootic virus abortion	Abortion in late pregnancy, placenta is retained, uterine in-fection.	No treatment to prevent abortion. Uterine infection can be treated with antibiotics.	Vaccination of susceptible first lambing ewes, hygienic lambing practices.
Lamb dysentery	Diarrhoea, fever, sudden death at 2-21 days of age.	Antiserum to reduce death rate.	Vaccinate ewes during the last month of pregnancy.
Navel ill	Swollen joints, fever.	Medicine / antibiotics can be given during the initial stage of the disease.	Disinfect navel at birth, disinfect wounds of castration and ear tagging.
Pulpy kidney	Bleeding in the heart and softening of the kidneys. Animal may die suddenly after a change of diet.	Medicine / antibiotics can be given during the initial stage of the disease.	Vaccinate ewes during the last month of pregnancy, vaccinate lambs when weaning, careful disposing of carcasses to prevent spread of infections.
Anthrax	High fever, followed by rapid bowel inflammation and death.	Medicine / antibiotics can be given during the initial stage of the disease.	Vaccinate the animals once every year and once every six months in high risk areas.
Foot and mouth	High fever, salivation, lame-ness caused by blisters in the mouth and on the feet.	No known specific treatment, medicine/ antibiotics can help against bacterial secondary infections.	Vaccination, control livestock movement.

Heart water	Rise in temperature, animal may walk in circles or against obstacles, nervous symptoms like jaw-clenching or muscle twitching.	Effective if given in early stages.	Tick control.
Rabies	Uncoordinated movement, aggression, paralysis of the throat.	None.	Vaccination, particularly of dogs.
Trypanoso-miasis	Acute cases: high temperature, anaemia, progressive weakness followed by death. Chronic cases: temperature variation, dry coat, animals become listless and thin.	Several drugs can be prescribed by veterinary department.	Clear bushes near the shed to destroy the tsetse fly's habitat.
Tubercu-losis	Animal is emaciated, enlarged udder, curdled milk, coughing.	None.	Cull animals that are not resistant.
Parasite	**Symptoms**	**Treatment**	**Prevention**
Round-worms	Diarrhoea, wasting, anaemia.	Weaners should be drenched monthly during the rains and one month after.	Practice rotational grazing, dose ewes after lambing and then move them two days after dosing, allow lambs access to the next new pasture.
Tapeworm	Wasting, rickets.	Young stock should be drenched at six weeks and at weaning.	Rotational grazing, graze young stock first.
Liver flukes	Animal is dull and has a distended abdomen, anaemia.	Animal should be drenched.	Keep stock out of wet pastures and stream banks.
Ticks, fleas, lice, scab	Appear on the body, especially on ears and rump.	Dip the animal.	Weekly dipping.
Salmonella	Fever, bad smelling diarrhoea.	Medicine / antibiotics can be given, see a veterinary officer.	Provide animals with clean water and feed.
E. coli	Watery, yellow diarrhoea, fever.	Medicine / antibiotics can be given, see a veterinary officer.	Provide animals with clean water and feed.

Source: IRACC (1997)

16.5 Further information

- https://www.dcbd.nl/sites/www.dcbd.nl/files/documents/Goat%20keeping%2C%20useful%20management%20practices%20for%20smallholders.pdf

Concerning breeding:

- http://www.fao.org/3/ah651e/ah651e08.htm
- https://utt.edu.tt/uploads/library/ebooks/AD07-Goat-Keeping-in-the-Tropics.pdf

Concerning health:

- https://oxfamilibrary.openrepository.com/bitstream/handle/10546/123108/bk-where-there-is-no-vet-part1-010199-en.pdf?sequence=50&isAllowed=y
- ITDG (1996)