4

Physical features on smallholder farms

This chapter provides an understanding of the important physical resources necessary for smallholder tropical dairy farms to be viable.

The following physical features are presented for a smallholder dairy (SHD) farmer milking say 10 cows, as well as rearing his or her own heifer replacements. If the ultimate plan for the farmer is to milk more (say 50 cows) or fewer (say five cows) stock, then the size of the physical features need to be adjusted in proportion to the size of their milking herd. This chapter deals with smallholder farms while Chapter 5 deals more specifically with larger-scale farms.

4.1 Land

4.1.1 Location

Factors to be considered when choosing land for dairy farming are:

- the presence of suitable fertile and uncontaminated soils
- no evidence of flooding during the wet season
- convenience for transportation within the area
- proximity to milk collection centres
- access to water supplies for farming and, of greatest importance

- year-round supplies of sufficient clean water
- highland areas because the air temperature decreases 6.5°C for every 1000 m increase in altitude above sea level.

Distance from factories (which may release bad odours or lead to pathogenic infections) and urban areas (where pollution from farm effluent will not be tolerated) should also be key influences on location. In addition, the availability of ground or surface water for irrigation and cleaning sheds, as well as for stock needs, all have to be considered when siting a dairy farm.

Ideally, the area of land allocated for the farm should be sufficient to grow all the forages required by the herd. This includes forages specifically grown for livestock feeding or forage by-products from other farm enterprises, for example from commercial crops, such as sweet corn or soybean. As it is generally in short supply, sufficient land for forage production should be available close by, or at least local farmers should be available and agreeable to grow the forages for sale. The greater the distance that forage sources are from the dairy herd, the more costly they can become and the more unreliable they are as regular farm feed inputs.

4.1.2. Forage production area

Area of forage grown

Moran (2005) developed a methodology to calculate the optimal area for forage production required to provide sufficient year-round forage supplies for a dairy farm. The calculated area required depends on key factors such as:

- The total yield of quality forages grown per ha per year, which depends on the agronomic skills in growing the forage crop, such as land preparation, weed control, using inorganic fertilisers in addition to cow manure and also harvesting the crop at optimum forage quality.
- The total amount of forages required over 12 months by each milking cow and replacement heifer.

The yields of forages grown are based on the typical yields of Napier grass under various levels of management, namely poor, average and good management are 67, 130 and 200 t respectively of fresh forage/ha/yr which corresponds to 10, 20 and 30 t DM/ha/yr respectively. Forage requirements for stock are 50 kg/cow/d fresh grass for milking cows (for 274 days in lactation), 30 kg/d for dry cows (for a 90 days dry period) and 20 kg/d for replacement heifers (for say 20 months).

For a farmer growing the maximum quantities of quality forages to feed his milking herd well, he should have no more than eight to 10 milking cows per hectare of forage grown on his farm. However, most farmers do not manage their forages sufficiently well to produce the highest yields of forage. Therefore, a more realistic recommendation would be six to eight milking cows (plus replacement heifers) per hectare of forage grown on farm.

This means that a 10-cow SHD farmer should aim to utilise a total of 0.75 to 1.0 ha for forage production. This recommendation is for a smallholder farmer in the humid tropics growing Napier grass as the primary forage source. This will obviously vary with the location and preferred forage species, but because of its relatively high yield, the required area is likely to be larger in regions where forage species other than Napier grass, are grown.

Types of forages that can be grown

Cook *et al.* (2005) developed a CD (entitled 'Tropical forages. An interactive selection tool') to select the most suitable forages that can be grown in different climatic regions in Asia, based on their optimum climate, soils, production system and management. These include both grasses and legumes. Growing tree legumes is another option. This requires additional planning in location of the trees, such as along roads or fence lines, and ease of access for harvesting.

Forages grown as single swards or as mixtures

Unlike temperate regions, it is not feasible to incorporate a forage mixture of grasses plus legumes into a single perennial forage sward. Different species of forages have different growing forms, or stem habits, namely: erect, prostrate, climbing, stoloniferous (stems growing along the ground) or rhizomatous (root nodules that convert atmospheric nitrogen into plant nitrogen). Erect forages will shade out prostrate forages, so it is best to grow each one as a separate crop. In addition, some forages are perennial while others are annual, requiring re-sowing each year. Others may be perennial but because of weed invasion and other constraints to production, they may require annual or biannual re-sowing.

Area available for grazing stock

Due to the shortages of suitable land, hence high land prices, Asian SHD farmers are forced into zero grazing production systems. Such stall feeding usually leads to less feed and water being offered, resulting in lower potential feed intakes than with grazing stock.

Stall-fed cows must be protected against the harmful effects of direct sunlight, mud, wind, and both external and internal parasites. However, such confined stock suffer more from certain diseases, such as mastitis, uterine infections and lameness, and also from poor heat detection, poor ventilation, dust, effluent and lack of proper bedding and poor cow comfort. Other benefits of zero grazing include protection against predators and thieves, reduced burden of day-to-day herding and lack of farmyard manure. However, labour requirements are greatly increased compared to grazing stock.

Allocating land for grazing dairy stock involves accepting lower yields of forage per ha because of the need for different grass species (than those used in cut and carry systems) and less efficient harvesting by the stock, compared to hand or machine harvesting. However, there are certainly benefits to stock wellbeing, and consequently performance, if provided with grazed forages. If land is available, grazing should be preferentially offered to growing heifers and dry cows, as they do not require twice daily attention as do milking cows and milk-fed calves.

Utilising shed effluent for forage production

Shed effluent can be used for fertilising forage crops in various ways. The most common is physically applying cow manure by hand. Nutrients from faeces and urine can be more efficiently recycled by applying all the effluent, diluted with water, directly onto the forage production area. Directing shed effluent into ponds reduces the loss of volatilised nitrogen from the urine thus enabling farmers to recycle more of this urinary nitrogen onto the forage crops. This system will require the construction of an effluent storage pond, and the installation of a recycling system such as a pump and hose, and/or a series of channels throughout the forage production area for distribution of the diluted effluent. If water is readily available for irrigating forages, such a distribution system could have a dual purpose. In dairying areas with available water for irrigation and suitable topography, consideration could be given to designing an irrigation system based on gravity (either flood or channels) rather than using pumps.

Other aspects of forage production and utilisation

Forages can be harvested by hand or machine (such as a mechanical brush cutter) to be chopped before feeding. It must then be transported to the cowshed, either by vehicle if distant, or by hand or hand-pushed trailer if close by. They may be wilted before being fed out to reduce moisture content that will stimulate voluntary forage intakes, in which case a series of wilting racks needs to be constructed close to the cowshed. Incorporating a plastic cover will provide protection against the rain to facilitate year-round wilting of freshly harvested forages. Finally, to reduce selection and wastage of grass stalks, they should be finely chopped, either by hand or machine, before feeding out.

4.1.3. Effluent storage

Shed effluent is quite bulky, as well as being difficult and unpleasant to collect, dispose of, or store and transport to the forage production area. Every day, each milking cow typically produces 30–35 kg faeces and 12–16 kg urine. In addition, most dairy sheds are washed with a hose, thus further increasing the volume of shed effluent. If rainfall is not directed away from any outside effluent storage, this run-off also contributes to the effluent load. A 10-cow (plus replacements) farm thus produces 0.2 to 0.3 t fresh manure and 120 to 180 L urine each day and this would amount to a total volume of 0.25 to 0.35 m^3/d, excluding any rainfall run-off.

On most of the smaller tropical dairy farms, the manure is collected with a shovel soon after it has been excreted and stockpiled near the exit to the shed while the urine and shed washings are directed away from this stockpile. Several times each week, this manure would be transferred into a wheelbarrow and taken out to the growing forages for distribution. As stated earlier, some farms direct all the faeces and urine into a storage pond for subsequent pumping out onto the growing forages. In some countries such as Pakistan, the shed manure is sun dried for use as kitchen fuel for cooking. It can also be used to produce biogas.

Most 10-cow farms would rely entirely on physical labour to collect and distribute the shed effluent. However, larger farms may be too big to depend entirely on physically carrying the effluent from the shed to the forage production area. Therefore, to minimise such labour, these farms would require a large storage pond plus manure pump and distribution system. The size of the storage pond would depend on the annual rainfall, the ability to divert run-off water to other disposal systems, the daily input from the dairy shed and the frequency of applying the effluent to the forage production area. However, it would have to have a capacity of at least 10 m^3 to provide for several days' storage.

The depth to groundwater under the soil surface is important as this will limit the pond depth and thus increase the required surface area. The base of the pond should be at least 1 m above the highest seasonal watertable. The permeability of the soil is also important, as this will influence any seepage into groundwater supplies.

The management of animal manure may represent a major sanitary and human/animal health hazard on SHD farms, with the problem increasing with herd size, unless specific facilities are constructed. The problem is associated with several issues:

- quantity and quality of faeces and urine produced
- adequacy and frequency of removal
- storage in proximity to shed
- labour availability
- methods of storage and disposal
- value and use of manure
- community concern about pollution (smell as well as contamination of groundwater and water courses).

The human health hazards are also becoming more serious than previously realised, due to inadequate supervisory and sanitary measures. For example, in Thailand a survey noted wastewater from SHD farms constituted a considerable risk to public health because of its very high contents of inorganic pollutants and the presence of coli-form organisms. Furthermore, there was considerable contamination of groundwater supplies in nearby towns via wastewater from local farms as well as via leaching from stored manure.

Not only is effluent management an environmental constraint to smallholder dairying because of its potentially adverse influence on cow performance and cost of forage production, but of equal importance, it can alter the livelihood of farmers themselves through community legislation limiting locations of farms. This can be particularly important for dairy farmers situated close to large towns and cities. In developed countries, there is now considerable effort to ensure farming activities are seen as 'clean and green' and this concept will no doubt extend into the humid tropics in years to come.

It is important to collect as much urine as possible from the shed. It is advisable to use minimum water to initially wash out the manure drains, then direct the main washings from the floor into another pit or direct out to the forage producing area. An ideal effluent system is to direct all manure and shed washings into the one pit equipped with a manure pump to direct the effluent to the forage producing area, along gutters between the rows of plants.

4.1.4. Water supplies

It is essential that dairy animals are provided with adequate supplies of good quality drinking water. If this is not readily available year-round, then a system should be developed for collecting rainwater during the rainy season and storing it until required. Throughout the humid tropics, greater attention needs to be given to ensuring all sheds and houses have gutters and downpipes to facilitate the collection and storage of clean drinking water.

Lactating dairy cows in the tropics require 60 to 70 L water each day for maintenance, plus an extra 4 to 5 L for each litre of milk produced. Water requirements rise with air temperature. An increase of 4°C will increase water requirements by 6 to 7 L/day per L milk produced. High yielding milking cows can drink 100 to 150 L water/day during the hot season. A 10-cow herd would then require up to 1500 L/d to ensure limited water intakes do not restrict appetite and consequently production. In areas such as Central Java, where the lengthy dry season leads to very deep underground bores being the only reliable source of stock water, the high cost of accessing this water often leads to shortages in drinking water, which can reduce feed intakes, accentuating the problems of reduced milk yields arising from low nutrient intakes. All too common, cow performance (milk yields and fertility) is limited by the shortage of clean drinking water.

Good quality water is also important for the effective use of the detergents and sanitisers for washing milk-harvesting equipment. This is essential in maintaining good milk quality. Non-potable water supplies must also be sufficient year-round for effective shed cleaning.

4.2 Buildings

It is essential to provide good housing and farm layouts for rearing and milking dairy stock in the tropics, for ease of cleaning out sheds and to reduce the extreme effects of air temperature and humidity. Such control improves milk production by reducing stress and disease hazards and also by making herd management easier. Environmental control includes sanitation and effluent management.

Good dairy sheds have many simple design features to improve cow and farmer comfort, hence cow performance and farm profitability. In hot climates, the following features are particularly important:

- sufficient well-drained yard space
- plentiful supply of water
- comfortable and dry resting area
- high roof, allowing breeze to blow through and reduce radiant heat
- sufficient water and feed trough space for each cow
- shade over the feeding as well as over the loafing area
- wire fences instead of solid walls so as not to restrict air flow
- planting trees to lower temperatures
- sowing grass or other forages in the area surrounding the shed
- white painted buildings
- shading over drinking troughs to keep drinking water as cool as possible.

It is often just as expensive in the long term to renovate old buildings that have been originally built for other livestock species or for a smaller dairy herd, than to remove the building entirely and start with a greenfield site. For example, converting an old pig shed into a dairy cowshed is likely to create problems in the future due to inappropriate shed height. A roof that is too low means the effect of solar radiation heating on the cattle is increased and it also results in ineffective ventilation. The foundations may still be adequate so could be reused, but the rest of the building is unlikely ever to be well suited to milking cows.

When designing buildings, consideration should be given to future expansion plans by ensuring there is sufficient space around them, as well as the adequate provision of utilities such as water, electricity and shed drainage. There may be regulations regarding buffer distances, that is space between buildings, which can restrict the ability to expand building layouts. Furthermore, effluent, odour and noise originating from cowsheds should have minimal impact on neighbours. The superstructure consisting of beam constructions, roofing and possibly walls, should be built preferably from local materials and follow local designs. There are several options for constructing the roof, such as iron, bricks or even bamboo/mud in a low rainfall area.

Soils should be evaluated to assess their suitability for constructing the buildings, and strong enough to carry the heavy loads of machinery, building foundations and, of course, the stock. During construction, better compaction can be achieved by removing and stockpiling the topsoil for later use for landscaping or adding to the forage production area. The proposed cowshed should be conveniently located close to the sources of home-grown forages.

Ideally buildings should be located above the 1 in 100-year flood level and all earthworks should be designed to avoid offsite impact of floodwater discharge either through funnelling or backwater effects. The natural drainage regime of the area must be considered so that uncontaminated rainfall run-off can be easily diverted away from the effluent storage. As already mentioned, gutters and downpipes could lead to drains or water storages to allow more effective control of such run-off.

The ideal aspect of the buildings depends on its geographical location. Orientation of buildings will impact on the severity of hot or cold environmental stresses at different seasons during the year. Buildings should be orientated to either maximise or minimise exposure to climatic elements such as prevailing winds, sunlight and rainfall. Locating the shed perpendicular to prevailing winds aids cross-ventilation. A north–south orientation promotes drying in exposed areas because the shade moves across the shed during the day.

4.2.1 Cowshed

Dairy facilities should be designed, constructed and maintained to minimise obstructions and hazards that have the potential to cause distress and injury to stock. Floors should provide satisfactory footing on non-slip surfaces, be well drained and easily kept free of mud and manure. Fences and gates should allow good animal flow and prevent injury. Crushes and head bails should allow efficient handling of stock without endangering them and allow their easy release. Sufficient space should be provided to prevent discomfort and ensure animals can meet their normal behaviour requirements for lying down and resting, moving around, eating, drinking and eliminating faeces and urine, and all without excessive social pressures.

Shed designs should ensure adequate air circulation, temperature control and removal of excess ammonia, carbon dioxide and slurry gases. Lighting should be adequate to enable inspection but not so intense as to cause discomfort. Animal groupings should be kept to reasonable sizes with stock sorted into different size or age groups to minimise social stresses such as bullying.

As all cowsheds need to have sloping floors to aid effluent removal, there should be sufficient soil depth to accommodate the cut, fill and borrowing requirements necessary for undertaking the earthworks. The shed should be formed well above the natural surface level to promote such drainage, as well as increase air movement. This will decrease shed odours and discourage insects. The cost of sourcing and moving sufficient suitable soil needs to be taken into account. Buildings should not be located on steep slopes, greater than 20% (1 in 5).

The surface should allow for effective drainage and prevent wastewater reaching the subsoil. Minimum gradients are 0.2% (1 in 500) for compacted earthen surfaces whereas concrete can drain at a slope of 0.5% (1 in 29) to 4% (1 in 13). From operating experience, slopes should be within the range of 2% (1 in 29) to 4% (1 in 13). Slopes can be steeper but these require a higher standard of construction and operational management. Excess run-off and sediment transport can occur, causing potential erosion on exposed areas as well as pollution problems. Specifications for concrete strength and thickness should be followed.

Shed design

The essence of good shed design is making the best use of natural ventilation, with open sides, a high and well-pitched roof together with an open vent along the top. The presence of cobwebs under the roof is indicative of poor ventilation.

The following discussion is for dairy farms located in tropical regions where the emphasis in shed design is to minimise heat stress. It is worth repeating that sheds should be constructed to maximise natural cross-ventilation, with open sides, a high and well-pitched roof together with an open vent along the top.

The shed should be sited so that breezes are not blocked by any obstacles or other buildings. Ideally, the shed should be on the highest ground possible, which will also be good for effluent drainage, with other buildings located downwind on the site. There should be a minimum of four times the height of the nearest wind barrier as a horizontal separation.

A north–south orientation is preferable to allow the sun to dry underneath both sides of the shed. An east–west orientation is not recommended, as the southern side will have less opportunity to dry out. Trees should be planted and protected from stock damage, on the western side of the shed to reduce solar radiation. Shadecloth that blocks 80% of the light can also provide protection as long as it does not interfere with ventilation within the shed. Eaves that extend one-third the side height also provide good sun protection.

White painted buildings reflect the solar radiation better than dark painted buildings. Reflecting roof materials such as galvanised iron or aluminium are good long-term investments. Insulation under the roof or solar panels on the roof, can reduce the heat load. Spraying water on the roof may only be effective in reducing roof and shed temperatures in areas with low humidity.

Effluent disposal systems

The floor of the cowshed should be made from concrete or easily washable material and designed for efficient drainage with a good slope with wide channels for easy urine and faeces removal. As previously mentioned, an effluent pond should be dug large enough to hold the shed's manure and shed wash for at least two or three days without emptying. A channel should be dug leading from the walking area to the pond and ideally lined with concrete. If manure is stored in a pit, it should be covered with a plastic sheet or banana leaves to reduce the sunlight, as this volatilises the nitrogen in the manure, reducing its value as a fertiliser. This will also allow the installation of a biogas plant during its construction or at a later date. A fence around the pit will minimise risks to children and wandering stock.

4.3 Farm infrastructure

4.3.1 Cow stalls

There are two basic types of housing, tie-up housing (tie stalls) and loose housing.

- With *tie stalls*, each cow is restrained in a stall. Feed is delivered in a trough in front of the cows. Milking usually takes place individually in the stall, by bucket or machine (bucket or pipeline milking). Manure is collected in a gutter behind the stock. As cows tied up all year round can suffer from feet problems and become stiff, they should be provided with an easy-to-clean, soft surface on which to lie down, such as rubber mats or mattresses. Providing cement only to lie down on will lead to excessive periods of standing and reduced appetites, which can eventually result in acidosis and lameness, hence poor milk yields and reproduction. Heat detection demands more attention in tie stalls while a high incidence of trampled teats can become another problem. Throughout Asia, dairy cows have been traditionally housed in tie stall sheds.
- With *loose housing*, cows are not tied up and can walk around freely. Such systems usually have a loafing area and require a comfortable and dry lying area, with the feeding area separated from the lying area. As the cows are forced to walk frequently, the manure is spread over a large floor area so has to be collected by scraping the dung by hand (or sometimes mechanically) into a manure pit. With adequate water supplies, rapid flushing of large amounts of water can clean alleys, directing effluent into a pond. With larger herd sizes, milking is often carried out in a separate milking parlour. The feed trough is separated from the loafing alley by either a feeding rack or wire rope.

Loose housing can be of two types, either with a common lying area with open lounging or with cubicles or free stalls.

- In *open lounging* systems, cows can lie down anywhere. The floor can be earthen or cement, generally with bedding material, the base being well drained. In dry climates, earthen floors with or without bedding can be used as long as the floor is turned over daily. This is called a 'compost barn' where the manure is sometimes cleaned out every day and the ground is turned and becomes hot, thus killing all the pathogenic bacteria. These areas must be managed well to ensure they do not become too wet which can result in increasing mastitis loads. The area directly behind the feed troughs should be cement and at least 3 m wide. Each cow should be allocated a total of at least 9 m^2 resting area.

- With *free stalls*, each cow is provided with a cubicle, which she may enter and leave at will. Cubicles can be arranged in a single row or in more than one row with a central feeding alley or with feeding alleys along the sidewalls. The cubicles can be arranged with cows facing one another (head-to-head) or the other way around (tail-to-tail). With the tail-to-tail arrangement, a central loafing alley with a width 2.2 m between the cubicles is needed. If the cubicles are head-to-head, two loafing areas behind each row are necessary. Usually one of the loafing alleys is combined with the feeding alley behind the feed troughs.

Free stall layouts

The size of the cubicles depends on cow size. For cows:

- weighing 400–500 kg, they should be 104–109 cm wide and 198–208 cm long
- weighing 500–590 kg, they should be 109–114 cm wide and 208–218 cm long
- weighing 590–680 kg, they should be 114–122 cm wide and 229–244 cm long.

The surface of the free stall should have a consistent fall of 4%. It should:

- be comfortable to the cows to encourage high occupancy
- prevent hock damage and other injuries
- be easy to clean and be durable
- be cost effective to install.

The floor of the cubicles can be earthen with a thick layer of bedding, or can be solid, with a soft top layer. The simplest bedding is packed earth or sand, this often being inexpensive but needing daily care to maintain a flat surface. Sand is quickly pushed around by cows, so ideally, it should not be used with mechanical or liquid manure handling systems because it fills up storage tanks and is very abrasive, damaging equipment such as manure pumps. However, a sand trap can be installed, to allow the heavier sand particles to settle out before handling the other shed effluent.

A concrete foundation with a disposable bedding of chopped straw (and sometimes with the inclusion of lime and water), sawdust, wood shavings or crushed corncobs is more common in Europe, as rice hulls are not readily available. Rice hulls make ideal bedding for free stalls but their high silica content can also damage liquid manure handling equipment.

To prevent the cow from soiling the cubicle, shoulder, breast and head rails are needed. This provision will force cows backwards when they stand up. The distance of the adjustable shoulder rail to the back of the cubicle, measured diagonally, should be ~1.8 m, the height to the cubicle floor may vary between 90 cm and 1.05 m. It should be stressed that stalls must be designed to suit the average cow size and up-to-date information must be sought on stall design before any construction begins.

Open lounge housing create its own problems of regularly removing and cleaning the bedding and ensuring all cows will use it in preference to lying on dirty cement walkways, and hence increasing potential mastitis problems. Bedding must not be allowed to become wet from leaking water troughs or rainfall. Compost bedding systems vary greatly in their effectiveness and require constant monitoring. Some require daily input of straw and twice daily cultivation to maintain the correct moisture content. Others on sandy soil can be managed well by daily manure removal and occasional input of straw and daily cultivation.

Concrete alleys of loose houses should slope in the direction of the manure movements with a 3% slope and level from side to side. They must be easy to clean and allow for quick and free drainage with all effluent directed towards the storage pond, either for recycling as fertiliser or for initially producing biogas. In countries where dried manure is a value-added product for kitchen fuel, floor designs may differ slightly to those in other countries, where all effluent is directed to open drains. Effluent can also be directed towards a closed tank to be used for biogas production.

4.3.2 Problems with tie stalls

As far as the cow is concerned, tie stalls often:

- are extremely uncomfortable and have a hard surface
- cause pain, with risk of inflammation of knees and hocks
- are frustrating, because lying down with the head constrained is more difficult and the animal cannot lie down with a stretched foreleg or with its head tucked into its front legs
- are boring, because they restrict any opportunity for social contact or interaction and foraging
- restrict the ability for each cow to self-groom, particularly if the tether rope or chain is too short
- reduce lying and resting time, which can lead to increased lameness and stress
- can lead to abnormal behaviour, such as swinging from side to side and shifting/moving back and forth. Many cows often stand in a dull state if not eating or otherwise stimulated
- can lead to more frequent occurrences of stereotypical activities, such as bar biting or tongue rolling, which disappear when animals are transferred to loose housing

- remove the ability for stock to find the best location in the shed for reducing climatic stresses
- reduce the quality of the microclimate (higher relative humidity and air ammonia concentration and lower air movement), which can lead to reduced cow comfort and performance
- are all too commonly associated with poor hygiene, meaning that the cow is forced to lie in her own manure, thus creating additional problems with animal health and milking hygiene, such as mastitis
- can adversely affect reproductive performance, partly because cows stand for long periods, cannot move freely or assist in identifying other cows on heat
- can lead to higher teat injuries due to physical damage
- can have dimensions that may influence cow behaviour, cleanliness and wellbeing.

If circumstances require that the animal is temporarily tethered, she should be tied with a halter and released as soon as possible. Nasal tying, that is threading a rope through a hole in the nasal septum, can cause irritation and infection. A temporarily tied or single housed animal must always be able to keep at least visual contact with her herd mates to lessen stress reactions. A mirror may even substitute for other cows, for a short time. Some behavioural scientists argue that cows in tie stalls are considered to have had regular exercise if they are released for just 1 hr/d for 2 days per week. But one could likewise argue that 'the more exercise the better'.

If farmers persist with tie stalls, they need to pay closer attention to stall dimensions and bedding, because

- shorter stalls are associated with more cows with dirty hind limbs and rotated hind claws
- low tie rails can lead to more cows with neck lesions and broken tails, the latter resulting either from the tail being stepped on or forceful manipulation by the farmer
- short tie ropes or chains can lead to more swollen hocks and dirty hind limbs with cows struggling to stand and lie down easily
- hard bedding will lead to long standing times, acidosis and lameness.

In summary, tie stalls are *not* appropriate for the optimum wellbeing of milking cows and these conditions can negatively affect milk yields, reproduction and cow longevity. Tie stalls have been the traditional method of maintaining dairy cows in some European countries for many decades. This has created so much public concern that certain countries, such as Norway, have recently legislated against their future use in preference to loose housing.

4.3.3 Other facilities in cowsheds

Considerations in flooring

The required floor slope depends on the cleaning method adopted and the natural slope of the site. A minimum slope of 0.5% (1 in 200) is required to prevent pooling of water. Steep cow alleys (greater than 1 in 15) will result in cows not standing perpendicular to the feed trough, but standing uphill. Flood washing of the cow alley ideally requires a slope of between 2.5% (1 in 40) and 3.0% (1 in 30), to achieve acceptable wash with minimum amounts of water. If the slope is less than 2.5%, the volume of flood wash water has to be increased to get extra water depth to compensate for the lack of slope. There should not be any sideways slope on cow alleys with flood washing. If flood washing is not used, the cow alley should have a 2.5% slope away from the feed trough. Hose washing and dry scraping are not slope sensitive, so the site slope will influence the alley slopes. The feed alley needs a concave floor (with 50 mm fall) sloping away from the feed to the centre of the alley to prevent run-off water mixing with the feed. The lengthwise slope will be the same as the cow alleys.

Cows can be standing or walking on shed floors for up to 10 hr/d (Moran and Doyle 2015). In tie stalls, cows should be provided with rubber mats to cushion the hard concrete floors. With loose housing, concrete floors should be roughened to reduce slippage but not too rough so that they wear out hooves and lead to lameness problems. Another alternative is to install grooves or patterns in new concrete floors. These can even be cut into old concrete floors.

Grooves should be positioned so that at least one of the four feet lands in a groove whenever cows put their feet down to stop slippage. Parallel grooves should be spaces ~15 cm apart, 12 mm wide and 12 mm deep. Although placing grooves perpendicular to the length of the alley will maximise their effectiveness, they may compromise removal of shed effluent. So they should be located parallel to normal alleyway cow flow.

Anti-slip aggregates can be mixed in with the top layer of concrete or epoxy floor coatings can be applied to existing floors. Another alternative in areas of high cow usage, such as in feeding alleys, is constructed in-place rubber floors, such as those used on athletic tracks.

High traffic areas of concrete, especially in areas where cattle turn, should have rubber matting to reduce hoof wear.

Water troughs

Stock must be provided with sufficient drinking water at all times and the system should be able to supply at least 20 L/cow/hr to meet likely peak demand. Peak demand often coincides with feeding times and just after milking. Cows often drink a third of their daily water intake in the hour after morning milking on a hot day. The water supply pipe diameter needs to be at least 75 mm with an operating head of at least 10 m. The optimum temperature for drinking water is 15–17°C. Water troughs should be well separated (but within 15 m) from feed troughs with the same water trough servicing adjacent pens. Trough design should allow for regular, easy cleaning with a removable bung for complete drainage. Watering points should be cleaned out at least weekly to remove any feed and other contaminants. Water troughs should not be sited over or near bedding areas in sheds.

Each cow should be provided with 75 mm of linear watering space in free stall sheds, while for circular water tanks, one watering space (60 cm of tank perimeter) should be available for every 15 to 20 cows. A water depth of 15 to 20 cm helps keep water cooler, fresh and easier to clean because less debris accumulates. The optimal trough height is 60–90 cm, from ground to the top of the trough.

With loose housing, water troughs should be well separated and close to the concrete feeding area with provision for water spillages, or leakages, to directly enter the drainage system with no spillage onto the compost bedding area. Troughs should be located at the high point of a water line to reduce sediment and to facilitate purging air from the pipeline. In free stall sheds, they should be located at crossovers to reduce the incidence of stock blocking each other in alleys.

If cows are tethered, it is possible to install individual cattle drinkers, with two animals sharing one drinker. To ensure water is freely provided, troughs need to have float valves rather than depend on a hose whenever the farmer decides to refill it. A single watering trough system can control water levels in up to 10 small troughs just by one float valve in a central reservoir with syphon pipes leading to all the troughs.

Upgrading the facilities can involve increasing the rate at which troughs fill or providing greater trough capacity. Options involve upgrading pumps and water pipe diameters or increasing the number of watering points, particularly those close to the feeding area.

The tradition of mixing water with the concentrate portion of the ration is widespread throughout Asia. Farmers wrongly believe that cows will better utilise concentrate slurries compared to dry mixes. This may be one way of providing additional water, in housing systems where there is limited free access and stock are only provided with restricted times to drink. However, given free access to water, there is no need to feed slurries of concentrates.

Feed troughs and feeding strips

It is important that all stock can eat comfortably with minimal competition. Whether feeding into troughs or onto cement feeding strips, 70 cm feeding space should be allocated per mature cow. For a feeding strip or trough when cows eat from both sides of the strip, hence face each other to eat, this equates to a total feeding strip allocation of 35 cm/cow. Trough space can be reduced to 45 cm/head for 6-month-old cattle, or to 55–60 cm/head for stock 18 months old.

With feed troughs, the width should be related to the reach of the animals which is up to 80 cm for mature dairy cows eating from the base of a trough 30 cm above ground level. The base of the trough should then be raised 10 to 30 cm, with the front 50 cm above this. Cows in tie stalls are likely to have restricted reach. In loose housing systems, lockable feeding head bales will reduce the incidence of cows throwing feed around as they lift their heads, this means less wastage.

Feeding strips should be positioned 7 to 15 cm above cow feet level, with a nib wall 40 to 55 cm above the feeding strip, to protect the feed from the effluent. Feed barrier walls wider than 15 cm can restrict how far stock can reach into troughs or onto feed strips.

Feed troughs and strips should be situated on the high side of the pen, running parallel with the contour to minimise pad drainage. They should also have smooth surfaces, as those without grooves or holes that can trap feed are easier to clean and help reduce build-up of waste feed, mould growth and unpleasant odours. The base of the trough should then be raised 10 to 30 cm, with the front 50 cm above this. If too much room is allowed, wastage can increase as the objective is to allow the stock to feed and then move back.

Farm office and staff quarters

Maintaining good farm records is much easier in a farm office. An area at home or in the dairy shed should be dedicated to keeping records. It must have a desk and good lighting. It must be a quiet place to set up the office files (preferably in a filing cabinet) and computer and office supplies. The how and when of keeping farm records depends on the person recording them and this is discussed in more detail in Section 7.1 in Chapter 7. Computers are very convenient but require money to purchase and skills to operate efficiently. They also need to be kept cool and dry. Record keeping should be given as high a priority as other farming activities. Suitable chairs and tables should be included for business meetings with service providers and other farm-related visitors.

Farm staff should be provided with space to eat and relax when off duty. This could include a shower and toilet, food preparation area, and storage for their work clothes.

4.3.4 Cooling cows

Effect of altitude on air temperature

The air temperature decreases 6.5°C for every 1000 m increase in altitude above sea level.

Garden hose

The easiest method is to hose down the cow for several minutes. Water should be applied to the head and back of the animal with enough applied so it runs off their back and down their sides.

Sprinklers

Sprinklers need to be suspended 2.3 m from the ground above the feed troughs with the water directed to the back of cows. The droplet size should be medium to large, depending on the humidity. A filter should be installed at the beginning of the waterline and the adjustable sprinkler nozzles should be easily removed for cleaning.

Cows should be sprinkled for 1 to 3 min, applying 1 to 2 mm of water per 15 min cycle, followed by a 5 to 10 min period when the sprinklers are turned off, to allow the ventilation (usually aided by fans) to dry off the cows' coats. The pipe size depends on the length and area of the shed to be sprinkled, the number of sprinklers and the flow rate. Use 32 mm diameter pipe for up to 30 m length or 51 mm diameter pipe for 60 to 150 m length. Nozzles should be spaced at twice the radius of their throw, for example, every 2.4 m for nozzles with a 1.2 m radius. Water misters are usually not suitable for use in the humid tropics, as they will often increase the humidity and reduce the ability of the air to cool the cow.

Cooling fans

Providing a fan increases the rate of cooling especially at low relative humidities. A simple electric fan, that can be moved around the shed to be strategically placed behind any cow, is an effective method to increase the cooling rate of heat stressed cows after being hosed down. These are also effective in humid areas, so long as the sprinklers are thoroughly wetting the cows.

Permanent ceiling fans can be arranged in many ways. A 0.5 horse power, 0.91 m diameter fan rated at 5–6 cu m/min will blow a distance of 9 m, while a 1.0 horse power, 1.21 m diameter fan rated at 9–10 cu m/min will blow a distance of 12 m. The direction of the fans should be with the prevailing wind. In wide sheds, the side-by-side spacing width of 0.9 m fans should be ~6 m, whereas 1.2 m diameter fans should be spaced 9 m apart. They should be positioned ~2 to 2.2 m above the floor. Fans should be tilted so they blow down to the floor directly under the next fan (~25–30° from the vertical).

Exhaust fans and roof vents, that do not require external power, may be worth considering to encourage greater heat removal through the roof.

Outdoor area for night-time

Air temperatures of less than 21°C for 3 to 6 h at night can minimise reductions in milk yield due to daily heat stress. Once the sun sets, outdoor areas are cooler than inside any shed. Therefore, it seems logical to allow the stock outside the shed at night. Cows will eat more during the cooler part of the day, so provisions must be made for adequate feeding space. It is better to provide the bulk of the forage in the evening, particularly during summer, so adequate feeding and watering spaces are important. Also, as it is easier to observe oestrus when cows are loose in a yard at night, permanent lighting is important. Even if they are restricted to tie stalls during the day, they can be untied for afternoon milking and re-tied after the morning milking.

Saudi Arabian dairy feedlots have outdoor areas, as do many Australian dairy feedlots. They are much less common in Asia because of the high rainfall and problems with mud. Where cows are frequently housed indoors, outdoor loafing areas should be an integral part of any shed design. Whether the floor needs to be concrete or brick or just plain dirt, is another issue. Free access to adequate watering space is essential.

A lounging area for the milking herd should:

- be located in a well-ventilated area
- be well drained
- have a dirt or gravel surface
- provide at least 5 to 10 m^2/cow
- incorporate water troughs
- incorporate troughs for feeding forages.

4.3.5 Other farm buildings

Farm machinery should be stored under cover. Such a facility could be used as a workshop for minor maintenance and servicing of machinery and also a storage area for bagged inorganic fertilisers.

A biogas plant can easily be constructed to better utilise shed effluent. The gas stored in a large plastic bag would then be piped into the kitchen for cooking or into the milking parlour to heat up water for cleaning the equipment. It can even be used to produce electricity from a generator, but this requires special equipment to pressurise the gas. The residue from the biogas plant is still a good source of organic fertiliser for growing forages.

4.3.6 Housing for other stock and milking parlour

As these topics are more relevant to herds larger than 10 milking cows, they have been presented in the following Chapter, at Sections 5.3.3 and 5.6 respectively.

4.4 Feed storage

Feeds should be stored in secure locations with easy access to the stock. Vermin control will be necessary. They should be located well away from waterways. Most feeds are sourced in bags, although larger farms may handle feeds such as by-products in bulk. In these cases, good road access for trucks is essential with the feed bunkers under cover. Such bunkers should have concrete floors and brick, concrete block or prefabricated or reinforced cement walls. For storing by-products with very low dry matter contents, soil ramps adjacent to these bunkers will aid discharge from trucks.

4.4.1 Storage of conserved forages

Forages can be conserved dry as hay or straw, or moist as silage. Hay or straw must be stored in weatherproof buildings and should not be stored in confined places if it is likely to be moist, where it can become mouldy or spontaneously ignite. Silage must be continually covered with plastic sheets to exclude any air before feeding out. Silages can be stored above ground in bunkers or below ground in pits. In-ground pits are best for long-term storage, but above-ground storage is preferred in areas with high rainfall but must allow drainage from the pit. Buns or stacks are the silage units without structural support. However, with their high surface area to volume ratios and plastic costs per tonne of silage and wastage rates, costs can be high. Bunkers or clamp silos are the most common storage systems, while individually covered bales or stretchable bags are often used in regions well serviced by silage-making contractors. The dimensions, particularly their width, should be determined before their construction, based on the predicted daily rate of removal from the silage stack.

Silages can produce a lot of liquid during storage, called leachate, which is very corrosive and lethal to aquatic life if it escapes into rivers or streams. The production of leachates can be reduced by incorporating dry material such as rice straw or rice bran at the base of the silage bunker.

4.4.2 Preparing concentrate mixtures

It is rare for milking cows to only be offered one type of concentrate, because of their high nutritive demands and the poor nutritive value of tropical forages. Concentrate mixtures usually contain a variety of energy and protein supplements together with minerals, usually macro minerals, and for high yielding cows, maybe even micro minerals, probiotics and other feed additives.

One very simple method of hand-mixing a complex concentrate mix for storage or immediate feeding is to spread each ingredient on top of each other in layers (even the mineral premixes), then collect the mixture into bags or buckets by shovelling it perpendicular to the floor. This method is ideally suited for dry concentrate ingredients, although it could be used each day for offering mixtures containing wet by-products such as cassava or soybean waste.

Molasses blocks are a good supplement, and can be used as carriers of non-protein N or minerals. The blocks are solid, fairly easy to make, transport and store.

Molasses intakes should not exceed 20% of the total intake, because at higher levels it will depress digestibility.

Many farmers in Asia mix dry concentrates with water to make a slurry, before feeding. There is little benefit in this practice in terms of encouraging stock to consume more or improve its utilisation.

If the basic ingredients of concentrate mixtures are stored, a space must be allocated to blend them into a formulation. Hand-mixing may be practical with small herds of stock, but a mechanical mixer is preferred to ensure complete blending of mixes for larger groups of animals. These formulations are either placed in top of forages or fed out following removal of residual forages from the feeding troughs. With large herds, however, a mixer wagon is a good investment as it ensures consistency of ration formulations. Mixer and feed-out wagons are even available for small milking herds of as few as 20 cows. Such mixtures are called total mixed rations (TMR), or partial mixed rations if cows also have access to grazed pasture.

4.5 Checklist for planning dairy sheds

Physical aspects

- Aspect of shed with respect of wind and sun.
- Flooring (material, slope).
- Rubber mats for floors.
- Wooden or metal uprights.
- Roof height.
- Roofing material (colour bond or tiles).
- Ensuring maximum natural ventilation.
- Feed troughs (cement, wood or other material).
- Water drinkers (automatic, trough plus float valve, trough plus hose).
- Location near feed growing areas (for effluent recycling).
- Design of shed to allow easy stock observation.
- Wide aisles for ease of carrying heavy loads.

Services

- Electricity (single or three-phase).
- Water (drinking, cooling, washing, sanitising).
- Water heating (liquid petroleum gas or fire).
- Water for washing down, taps and hose or floor flushing.

Environment

- Insulation for under roof.
- Sprinklers for cooling.

- Hose for washing down hot cows.
- Cooling fans (large overhead or small moveable).
- Fans for all milk cow areas or just for high yielding cows?
- Computerised system to initiate specific cooling cycles.
- Plant and protect trees, grass around sheds.

Effluent disposal

- Suitable gutters to keep floors clean.
- Effluent pit (sufficient capacity).
- One large pit for several sheds.
- Liquid effluent removal (pump and pipes).
- Solid effluent removal.
- Location of fodder growing areas for recycling.
- Area to dry manure and make bricks/cooking fuel.

Feeding facilities

- Separate feed storage areas.
- Bird, vermin and insect-proof.
- Silage pits.
- Bunkers for urea treated straws.
- Fresh or dry forage feeding.
- Hay shed for bulk storage of purchased hay/straw.
- Concentrate storage (bulk or bag).
- Chopper for processing roughages.
- Feed mixer (horizontal or vertical) for concentrate formulations.
- Stationary mixer wagon to process total mixed rations.
- Farm utility for transporting feed, stock and milk.
- Farm tractor for handling bulk feed.
- Floor space for hand mixing concentrates.

Milk harvesting

- Hand or machine milking.
- Separate milk harvesting area.
- Mobile mini milkers or milking plant.
- Vacuum lines above cows.
- Engine room for milk plant.
- Specific buckets/milk cans for each shed.
- Handling bulk milk (vat, milk can).
- Refrigerated milk vat in each shed or for entire complex.
- Other milk processing equipment (pasteurising, packaging).
- Specific equipment for cleaning/sanitising milk-handling equipment.

Adult cows

- Tie stalls or free stalls.
- Adequate feeding space per cow.
- Access to drinking water.
- Level of milk production.
- Grouping cows on stage of lactation.
- Halter and rope or neck yoke.
- Separate large yard for heat detection and night cooling.
- Handling yards and crush for veterinary attention (see Figure 4.1).
- AI or natural mating.
- Mating yard for bulls.

Young stock

- Separate milk rearing shed.
- Separate weaned young stock shed.

Figure 4.1: Smallholder farmers, often with limited resources, have to be innovative with their farm facilities. This Kenyan dairy farmer, with just 4 milking cows, generates a high proportion of his dairy enterprise income from the sale of pregnant dairy heifers. He obviously needs a strong cattle race in which to inseminate and provide health care. He considers this adequate.

- Suitable capacity for 25–30% replacement rate in same shed.
- Design of calf-rearing pens (above ground or deep litter).
- Location of milk-fed calves (away from adult stock) (see Figure 4.2).
- Material for calf pens (bamboo, wood, metal).
- Area for mixing milk replacers and calf concentrates.
- Hot water for cleaning equipment.
- Feed scales for weighing all feeds.
- Livestock scales for weighing stock.
- Hospital/isolation pen for infectious diseases.

Personnel

- Office and suitable furniture.
- Computer facilities.
- 'Smoko' or tearoom.
- Living quarters (if overnight work is required).
- Lockable storage of veterinary drugs and valuable equipment.

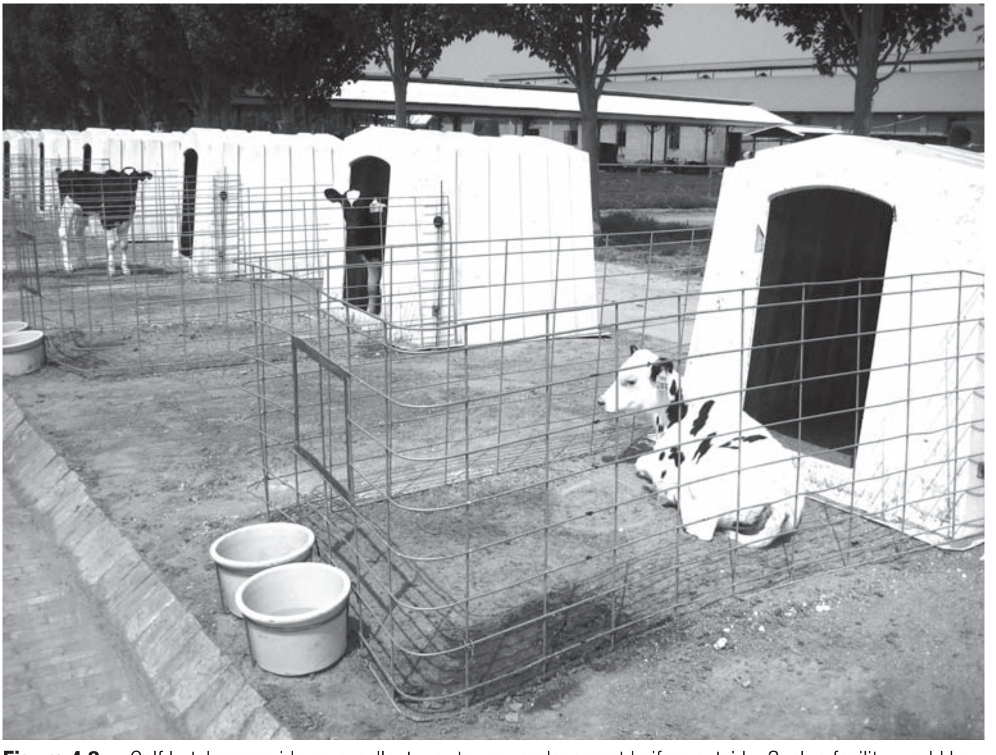

Figure 4.2: Calf hutches provide an excellent way to rear replacement heifers outside. Such a facility would be equally ideal for a smallholder farmer or a large-scale dairy feedlot farmer.