7. Manure and its application

Manure is evidently the Black Forester´s main treasure, his coin, his jewel, his pride, his Old Master, his ceramics, his bric-à-brac, his darling, his title to public consideration, envy, veneration, and his first solicitude when he gets ready to make his will.

Mark Twain (1912): A Tramp Abroad

7.1 Introduction

In the tropics there are many traditional links between arable farming and livestock husbandry, though these are not always found together on the same farm. Agreements between crop farmers and pastoralists or between different types of farm within an extended family are of greater importance in many areas than the integration of crop and livestock enterprises within a single production unit (BAYER and WATERS-BAYER 1990). The production of manure is one of numerous links between crop farming and livestock raising, and is gaining in importance as populations rise and soils become more depleted.[105]

Examples are found among the Kikuyu in Kenya, the Kofyar in the central mountainous region of Nigeria (NETTING 1968), and the Wakara on Lake Victoria (LUDWIG 1967). These peoples have combined livestock raising with the management of farmyard manure and compost production. Livestock production serves primarily to maintain the yield capacity of the soils. DRESSLER (1983), interviewing farmers in densely populated Rwanda, noted that the vast majority of farmers

[105] Other important links are: the exchange of grain and milk/meat between livestock owners and crop farmers, investment (income from selling crops is invested in animals), draft power (for plowing fields and transporting farm supplies), income-generating opportunities (e.g. members of a farming family are hired as herdsmen by livestock owners)(BAYER and WATERS-BAYER 1990).

questioned gave manure production as their main reason for keeping cattle and goats. Intensively managed cropping systems in Asia are almost invariably associated with livestock production. In this region pigs and poultry are more commonly kept than ruminants (KING 1911).

OMENGAN and SAJISE (1983) investigated the rice cultivation system of the Bontoc in the Philippines. They came to the conclusion that raising pigs plays a key role in ensuring high, sustainable rice yields, since farmers composted their plots with pig manure. The authors hypothesized that it was for this reason that the keeping of pigs had found a place in their religious traditions and duties.

Despite increasing land scarcity, which makes it more and more difficult for many subsistence farmers to ensure adequate feed supplies for their animals (DRESSLER 1983), livestock production remains a vital component of the farming system in many developing countries. This is especially so in traditional systems under pressure, where a small amount of land must support a high population. In such systems it may well be that livestock are indispensable to the maintenance of soil fertility where permanent cropping is practised.

A few features of smallholder livestock production relevant to the production and management of manure should be highlighted here:

* As agricultural land use intensifies towards permanent cropping, livestock production must also intensify.
* As land becomes scarcer, extensive grazing must gradually give way to more intensive systems involving housing.
* In more intensive systems fodder cropping replaces grazing as the main source of feed.

The following points argue in favor of the integration of crop and livestock production:

* Animals eat plants and plant parts that human beings are unable to use (unless as compost material, mulch or green manure). They convert plant biomass into products that people can use, such as meat, milk and draft power.
* Animal manure adds a concentrated, transportable and rapidly effective fertilizer to the nutrient cycle of the farm. It provides a convenient way of applying nutrients to fields when and where they are needed.
* Nutrients that have been removed from a farm's nutrient cycle (for example through erosion on steep slopes or leaching to valley bottoms) can be brought back up the slope for use as fertilizer either in the form of manure gained through the grazing of bottom land or by cutting and carrying hay or fodder crops grown on lower lying fields (MILNE 1947).
* Making compost is greatly facilitated by the addition of farmyard manure, which improves the C/N ratio. Without animal manure the process is usually very slow and, with some materials, virtually impossible.
* Natural fallows or wasteland can be made more productive by planting fodder legumes or a grass-legume mixture. The costs of planting are recovered through the provision of fodder. More fodder also means more manure in the stable and therefore also better crop yields.[106]
* The opportunities for improving fields by growing hedges, introducing trees, planting anti-erosion belts, etc are multiplied when livestock are kept. The profits from livestock products and from manuring other fields compensate for any sacrifice of cropland that adding these elements may entail.
* The farm's transport facilities are vastly improved if draft animals are kept. For example, collecting compost materials and applying compost or manure to fields becomes more efficient (see also Section 7.7, Table 7.17).

Because the profitability of keeping livestock on a small arable farm depends greatly on the quantity and quality of manure produced, this point will be discussed in more detail below.

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[106] In Germany, in the year 1783, Johann Christian SCHUBART published the article "Pastureland, grazing and fallows, the greatest diseases and the plague of agriculture", in which he made an urgent plea for the stabling of livestock and the cultivation of fallows with fodder legumes. In the years that followed his ideas gained acceptance and led to an improvement in yields of up to 100%.

7.2 Quantity and composition of manure

The amount of animal manure produced worldwide is enormous. In India alone, where one-fifth of the world's cattle are raised, it is estimated that 1,762 million tonnes of manure are produced yearly (BALASUBRAMANIAN and NNADI, 1980). With an average nitrogen content of 0.3%, this contributes almost 50 kg of nitrogen per hectare of cropland in India.

In practice, such values can only very rarely be achieved, since a large part of the manure and the nutrients it contains are lost to agriculture. Exactly how much is lost depends on the form of animal husbandry, the method of storage and the way manure is used. For the individual farmer it is important to know approximately how much fecal matter and urine is theoretically available to him or her - that is, how much of these each kind of domestic animal produces per day or per year.

Table 7.1. Dung and urine production of different agricultural livestock (rough estimates)

Animal species	JAISWAL et al. (1971) Dung	JAISWAL et al. (1971) Urine	SAUERLANDT (1948) Dung	SAUERLANDT (1948) Urine	Estimated amount per TLU* Dung	Estimated amount per TLU* Urine
	------------- kg or liters/day (fresh matter) ------------					
Milk cow	23.5	9.0	20-25	12	11	6.5
Horse	16.0	3.6	10-15	5	5-7	2.5
Pig	2.7	1.5	1.5-2.5	1.5	-	-
Sheep/Goat	1.1	0.6	1.0-1.5	1.0	-	-
Chicken	0.04	-	-	-	-	-

* A Tropical Livestock Unit (TLU) is a head of cattle with a live weight of 250 kg. Estimated values are given in this measurement rather than in the German "heavy livestock unit" (*Großvieheinheit*, GVE) of 500 kg live weight)

Rough estimates can serve as a guide, but it must be remembered that there are wide regional and seasonal differences owing to changes in the animals' feed supply and water regime. The availability of green forage is strongly correlated with the quantity and quality of manure produced. Whenever possible, regional data should be consulted or researchers should carry out their own survey. The values shown in Table 7.1 are compiled from Indian (JAISWAL et al. 1971) and German data (SAUERLANDT 1948).

Table 7.2. Composition of fresh dung from several species of livestock

Animal	Water (%)	Organic matter (%)	N (%)	P_2O_5 (%)
Cow	80 (79-82)	16 (15-18)	0.3 (0.3-0.5)	0.2 (0.18-0.2)
Horse	73 (60-76)	22 (21-24)	0.5 (0.5-0.6)	0.25 (0.2-0.3)
Sheep/Goat	64 (62-68)	31 (29-33)	0.7 (0.6-1.2)	0.4 (0.3-0.5)
Pig	78 (75-82)	17 (16-18)	0.5 (0.4-0.6)	0.4 (0.3-0.5)
Chicken	57 (50-60)	29 -	1.5 (1.2-3)	1.3 (1.1-2.6)
Duck	-	-	1.0	1.4
Rabbit	-	-	1.1	1.2
Water buffalo	81	12.7	0.25	0.18

Table 7.2 continued. Composition of fresh dung from several species of livestock

Animal	K_2O %	CaO %	C/N ratio
Cattle	0.15 (0.14-0.18)	0.2 (0.1-0.3)	20-25
Horse	0.3	0.2 (0.17-0.25)	24
Sheep/Goat	0.25 (-0.29)	0.4 (-0.46)	20-25
Pig	0.4	0.07 (0.05-0.09)	19-20
Chicken	0.8 (0.6-2)	4.0 (2-6)	9-11
Duck	0.6 -	1.7 -	-
Rabbit	2.7 -	0.1 -	-
Water buffalo	0.17	0.4	25-28

Sources: SAUERLANDT (1948); JAISWAL et al. (1971) and McCALLA (1975)

Similar differences exist in the quality of animal manure. Within the same animal species, the composition of dung and urine varies according to fodder (site, season) and water supply, as well as to the age of the animal and how it is used. For example, young animals and good milk-producing cows excrete less nitrogen than working or old animals because of their more efficient use of protein. Tables 7.2 and 7.3 present some average values (with range).[107]

[107] The nutritional differences between species are apparent despite the wide ranges.

Except in the case of poultry, the proportion of soluble nitrogen in fresh dung is relatively low. In fresh cattle, horse or sheep dung it is about 0.05 - 0.06%; this means that only some 10% of the total nitrogen is immediately available.[108] Storing and rotting the dung increases the content of available nitrogen .

Table 7.3. Average urine composition of some species of livestock

Animal	Water (%)	Org. matter (%)	N (%)	P_2O_5 (%)	K_2O (%)	CaO (%)
Cow	92.6 (92.5)	4.8 (3.0)	1.21 (1.0)	0.01 (0.1)	1.35 (1.5)	1.35 (0.3)
Horse	89.6 (89.0)	8.0 (7.0)	1.29 (1.2)	0.01 (0.05)	1.39 (1.5)	0.45 (0.15)
Sheep	86.3 (87.5)	9.3 (8.0)	1.47 (1.5)	0.05 (0.10)	1.96 (1.8)	0.16 (0.3)
Goat	- -	- -	- (1.9)	- (0.12)	- (0.59)	- (0.16)
Water buffalo	81.0	-	0.6	traces	1.61	traces
Pig	96.6 (94.0)	1.5 (2.5)	0.38 (0.5)	0.10 (0.05)	0.99 (1.0)	0.0 (0.02)

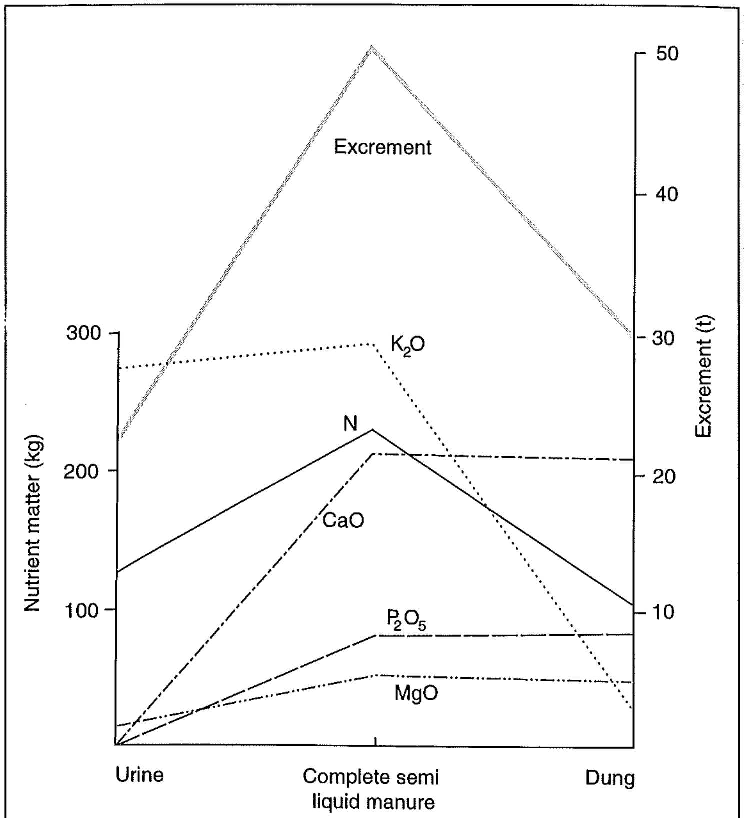
Source: SAUERLANDT (1948) and JAISWAL et al. (1971) (Data from SAUERLANDT in parentheses)

The composition of urine varies even more widely than that of dung. Table 7.3 compares values from India and Germany. It shows that urine is especially rich in potassium and nitrogen, whereas dung contains mainly calcium, nitrogen, phosphate

[108] In addition to mineral matter, dung consists largely of bacterial matter, humic matter (early stage of humic acid), lignins, cellulose, etc (KLAPP 1967).

and magnesium. The nitrogen in urine is present in soluble form and is readily available to plants. However, liquid manure made from urine should be applied with care, as undiluted urine manure causes burns on plants.

Figure 7.1. Dung and urine production of dairy cattle (in tonnes) and the division of nutrients between dung and urine



Source: FLAIG et al. (1978)

The example of cattle excreta in Figure 7.1 again illustrates how nutrients and quantity per weight are divided between dung and urine. The figure also shows that dung and urine are relatively one-sided fertilizers on their own. Only the combination (represented here as complete semi-liquid manure) results in a harmonious nutrient balance.

7.3 Producing and managing farmyard manure

7.3.1 Background

Farmyard manure is the most commonly used and readily available organic fertilizer worldwide. However, it is used hardly at all in many regions of the world, since it is both impossible and unnecessary to use cattle dung on extensively grazed pastureland (BURNETT, 1975).

Crop and livestock production are not separate agricultural activities. In many parts of the world, including much of Africa, integration is the norm not the exception. In India, Pakistan, and Bangladesh mixed farming is widely practised, such that the exploitation of dung is easier. Nevertheless, vast amounts of organic matter and nutrients are still lost to agriculture through lack of care in the collection of dung and through burning dung as fuel. ARAKERI et al. (1962) estimate that about 40% of the dung in India is burned each year. Another 20% is lost, and only about 40% is used as fertilizer.[109]

The inhabitants of densely populated East Asia have for centuries recognized the value of carefully managing animal (and human) excrement. This has enabled them to sustain permanent cropping systems.

[109] Based on a yearly dung and urine production of 1,762 million tonnes with an average N-content of 0.3%, this represents an annual loss of 2.1 million tonnes of nitrogen for India alone.

The problems that arise in connection with handling and using animal dung are complex. Often dung is inappropriately prepared and processed (MINISTRY OF AGRICULTURE 1975). The labor required to process it properly may be regarded as unacceptable. In some places farmers refuse to have manure heaps in their farmyards (LENZNER and KEMPF 1982). Other social and cultural conditions may present obstacles to the use of manure. For example, the raising of livestock on communal rangeland practised in many parts of Africa makes it more difficult to utilize dung.

The technical problems should not be underestimated. In areas where animal fertilizers are traditionally used or where livestock have been introduced only recently, many farmers may be unfamiliar with the use of animal manure (WEBSTER and WILSON 1966). MUSA (1975) regarded the lack of information and training for farmers on efficient methods of conserving and storing manure as a major problem. Additional losses may occur when manure is brought to the fields, if it is left for long periods unprotected from the sun and rain. As a result of these shortcomings farmers may fail to recognize the potential of using farmyard manure. For these and other reasons (e.g. transport problems), the use of manure is often confined to the home garden.

The more widespread use of farmyard manure depends greatly on proper preparation methods. Proper preparation, storage and application increase the value of farmyard manure, reduce costs, and enhance effectiveness, thereby increasing its acceptability.

7.3.2 Litter

A bedding of litter should always be put down when animals are kept in stables. First, this improves stable hygiene: cleaner animals and a dry stall give better protection from diseases. Secondly, the litter absorbs and collects dung and urine. The bedding is a prerequisite in closed stables, where it improves the microclimate of the stall and thus the comfort of both animals and people. A particularly important function of straw litter is its absorption of nitrogen in the form of ammonia from the urine, as this

would otherwise evaporate in the stable, which is unhealthy for the animals, and be lost in the atmosphere, adding to nitrogen losses. According to SAUERLANDT (1948), slightly rotten litter is especially good for binding large amounts of ammonia.

The presence of stable bedding promotes and regulates the decomposition of dung, encouraging the formation of humic acids and improving the chemical and physical properties of the dung (handling becomes easier). Absorbent materials such as straw make especially suitable bedding. Litters rich in waxes or wood, on the other hand, are less suitable as they cannot take up so much liquid. The absorptive capacity of different bedding materials is shown in Table 7.4.

Table 7.4. Water absorption of different stable bedding materials

Bedding materials	Water absorption in liters per 100 kg dry litter (after 24 hrs of watering)
Wheat straw	220-250
Reed litter	200-300
Bean straw	250-300
Leaf litter	200-250
Potato leaves	200-250
Peat litter	600-800
Sawdust	350-400
Earth	40-60

Source: SAUERLANDT (1948) and JAISWAL et al. (1971)

In practice, materials usually achieve only about 50% of their absorptive potential. It should be noted that the ability of straw to absorb moisture also depends on the length and nature of the straw. Chopped and mashed straw absorbs 20-30% more liquid than long straw (SAUERLANDT, 1948). Chopped straw also makes handling easier, a fact well worth considering where spreading manure and incorporating it into the soil are tasks performed manually (KLAPP 1967).

With regard to materials, straw may make very good stable bedding, but it is often too valuable to be used for this purpose given possible alternative uses as fodder, raw material for handicrafts, and so on. In such cases other materials must be used, such as sawdust. The latter is very absorbent but makes a manure with a high proportion of lignins, which decompose only slowly, and a high C/N ratio. Pure sawdust manure should therefore be composted. Usually, combinations of many different kinds of waste and crop residues are used as litter. Some of these serve first and foremost as fodder, with what the animals do not eat remaining as bedding. When litter materials are scarce, instead of changing the litter the dung can be shaken out of it and stacked or composted. In the highlands of Rwanda, LENZNER and KEMPF (1982) observed that litter cleaned in this way was reused twice.

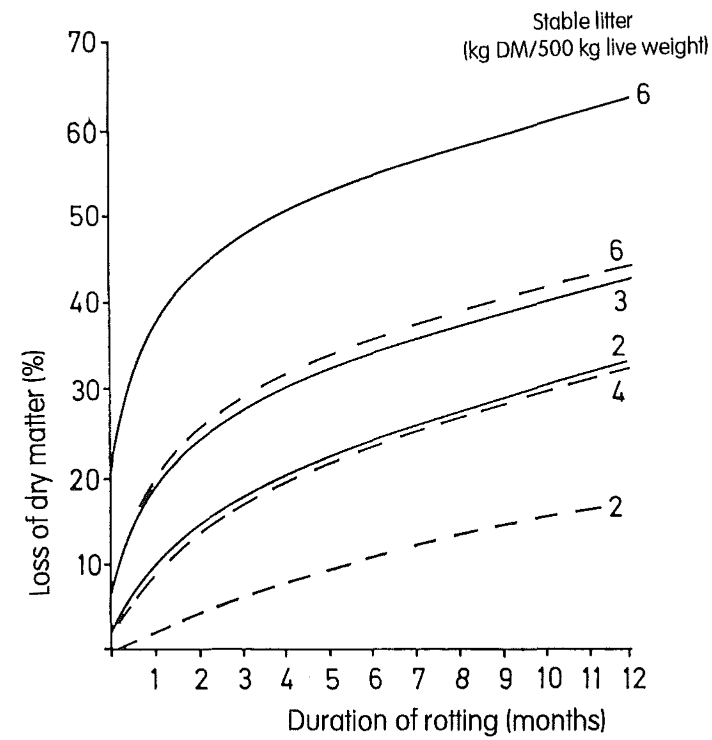
In some areas of India, earth must be used as litter, due to the lack of other materials. The earth is shovelled out of the stables regularly and replaced with fresh earth. But both manure loss and labor requirements are very high with this method, which should therefore be considered as a last resort. In parts of Asia, a thin layer of gypsum is sprinkled, to bind the ammonia as sulfate. JAISWAL et al. (1971) recommend 0.5-1 kg per cow per day. How much litter is necessary depends on the type of stabling used, on the species of animal and on the fodder. The latter two factors, for example, influence whether the dung is solid or liquid in consistency. In stanchion barns 1.5-3 kg of straw-like litter is sufficient per tropical livestock unit[110] per day. More litter (3.5 kg/day) should be used for animals kept in deep stables. Urine that cannot be absorbed by the straw should be collected and poured onto manure and compost heaps.

The amount of organic matter lost when farmyard manure is stored depends greatly on the proportion of litter it contains, since this influences the ventilation, the share of decomposable inorganic compounds and the C/N ratio. According to KOHLENBRANDER (1955), in Europe, the loss of dry matter from farmyard manure increases in proportion to the amount of litter it contains. If the manure is stacked loosely, up to 50% of the organic matter may be lost within 4 months, whereas only 20-30% is lost with close anaerobic storage (Figure 7.2). In the case of deep stable manure

[110] In Europe 8-10 kg of dry straw is commonly considered adequate per 500 kg live weight in deep stables.

(thoroughly soaked and trampled down) the losses are seldom higher than 20%, despite a high proportion of litter. These orders of magnitude were confirmed by PIETROWICZ and NEUMANN (1987) in their trials in Nyabisindu, Rwanda. Some loss of organic matter is desirable, since this limits the C/N ratio to about 20:1, but the loss should not be so great as to deprive soil organisms of energy-rich organic matter.

Figure 7.2. Dry matter loss in stacked stable manure as affected by duration of rotting, amount of litter (kg per 500 kg live weight) and type of storage



(—) Aerobic (---) Anaerobic

Source: KOHLENBRANDER (1955)

7.3.3 Fresh manure

The simplest method of manure preparation is to do nothing with the dung at all but to store it directly on the fields. Two arguments against this practice are that it is cumbersome from an operational point of view and that often there is no field available to accommodate the manure. SAUERLANDT and TIETJEN (1970) point out in addition that fresh stable manure is prone to form organic acids. These are rapidly processed by soil organisms, which can lead to an overload of oxygen and nitrogen in freshly manured soils.

The C/N ratio of fresh manure is often too high. This can result in a temporary N block, such that hardly any manure nitrogen will be available in the following growing period (FLAIG et al. 1978). An improvement in the humus content of the soil cannot be expected from fresh manure as it can from rotten manure. In addition, the content of lactate soluble phosphates in crop soils is increased only by decomposed manure, not by fresh manure (SAUERLANDT and TIETJEN 1970). Storing stable manure is therefore preferable to using it fresh. Fresh manure can inhibit crop growth considerably.[111]

7.3.4 Storage and stacking

Almost all methods of manure conservation and preparation involve stacking the manure in one form or another. In addition to saving space, stacking should achieve the following aims (KLAPP 1967):

* It should narrow the C/N ratio (this will improve the fertilizing effect),
* It should enrich the humic matter and build permanent forms of humus. Many factors that determine value act only as the manure ages, which is why decomposing - though associated with the loss of organic matter - is recognized as positive, increasing the proportion of beneficial components and breaking down harmful elements. Whereas little or no humus is formed when manure is spread fresh, formation is promoted by the special chemical and physical conditions prevailing in a manure pile (pH, gaseous balance, etc). Many of the humic compounds formed in this way are more resistant to decomposition than those present in fresh manure,
* Mineralization of nutrients should take place with as little loss as possible,
* Weed seeds that may later germinate should be destroyed (or reduced to a minimum),
* The physical, biological and chemical properties of the manure should be improved (i.e. it should become more convenient to handle and more effective).

[111] There are exceptions. Fresh farmyard manure can be used successfully on light, sandy soils, provided the litter content is sufficiently low (MUSA 1975). AUGSTBURGER (1983) achieved good results on acid mountain soils in the highlands of Bolivia (2500 m a.s.l.), where fresh chicken manure (pH = 9.0) gave better results than stored manure.

Storage places for manure, like those for composting (see above), should ensure its protection from sun, wind and rain (perhaps including a roof or cover). Stagnant moisture caused by seeping liquid should be avoided. The best place is on firm, impermeable, slightly sloping ground (2% gradient), so that liquid manure can flow out to be collected (with the urine from the stable) in an airtight pit. A base wall surrounding the manure pile prevents the semi-liquid from running out and rainwater from flowing in (see Figure 7.3)

Fresh manure for stacking should have a moisture content of 60-70% (i.e. it should be quite moist). In the case of sheep dung, goat dung and perhaps also horse dung, it may be advisable to water the manure before stacking. It is even better to pour urine onto it (JAISWAL et al. 1971, KLAPP 1967). Losses occur if the manure is too dry and decomposition is hindered. White mycelia in the heap are a sign that it is too dry. Manure that is stored too wet exhibits yellow-green discoloration. Stored manure should be an even brown to black color. This is the easiest way of recognizing that it is well stored.

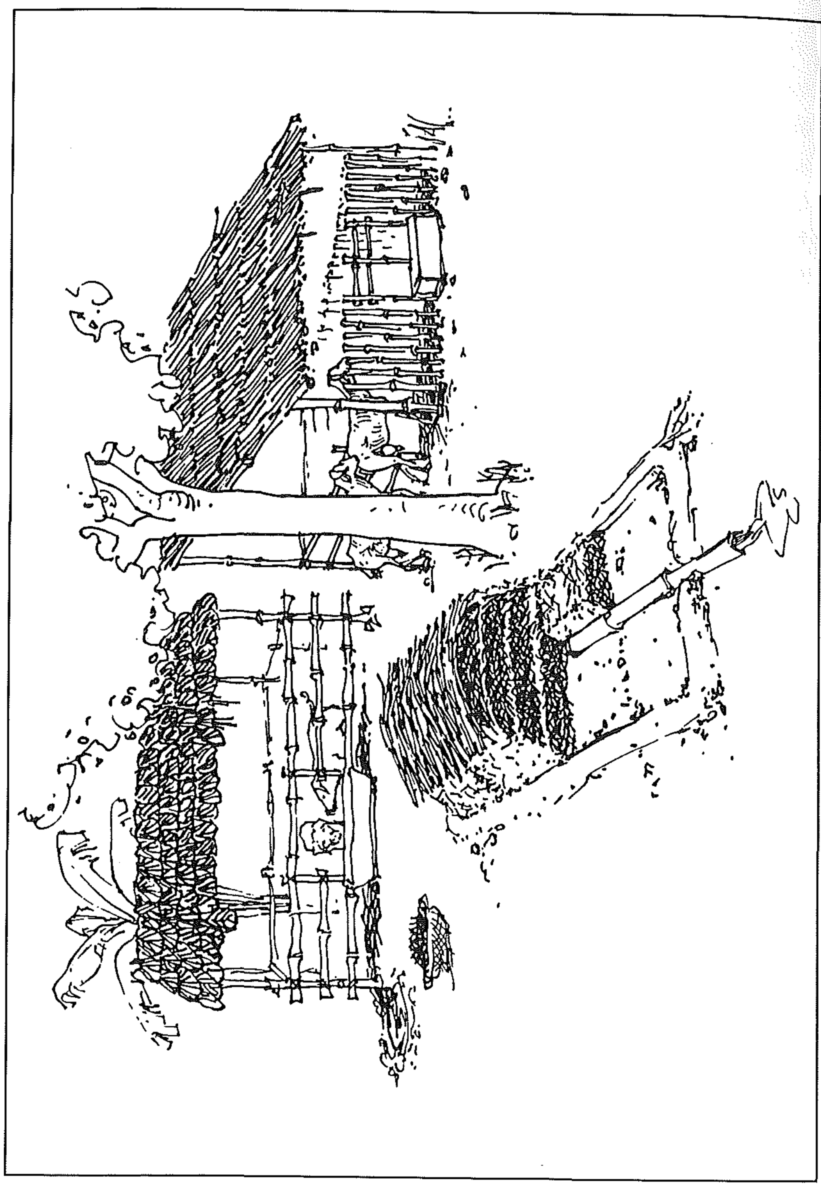


Figure 7.3. Common manure heap in layers and sections

7.3.5 Stacked manure

Normally, dung is placed on the manure heap daily or every 2 days. It is better to build the heap up in sections and to stack up a small section quickly than to spread manure over the whole farmyard.[112]

Small-scale farmers are advised to build a heap 1.5-2 m high with a wooden board or low wall surrounding it for protection. The section is then covered with a layer of earth (15-20 cm) to reduce drying and loss of ammonia. Especially if it contains a high proportion of litter, the manure should be trampled down firmly. This step can be omitted only for densely compacted manure that is poor in litter. Heaps should be firmly reinforced round the edges to give them the necessary stability and to limit the exchange of gases. The manure heap is thus filled and stamped down section by section. It is a good idea to organize the heap in such a way as to allow access to older sections before newer ones, so that decomposed manure is always available.

The process of decomposition, described below, essentially depends on the ratio of dung to straw in the manure. Manure that contains a high proportion of straw easily heats up to 70°C, resulting in high losses of C and N and drying of the manure pile. In such cases it is advisable to compress the pile again so as to reduce the influx of oxygen or to pour liquid manure over the pile several times. Temperatures of 35°-45°C are normal and promote good decomposition. Manure that remains cooler is usually very poor in litter. It may require more litter or a little earth to ventilate it.

This method of storage was and still is widely practised in Germany.[113] It should be suitable for most places in the tropics as well.

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[112] The aim is to avoid losses by exposing as small a surface area as possible to leaching or drying.

[113] "Keep it moist and stamp it sure - that's the best thing for manure." Popular German saying.

7.3.6 Methods of heat fermentation

A variation of the stable method is the heat fermentation of manure (SAUERLANDT and TIETJEN 1970). With this method the manure is deliberately stacked very loosely at first. It is broken into small pieces and stacked to a good 60-90 cm in height. Then it is covered (with a plastic sheet or something similar) to keep the heat inside the stack and prevent the loss of moisture. On the second, third and fourth days a new pile is stacked in the same way (three to four stacks are built next to each other). Only after 3-4 days or when the manure has reached a temperature of 60-70°C is it compacted, to press the air out. The initial aerobic phase is thus ended and anaerobic fermentation begins. This brings the manure to maturity.

With this method it is important that the farmer manages to complete the initial aerobic phase. This is difficult with manure that is rich in straw. If this phase is completed properly the temperature drops after 2 weeks to 30-35°C and the loss of CO_2, moisture and N are kept within tolerable limits. The advantage of this somewhat laborious method - which is better suited to old hands at manure stacking than to beginners - is that weed seed loses its ability to germinate after 2 weeks at high temperatures. Manures developed in this way are thus known as fermented manures.

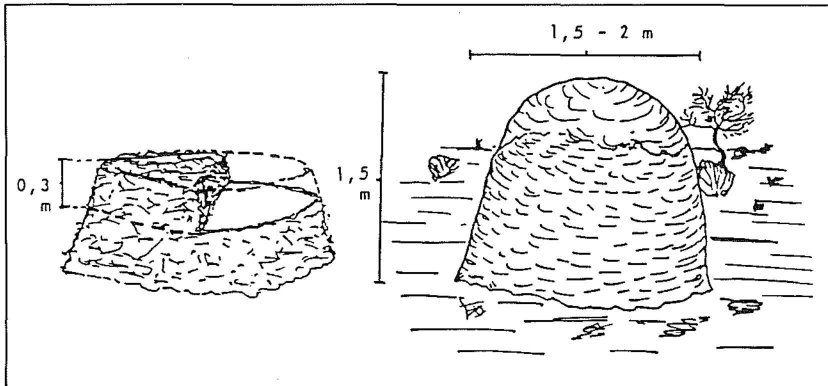
This method is recommended only when the litter contains many weed seeds that would run riot on fields fertilized with the manure, or when the livestock feed used contained seeds that retain their ability to germinate while in the digestive tract and that will cause problems when the manure reaches the fields. Otherwise, this method is not recommended as the quality of the manure is not appreciably better than that achieved with simple farmyard manure methods, so the extra labor is not worthwhile. The following two methods are very similar to those described so far, but were developed in India.

7.3.7 Pile method

The heap or pile method of treating manure is recommended in India for areas and seasons with high rainfall, whereas the manure pit method described below is more advisable for semi-arid to arid regions. In the pile method, developed for manures that are relatively poor in straw, somewhat smaller areas are stacked high as quickly as possible. When complete the pile is covered and protected for storage and maturing.

The pile is established near the stable, but not where there is any risk of flooding. The dung is added daily, together with a variable amount of litter, in layers about 30 cm thick on a circular area of ground 1.5 to 2 m in diameter (see Figure 7.4). When a height of 1.5 m is reached, the pile is given a domed top and the sides are sealed with a layer of clay. A covering made of straw or palm fronds seals the top and protects the pile from rain. The manure is ready to use after 4-5 months (ARAKERI et al. 1962).

Figure 7.4. Storing manure using the Indian heap method



a) Building the heap in layers of about 30 cm b) Covering c) Clay wash to seal the heap

Source: ARAKERI et al. (1962).

7.3.8 Pit method

The pit method is recommended in India for arid and semiarid regions and for the dry season. A pit is dug about 1.8-2 m wide, 90 cm deep and as long as desired (depending on the number of animals kept). The floor of the pit should slope slightly and be compacted, so that liquid manure will trickle down and flow into a liquid manure pit (via a gutter or pipe).

About 3-5 kg of straw per unit of livestock is then placed at the bottom of the pit. This is covered with farmyard manure section by section and layer by layer, so that the level rises by about 30 cm each day, just as in the pile method. The manure is compressed and covered with 1 cm of earth per layer. This process continues until the stack is about 1.2 m high and 30 cm above the edge of the pit (Figure 7.5). The manure is then covered with 10 cm of earth and/or straw and left in the pit for 4 months to mature. If possible the pit should be surrounded with a low wall to keep rainwater out.

The pit method has also been used with manures containing small proportions of litter. As studies in Northern Ghana show (Table 7.5), this method is better at conserving nutrients than other storage methods (KWAKYE 1980). Similar results were obtained by MUSA (1975) in the Sudan. These studies were carried out with cow dung that had a low straw content, and it is not known whether such clear advantages can be obtained with a litter-rich manure.

One advantage of the pit method is that the risk of the manure's drying out is almost non-existent. The manure can be kept moist without subsequent wetting or laborious restacking of small piles. Disadvantages are that stagnant water may form if the pit is not constructed properly, and the extra work involved in lifting the manure back out of the pit.

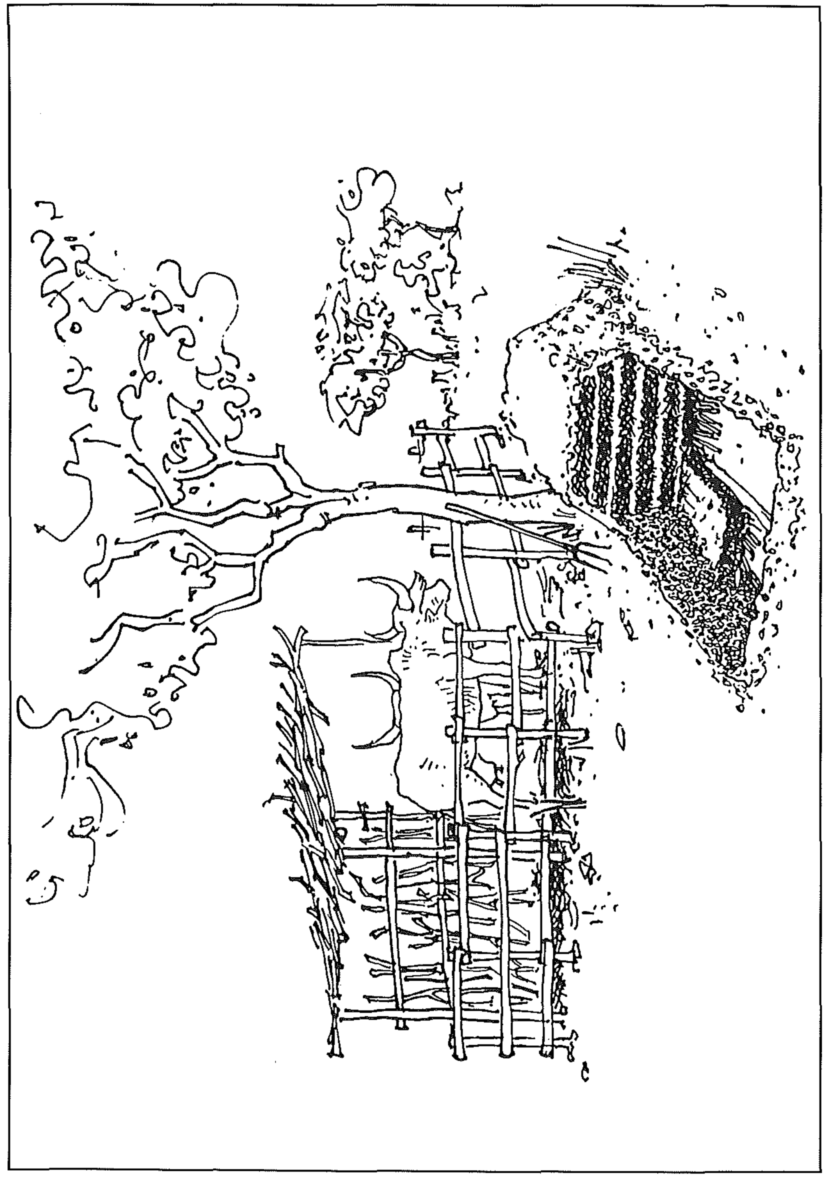


Figure 7.5. Manure storage using the pit method in semi-arid and arid regions

Table 7.5. Effect of different methods of storing cow dung in Ghana on N-, P- and K-contents after 3 months of storage.*

Type of storage**	Dry matter (%)	Nitrogen (%)	Phosphate (%)	K_2O (%)
a) Loose pile (without cover)	22 (-28)	0.71 (-59)	0.50 (-28)	1.32 (-45)
b) Stacked and immediately compressed (covered)***	26 (-16)	0.93 (-47)	0.51 (-27)	1.51 (-37)
c) Loosely stacked, compressed after 3 days (covered)***	24 (-22)	0.79 (-55)	0.55 (-20)	1.45 (-40)
d) Stored in a pit (covered)***	27 (-12)	1.48 (-15)	0.60 (-12)	2.14 (-11)

* The values in parentheses express the relative losses compared with the original material; ** Stack height in meters; *** Covering comprises a layer of earth and grass.

Source: KWAKYE (1980)

All the methods described so far have at least three points in common:

* Storage is as compact as possible, so that after a short phase of rapid decomposition a more anaerobic state is reached in which decomposition continues more slowly (maturing phase).
* A tall stack with a small surface area is aimed at.
* The storage place is protected from damp as well as from wind, heat and desiccation.

7.3.9 Earth manures

A special method of treating manure is that of adding soil. This method was introduced from China and was practised in England in the 18th century (KING 1911). It is based on the idea that stable clay-humus complexes may be created in the manure pile by adding clay minerals with a high lime content (KLAPP 1967). Depending on the method used, different proportions of soil and manure are mixed and layered and then stored for several months. The proportion of soil is nowadays usually limited to 20-25%, whereas formerly it often came to over 50%.

The soil to be added should be gathered during the less busy times of the year and should preferably be rich in nutrients (farmyard sweepings, mud from streams, alluvium deposits, etc). In China, such soil is mixed with lime (1-2 kg/m^3) and stored for at least 1-2 months before being mixed with the fresh farmyard manure.

Mature earth manure is spread on fields and lightly hoed in as a top-dressing. According to SAUERLANDT (1948) this increases the availability of P, strongly encourages soil life and improves soil structure. One disadvantage of this method is that large amounts of soil must be dug and transported. For this reason - and because trials carried out in temperate climates in the 1960s did not show any profound difference between this manure and any other - this method has been largely abandoned.

Whether earth manure is more effective in the tropics than in temperate zones is not known, but seems unlikely. In Côte d'Ivoire a mixture of one-third sand, one-third earth and one-third manure on a ferrallitic soil had a markedly better humus effect than did pure manure (GODEFROY 1979). Because of the high labor requirement for transporting soil, adding soil should be considered only if trials carried out locally indicate the superiority of this method, or if the aim is to reintroduce mud, sludge or farmyard sweepings into the farm's nutrient cycle.

The use of earth makes this method closely related to composting. Indeed, it is uncertain whether the material in question is compost or manure. The mixture of dung, litter, plant residues and soil can differ in composition, depending on the time of year. According to SAUERLANDT and TIETJEN (1970), farmyard manure composts usually have an even better humus effect than farmyard manure alone. This means that where there is an opportunity to produce compost using manure, advantage should be taken of it (see also Chapter 6).

7.3.10 Deep stable manure

High quality manure can be obtained from deep stables or long-established pens (KLAPP 1967; SAUERLANDT and TIETJEN 1970). In deep stables animals are fed on the spot and they themselves trample the dung down firmly together with the litter, which should be added regularly. Thus this method too has an aerobic phase followed by an anaerobic one. In addition to the dung, the stable manure absorbs all the urine without any extra labor being required. Nitrogen and phosphorus contents are improved and relatively low C/N ratios result. The manure does not need to be turned over but simply remains in the stable until needed.[114] The necessary roof over the manure pile consists in this case of the roof of the stable itself. Hence this method is especially cost-effective. Labor costs are lower than with any other method, and the recovery rate of excrement is high.

In Europe, this form of stabling - known in England as a "cattle-yard" since the 18th century[115] (SAUERLANDT and TIETJEN 1970) - is still in common use. Indigenous forms of this method are also found in Africa. EGGER (1982) mentioned the deep stabling of livestock practised by the Kikuyu in Kenya, while NETTING (1968) described goat keeping by the Kofyar in Nigeria, who build round pens out of stone (or wood) 1.5-2 m high and 3.5 m in diameter. Goats or cattle are kept in these during the growing period (8-9 months). The daily supply of fodder (weeds, grasses, straw, twigs from bushes and trees) usually exceeds demand, so that the surplus becomes litter. The manure accumulates up to a depth of 2 m. It remains in the pen until the beginning of the next growing season, when it is spread on the fields. In this

[114] The moisture content can be regulated by wetting with liquid manure or water or adding litter and/or draining away liquid manure.

[115] The "cattle-yard" is a round, sunken livestock pen, which also constitutes the manure yard (except for walkways around the outside). The fodder trough is set in the middle.

way the Kofyar produce large quantities of deep stable manure which they apply specifically to their most important food crops.

One disadvantage of this method may be the different ages of the manure in the upper and lower layers. Dividing the layers is impractical, so it is advisable to mix them thoroughly before bringing the manure to the field.[116] Storing manure for too long should be avoided,[117] or nitrogen losses will be high when the manure is spread on the fields. Manure which is too mature is relatively poor in available C compounds and therefore has a less stimulating effect on soil life (KLAPP 1967).

The large amount of litter required (83.5 kg of straw per tropical livestock unit per day) must be regarded as a disadvantage in areas where litter is scarce. This method can nevertheless be recommended where livestock are penned more or less all day and where enough litter is available. Figure 7.6 shows an typical deep stable.

7.3.11 Additives to farmyard manure

Additions are frequently made to farmyard manure to improve its quality. Rock phosphate, bone meal and mineral powders are the most frequent additives. On biodynamic farms, herbal preparations are added in homeopathic doses to enhance decomposition and fermentation as well as microbial life (ABELE 1976, von HALLER 1978, KOEPF et al. 1980).

Such additives are also recommended for tropical regions. The main requirement here is to add phosphorus, usually the growth-limiting nutrient (AUGSTBURGER 1983). JAISWAL et al. (1971) recommend adding up to 20 kg of rock phosphate per t of farmyard manure to improve its fertilization value and to reduce the loss of ammonia. The phosphate may be added either in the stable or to the manure heap.

[116] For fast-growing crops such as vegetables a highly mature manure with a low C/N ratio is preferable, so in this case layers may be separated, with the older manure at the bottom being applied to the vegetable crop.

[117] Most manures mature in 3-4 months.

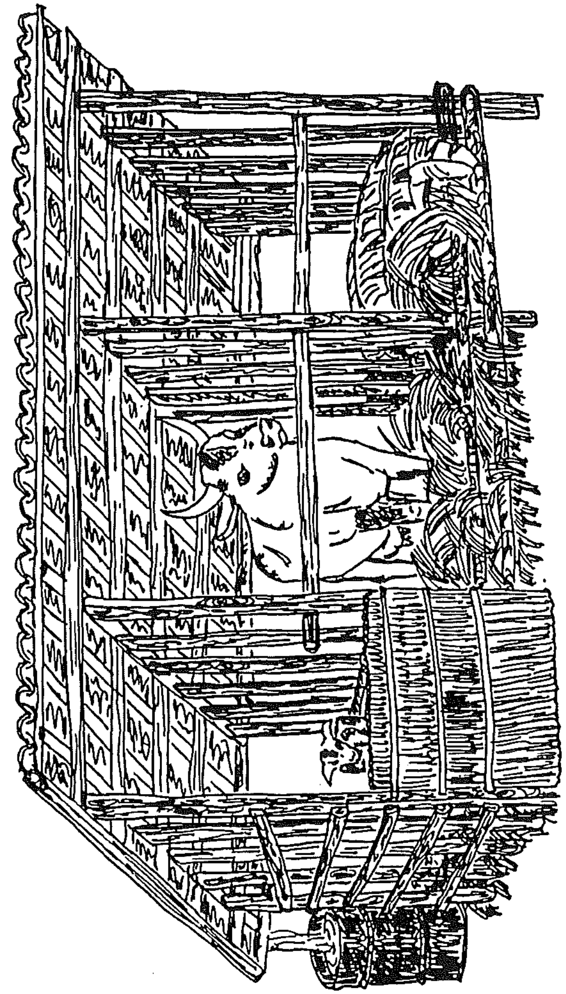
Such practices appear worthwhile. SAUERLANDT (1948) found phosphate was more effective when added to a highly concentrated manure than to a less concentrated one. Phosphate that was first added to the farmyard manure and then spread on the fields was less easily fixed than mineral phosphate applied directly.

In trials in Ghana (KWAKYE 1980) manures with a high N content and a low litter content were added to fertilizers containing different amounts of phosphate. After 3 months of storage, analysis showed that phosphate markedly reduced nitrogen losses. Superphosphate worked best (Table 7.6). There was positive stimulation of micro-organisms (lower C/P ratio) and increased N-fixing activity. According to SAUERLANDT and TIETJEN (1970), the humus effect of farmyard manure is also improved by adding phosphate.

Table 7.6. Effect of adding phosphate on the N-content of farmyard manure after 3 months of storage

Treatment	Nitrogen (%)	N increase (%)
Farmyard manure, no P added	0.87	-
Farmyard manure + superphosphate	1.50	73
Farmyard manure + triple-superphosphate	1.04	21
Farmyard manure + rock phosphate	1.29	49
LSD (p = 0.1)	0.09	-

Source: KWAKYE (1980)



KRÜGER (1983)

Figure 7.6. Deep stable for all-day penning of livestock in Nyabisindu (Rwanda)