FACTORS AFFECTING AMOUNT OF WATER OFFERED TO DAIRY CATTLE IN KIAMBU DISTRICT AND THEIR EFFECTS ON PRODUCTIVITY.

By

AUGUSTUS NYERERE MULI

(BSc. Range Management (Hons), University of Nairobi)

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other university.

Augustus Nyerere Muli

This thesis has been submitted for examination with our approval as the supervisors.

Dr. Charles K. Gachuiri
(University of Nairobi)

Dr. Raphael G. Wahome
(University of Nairobi)

Dr. Jon Tanner
(International Livestock Research Institute)

DEDICATION

This Thesis is Dedicated

To

Visser, Brian and Mwikali

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LIST OF ABBREVIATIONS

ARC -.................... Agricultural Research Council
BCS – .... Body condition score
BW .... Body weight
Cm .... Centimetres
DFID ....Department of Internal development
DM ....Dry matter
DMI ....Dry matter intake
F ....Fahreneight
g ....gramme
GIS.................... Geographical Information Systems
GLM ....General Linear Model
H^+ ....Hydrogen ion
ILCA ....International Livestock Center for Africa
I.L.R.I ....International Livestock Research Institute
ICRIST....................International Crop Research Institute for Semi Arid Tropics
KARI ....Kenya Agriculture Research Institute
kg .... Kilogramme
km .... Kilometres
l............................ Litres
lb .... Pound
LW .... Live weight
lwt .... Live weight
m .... Metres
MALDM .... Ministry of Agriculture, Livestock Development and Marketing
min. .... minutes
MY .... Milk yield
NARC .... National Agricultural Research Centre
Na .... Sodium
NRC .... National Research Council
OH^- .... Hydroxide ion
S.D.P. (R & D) .... Small Holder Research Project (Research and Development)
SAS .... Statistical Analysis Systems
UK .... United Kingdom

ABSTRACT

To study the factors affecting amount of water offered to dairy cattle and their effects on productivity, 20 smallholder dairy farmers in Kiambu District were randomly selected. Data collected once fortnightly for 11 months was analysed to study the impact of water on offer on productivity. Data was collected on source of water (on- or off-farm), water storage, distance to water source (categorised as 1) 0-200m, 2) 200-1000m or 3) >1km), watering frequency (continuous or non-continuous watering), mode of presentation (categorised as water troughs of 1 (<100), or 2 (>100 litres)), means of water transport categorised as none needed, manual, or carts/wheelbarrows/donkeys/bicycles. Total amount of feed offered, water offered, milk yield, live weight and condition score were also monitored.

Mean amount of water offered per farm per day was 134 l, or 35.6 l/300 kg LW/ day. However, the variability was high (range of 7 - 108 l/300 kg LW/day). Of the farms surveyed, 60% had on-farm water source, which was within a radius of 200m. 40% trekked between 0.2 - 2.5km to fetch water for livestock. Only 25% had water piped directly to the water trough. 55% carried water manually by bucket, while 20% used draught power or bicycle or wheelbarrows to transport water. Small water troughs (20-l-buckets) were used in 25% of the farms surveyed to water dairy cattle. 50% of the farms practised non-continuous watering and 55% had no water storage facilities.

Analysis of the data showed that source, distance to source, water transport means, water storage facilities, watering frequency, volume of water trough significantly affected the amount of water offered/day to dairy cattle (P<0.05). Distance to water source was

related to quantity of water offered, with mean quantities of 43, 23 and 21 l/300kg LW being offered to animals in the distance categories 1-3 cited above. Cows with on-farm water source received 43 l compared to 22 l offered in farms with off-farm water source. Mean quantities of 52, 30 and 25 l/300 kg lwt were offered to dairy cattle in farms with water piped directly to water trough, manual-hand bucket and those using draught/bicycle/wheelbarrow respectively. Watering frequency influenced water on offer with mean quantities of 49 l/300 kg lwt/day (continuous watering) and 21-l/300 kg lwt/day (non-continuous watering). Small water troughs restricted the amount of water on offer/day (21 l/300 kg lwt) compared to 39 l/300 kg lwt /day offered in farms with large water troughs.

Dairy cows were offered a variety of feeds. Napier and other types of grasses were the main feeds constituting more than half (1.58/100 kg lwt) of the total feed offered. Dry maize stover was second to napier/grasses in importance with an average of 0.567 kg / 100 kg lwt per day. Concentrates were offered in all farms to lactating cows at an average of 0.4855 kg /100 kg lwt per day. These included commercial dairy meal, cotton seed cake, bone meal, maize bran, maize germ, wheat bran and poultry litter.

It was observed that dairy cattle in farms with on-farm water source, large water troughs, practicing continuous watering and those with water storage facilities were offered high amounts of water and produced significantly ($P<0.05$) more milk. In addition, these farms were offered high amounts of concentrates and napier grass. In farms where high amount of dry maize stover was offered to dairy cattle, coupled with low water on offer, low milk yields were realised. This was observed in farms with small water troughs, off-farm water source and farms without piped water.

General linear model analysis of the data indicated that the amount of water offered (l/300kg LW/day), age, parity, body weight, stage of lactation, body condition score and dry matter on offer had a significant effect on milk yield. Increasing amount of water offered increased milk yield. In conclusion, high amount of water, concentrates and napier/grass on offer resulted in high milk yields. These results highlight the increasing importance of ensuring adequate provision of drinking water as milk yields in dairy cows increase. In this context, smallholder dairy farmers in Kiambu District should be advised to increase the amount of water offered to dairy cattle from the average 35 litres/300 kg LW/day currently offered to at least the recommended 60 litres per day.

CHAPTER ONE: INTRODUCTION

1.1. Problem Statement

Water is often taken as a bland, inert liquid, convenient for many practical purposes. Indeed, water and it's ionisation products, H^+ and OH^- ions, profoundly influence the properties of many important components of cells, such as enzymes, proteins, nucleic acids and lipids. It is also required for thermoregulation. Thus, water is an essential nutrient and a component of the body. It is usually assumed that water is available to the dairy cows *ad libitum* at farm level (Staal ***et al***., 1997). However, it can be the most limiting nutrient, being either unpalatable because it contains dirt or filth, is polluted, has a high mineral content, and not accessible or available.

Ruminants water requirement are fulfilled through water drunk, water from feedstuffs and metabolic water which contributes 10% or less of total water (King ***et al.***, 1977). Dairy cattle require regular and frequent access to free, clean and cool water (NRC 1989, Ensiminger ***et al.***, 1990, Beede, 1993). High water intake and consequently high water turnover has been known to result in high milk yields and also in high calf growth rates (Kamal, 1982). The provision of an unlimited supply of clean drinking water, with access to such a supply at least once daily should therefore be recommended. In case of lactating ruminants maintained in hotter tropical environments, such an adequate supply of water should preferably be available several times each day (Ensiminger ***et al.***, 1990).

Most data on water metabolism in ruminants have been derived from research data under relatively harsh conditions such as those existing in arid areas and in the cold climates where water availability can limit both plant and animal productivity (King *et al.*, 1977). Information on water use by livestock in high rainfall areas where water supply is seldom restricting is rare. Water deprivation affects feed intake, metabolism and productivity of animals (Kamal 1982; King *et al.*, 1977; King and Stockdale, 1981; Murphy, 1992; Reid, 1992; Anderrson *et al.*, 1984). It has been shown that cattle decrease their dry matter intake when they are deprived of water. The provision of adequate quantities of clean drinking water is an important prerequisite for satisfactory animal health and milk production, with water constituting 85-87% of milk. The need for water increases with increased intakes of protein and salt and with increased milk yields (Murphy, 1992; Reid, 1992). It is generally recommended that lactating cows have *ad-libitum* access to clean water to avoid restricting potential milk yield (ARC, 1980; Beede, 1993). Water requirements might be expected to be particularly high for lactating ruminants in hotter tropical climates (1980).

Although there is a considerable amount of work focusing on feed supply and feed utilisation; there is often an assumption that water is not a limiting factor. However, studies by Gitau (1997) and Staal *et al.*, (1997) identified water availability and accessibility to be a constraint in dairy production in Kiambu District.

Most farmers in Kiambu District (Central Kenya) haul water from off-farm sources (Staal *et al.*, 1997) especially in the dry season to water their dairy cattle. When farmers in six villages of Kiambu district were asked to rank the problems affecting their welfare in descending order (Gitau, 1997), water access was ranked first in 3 villages second in one village third in two villages. Staal *et al.*, 1997 found the following: i) of 365 smallholder farmers, more than 40% carted water from off-farm sources ranging from

0.6 km to 4 km, and ii) nearly 40% of the farmers have no farm transport facilities while the majority of them depend on wheelbarrows and bicycles. Moreover, different water sources and watering management practises may mean that amount of water on offer to livestock may differ from farm to farm. These findings suggest that water is unlikely to be offered *ad libitum*, which may indicate a strong likelihood that animals are restricted, particularly at certain times of the year when water is scarce.

This implies that in areas, where water availability and access is limiting, dairy cattle productivity is affected. Water deprivation can result from many ways, among them being water scarcity and availability in a farm, long distances to water source thus resulting to less water offered to the cows, and unsafe/unclean water for drinking.

In Kiambu District, the watering systems and regimes are many and varied. Modes of presentation of water, and water sources and types (roof catchment/rain water, bore hole, river and tap water) vary from farm to farm. The effects of these parameters on production efficiency of the dairy cow remain unknown. Therefore, this study aims at studying the factors affecting amount of water on offer to dairy cattle in Kiambu District and, the effect of amount of water on offer on milk yield of dairy cattle.

1.2. Objectives

1. Study factors affecting amount of water offered to dairy cattle in Kiambu District, Kenya.
2. Study the relationships between amounts of water on offer and milk yields of lactating dairy cattle.

CHAPTER TWO: LITERATURE REVIEW

2.1. FACTORS AFFECTING WATER AVAILABILITY AND WATER ON OFFER TO DAIRY CATTLE

Voluntary water intake applies when water availability and accessibility is not limiting. Drinking of water is influenced by factors that affect water on offer and thus availability e.g.. time of offer (Squires 1981). size of water trough (MacLusky. 1959; Castle and Thomas. 1975: Beede. 1993). flow rate - filling rate of water trough (Anderrson ***et al.***, 1984). source and distance to water point (Bekure ***et al.*** 1991). labour (Swift. 1981; Cossins and Upton. 1987: Bekure ***et al.*** 1991) among others.

2.1.1. Effect of Time of Offer of Water on Consumption

Patterns of water consumption are associated with feeding pattern (Nocek and Braund, 1985). These workers reported that. when four first lactation cows were fed 1, 2, 4 or 8 hours daily. peak hourly voluntary water intake was associated with peak times of dry matter intake. Cows would alternate the intake of feed with water. Given the opportunity. peaks of drinking can be associated with milking. Greater consumption is typically observed immediately after milking (Beede 1993). Therefore it seems judicious to provide abundant water to cows immediately after milking such as in the return lanes.

Squires (1981) observed that. drinking is a vital part of the daily activities of cattle. He reported that cattle are generally inefficient users of water and have a high rate of water turnover. It is prudent that water be availed to the cattle at all times of the day. Under normal circumstances. thirst ensures that water drunk meets or exceeds requirement for water.

Several studies of watering behaviour have been reported from arid Australia. A study by Squires (1978) showed that the watering behaviour of cattle is far from simple. These researchers reported that, during the night cattle hardly visited the water trough. But after 3 hours of daylight, cattle started drinking. Occasionally they would go back for more water. Cows prefer warmer water (Wilks *et al.*, 1990) to chilled /cold water and thus they drink more around mid-day than early in the morning or in the night. A direct effect of hot conditions on watering grazing cattle was shown by the fact that cattle returned to water earlier, spending more than 6 hours. (Squires, 1981). Moreover, any factor that reduced the heat burden, such as clouds or rain, also tended to disrupt the rigid hot-weather pattern of their behaviour.

Similar results were reported by Holder and Low, (1978). These workers reported that, the number of cattle going to water showed a significant relation to the mean daily temperature. In hot summer, 90% of the cattle watered at the same time while only 34% watered in winter. Also, cattle voluntarily watered more than 2 times a day during summer compared to winter and spring when cattle watered on average every second day. They also reported that watering frequency is complicated by other factors such as availability, moisture content and phenological state of forage on offer.

2.1.2. Effects of Distance to Water Source on Watering Frequency and Amount of Water on Offer

In small farms where water point location is within the farm, drinking frequency may be high, but as the distance to water point location increases, the time and labour required to reach water assumes considerable importance and drinking frequency may decline (Bekure *et al.*, 1991). Frequency of drinking is partly a function of water use efficiency and other factors such as degree of dehydration. nutritional status. feed type and water point location (Squires 1981).

Drinking frequency. even for a particular group of cattle is not a constant factor (French, 1956. Squires 1981). Changes in environmental conditions. physiological status. feed on offer. water availability. forage quality. and other factors can alter requirements.

Seasonal sources are commonly used in the rainy season (Bekure ***et al.***. 1991). These include pools and roof catchments. Under these circumstances. animals may have more water at disposal and drink more frequently because seasonal water sources are commonly within the grazing area. In dry areas. cattle drink from ponds during the rainy periods and in the dry periods. they drink from deep wells using human labour. Watering frequency for adult cattle vary from dairy (rainy periods) to once every 4 days (end of dry season (Coppock and Sovani. 1999).

Distant to water point locations determine watering frequency especially in grazing animals (Bekure ***et al.***. 1991). Maasai herders maintained a predetermined frequency of watering by selecting specific water points/sources within a minimal distance. Inspite of this. these workers reported that. watering frequency was influenced by distribution and type of watering facilities. In general. the further a livestock producer lived from a water point. the more likely it was that he practised alternate day watering. They also observed that season affected watering frequency with alternate day watering more common in dry periods than in wet periods. Small stock was watered less frequently during the rains than during dry periods. Watering facilities/sources e.g. bore holes. rivers and pipelines determined the watering frequency. This was mainly dictated by the amount of labour needed to water the cattle.

Proximity to water source was found to have a marked effect on the number of livestock per household (Bekure ***et al.***, 1991). Households closest to water owned fewer cattle than those farthest from water did due to the fact that feed was available further away from water source. Aerial surveys in dry periods in February and June 1982, showed that more than half of the cattle and three quarters of the small ruminants in Maasailand were within 5 km of a water source (King ***et al.***, 1987)

2.1.3. Effect of Size and Type of Water Trough on Amount of Water on Offer and Voluntary Water Intake

Castle and Thomas (1975) studied 14 mainly autumn-calving commercial British Friesian herds housed from November to April and concluded that 160 cm of trough length available for drinking would be sufficient for either 50 milking cows being offered a ration of low dry matter content or 30 cows given a ration of high DM content. One automated bowl per 10 cows on a low DM ration and 1 bowl per 6 cows on a higher DM ration were recommended (Castle and Thomas, 1975). The mean rate of drinking from automated bowls was 4.5 kg/minute and from troughs ranged from 5.6 to 14.9 kg/minute. This suggests that the use of water bowls could limit water intake in some circumstances since cows can drink at the rate of 16 to 27 kg/min (MacLusky, 1959; Thomas, 1971)

The type of water receptacle may affect drinking behaviour, which in turn would affect water consumption by cattle (Beede 1993). Compared on a herd basis in Europe, cows drank less frequently from water bowls (buckets) than from troughs (Castle and Thomas 1975). Also cows drinking rate was lowest with water bowls compared to big water troughs. Cows' drinking rate was found to be determined by amount of water available or the filling rate as they drunk.

Reid 1992 reported that rapid filling of water bowls increased water accessible to lactating cows. This lead to higher water intake and an increase in milk yield by 3 lb per day. In Sweden, water available (offered) and water intake behavior from water bowls with flow rates of 0.5, 1.8 and 3.2 gallons per min/day was investigated (Anderrson ***et al.***, 1984). Time spent drinking decreased from 37 to 11 and min/day as the flow rate increased. As flow rate increased, water on offer and water intake increased. Water intake increased from 20.4 to 22.0 and 23.3 gallons per day. However, milk yield and composition and dry matter intake were not affected.

Use of water bowls in most large herds is relatively infrequent due to their size. However, watering troughs with adequate accessibility and adequate flow rates are important, because cows tend to drink in-groups associated with other events (e.g., feeding or after milking) (Anderrson ***et al.***, 1984). Therefore adequate line dimension and size of trough, with enough filling rate (water available) are required to accommodate group watering. Otherwise, more submissive cows may not have adequate opportunities to consume water and may not return to the water trough at a later time (Anderrson ***et al.***, 1984 and Reid 1992).

2.1.4. Effect of Labour Requirements on Amount of Water Offered to Dairy Cattle

Labour requirements are particularly needed for critical tasks of feeding/herding and watering in livestock management. Bekure ***et al.*** (1991) observed that most time-consuming livestock management tasks are feeding/herding, watering and care of livestock in the boma. Cossins and Upton (1987) reported that, labour needed for water extraction and watering of livestock may limit livestock production.

Water sources determine labour requirements (Swift 1981, Cossins and Upton 1987, Bekure ***et al.***, 1991). The amount of labour required for watering depended primarily on water sources. For most watering facilities (boreholes, surface water, piped water) a single person per herd is necessary to regulate watering. These researchers also reported that extracting /drawing water from water wells is labour intensive; requiring one person to scoop water while the other supervise watering of the herd. This is common in pastoral areas. They noted that, where water was drawn and carried to the water trough, more labour was required.

2.1.5. Effects of Frequency and Periodicity of Watering on Amount of Water on Offer and Voluntary Water Intake

Under practical ideal conditions the frequency of watering is best determined by the animals, by allowing them access to clean, fresh water at all times (Ensiminger ***et al.***, 1990, Bekure ***et al.***, 1991). Reviews by Thomas (1971), Castle and Thomas (1975), Little and Shaw (1978), ARC (1980), NRC (1989), showed that dairy cows which have water continually available drink 18% more water, and yield more milk, than when watered once a day. Watering once every day or once every two days reduced consumption by 10% and 31% respectively when compared with unlimited drinking.

MacLusky (1959). and Finch and King (1982) reported that when water is freely available to grazing cows they usually drink 2-5 times daily and probably not more than 7 times. Wilson (1978). Anderrson *et al.* (1984) and Reid (1992) reported similar findings. Both frequency and duration of drinking were related to type of roughage and drinking water trough available (Castle and Thomas. 1975). Thus cows fed on silage drank less frequently than those fed on dry grass. These workers cautioned that it would be unwise to extrapolate these findings for hotter or drier environments.

2.2 WATER NUTRITION: EFFECTS OF WATER ON CATTLE PRODUCTIVITY

2.2.1 Functions and Metabolism of Water

Water is ubiquitous within the body and is a great solvent. Functions and metabolism of water were summarised by Beede. 1993. It is chemically neutral: thus. ionisation of most substances occurs more freely in water than other media. Water serves as a medium for dispersion or suspension of colloids and ions within the body, and is necessary for maintaining osmotic balance. It functions as a medium for processes of digestion (hydrolysis). absorption. metabolism. milk and sweat secretion. and elimination of urine and faeces. It provides a medium for transport of nutrients. metabolites. hormones. and gases and is a lubricant and support for various organ systems and the faeces. A special role is in heat exchange and maintenance of heat balance because of its high thermal conductivity. allowing rapid transfer of heat. High latent heat of vaporisation allows cows to transfer significant heat from their bodies to the environment with only a small loss of water volume; high heat capacity provides a thermal buffer by conserving body heat in cold climates and conserving body water in warm environments.

Water balance is affected by total intake of water and losses arising from urine, faeces, milk, saliva, sweating, and vaporisation from respiratory tissues. Amounts lost via various routes are affected by amount of milk produced, ambient temperature, humidity, physical activity of the animal, respiratory rate, water consumption and dietary factors (e.g., Na or N contents) as reviewed by Beede (1993).

Losses from the animal are via three main routes: in the urine and faeces, and by evaporation (King *et al.*, 1977). Evaporation occurs from the skin and respiratory tract and increases under hot conditions. To maintain a constant body water volume, water lost must be balanced by an equivalent water intake. Water intake originates from water in the feed, free drinking water and the water derived from metabolic reactions. If any two parameters of either water intake or output are known, a measure of water turnover will give the third parameter by difference. Thus, if faecal and urinary water losses are measured, evaporative water losses can be calculated; likewise, if free water and metabolic water production are known, the water ingested in food can be determined (King *et al.*, 1977).

Water intake as high as 118 L/day for a lactating cow and a herd average of 70 L per cow has been measured in Jersey and Friesian lactating dairy cows (Wright and Jones, 1975). They also reported that dry cows have a lower water turnover while lactating Romney ewes suckling lambs and grazing lush pasture in early summer have a high water turnover. Wright and Jones (1975) observed that high water turnover values are found in ruminants grazing pasture where at times the feed water content is as high as 90%. The significance, if any, of ingesting large amounts of water and thereby requiring a high urinary excretion rate is not clear, but one of the important factors limiting feed intake of grazing dairy cows is the bulk of plant material. much of which is water (Ensiminger *et al.*, 1990).

King *et al.* (1977) reported that high water turnover resulted in high milk yields and also high calf weight. This shows that high producing animals require more water. Water drunk is only apparent balance. but water requirement is much larger than water drunk because it includes water from feedstuffs and metabolic water.

King *et al.*, (1977) found that metabolic water appeared to contribute 10% or less of the total water input. thus water requirements are fulfilled by water drunk and water from feedstuffs. especially in dairy cows. Ranjhan *et al.*, (1982) observed that metabolic water was inversely proportional to the water turnover rate. A similar finding was observed by King *et al.*, (1977). Water turnover values have been related to the food and water intake and metabolism of an animal (Aggrey, 1982).

Ingestion of large amounts of feed water results to its subsequent excretion through urine and faeces. consequently. a high water turnover is observed in the wet season feeding (Aggrey, 1982). In addition. water turnover is related more to energy turnover than heat dissipation in animals living in the tropics. Aggrey (1982) concluded that water turnover and intake in ruminants are associated with changes in the nutrition of the animal as determined by climatic conditions. The supply of feed determines the accumulation of solids or fluids in the body, while water turnover is an indication of the rate of metabolic activity in the body.

2.2.2. Water requirements and intake in ruminants

Under practical conditions, the needs for water can best be met by allowing the animals free access to plenty of clean and fresh water at all times (Ensiminger *et al.*, 1990). Murphy *et al.*, (1983) developed a prediction equation to estimate intake of drinking water. Data were from the first 16 weeks of lactation of 19 multiparious Holstein cows (average BW 1276 lb) averaging 73 lb MY/day. Diet was approximately 40% corn silage and 60% concentrate, dry basis. Sodium intake varied because sodium bicarbonate was fed to part of the cows. Factors included in the prediction equation were DMI (lb/day), MY (lb/day), Na intake (lb/day), and weekly average minimum environmental temperature (°F).

The predicted equation for: water intake (lb/day):

- 0.90 x (MY, lb/d) + 1.58 x (DMI, lb/day) + 0.11 x (Na intake, lb/day) + 2.64 x (°F/1.8 - 17.778, average minimum temperature) + 35.25.

Milk yield and DMI were estimated, with typical expected declines in DMI in warm season when MY was 60 lb/cow/day or more. Sodium intake (lb/day) was calculated based on specified DMI and dietary Na concentrations of 0.18% (NRC, 1989) or 0.50%, which would be typical of diets with supplemental Na-containing buffer. Water contained on or in feeds consumed was not considered in prediction; water content of experimental diets used to develop equation was about 38% (Murphy *et al.*, 1983). Water intake in gallons per day was calculated by multiplying lb/day by 0.1198.

The prediction equation indicates that intake of drinking water changes 0.90 lb for each 1.0 lb change in MY, 1.58 lb for each 1.0 lb change in DMI, 0.11 lb for each 1 g change in Na intake, and 1.47 lb for each 1 °F change. Thus, DMI has the most relative influence on water intake. However, absolute magnitude of change of various factors has direct bearing on how much water intake will be affected.

Sodium has a relatively small influence (3-4% increase) on water intake when Na content is increased from 0.18 to 0.50% of diet DM. Using 70-yr average minimum temperatures of Feb and Aug, water intake increased about 25% during the warmer month when DMI, MY and Na intake were the same. Winchester and Morris (1956) found a relatively constant ratio of 3 lb of water consumed/lb of DMI within temperature range of 0 to 41 F. However, water intake per unit of DMI accelerated rapidly as ambient temperature rose above 41 F, reaching over 7 lb of water/lb DMI at 90 F.

2.3. FACTORS AFFECTING WATER REQUIREMENTS AND WATER INTAKE.

2.3.1. Physiological condition and the stage of growth of the animal

Water intake varies according to whether the animal is in a state of maintenance, growth, fattening, pregnancy or lactation (NRC, 1989). Reviews by ARC (1980), ARC (1984), and NRC (1989) pointed out that the physiological state of the animal dramatically affects the water requirements. A steer fed maintenance ration will consume approximately 16 litres of water daily, whereas a steer fed a fattening diet will double this quantity. A dry cow will drink about 40.7 l of water daily; during the last 4 months of pregnancy, she will consume 30%more water than when dry and open; when she produces 9 to 22 litres of milk, the daily water consumption will increase to about 72 litres; and when she produces 36 litres of milk per day, water intake will be near 90 litres. Young calves generally drink 5/4 to 3/2 times more water per pound of dry matter consumed than older cattle.

The amount of water consumed per kg DM consumed by pregnant ewes increase from about 2.0 litres in the first month of pregnancy to 4.3 litres in the fifth month. Ewes carrying twins will consume over twice the amount of water of non-pregnant ewes: and those carrying single lambs will consume 138% more water than non-pregnant ewes (Ensiminger *et al.*, 1990).

2.3.1.1. Young Calves

Calves receiving liquid milk diets consume greater amounts of water in relation to the dry matter of their diets than older animals receiving dry diets because of the high water content of milk. 1-5 weeks-old calves receiving liquid milk diets consumed from 5.4 to 7.5 kg water/kg DM (ARC, 1980). These intakes of water consist mainly of the water contained in the diet, but small additional amounts of water were drunk. Restricting the amount of water in the milk tended to reduce weight gain. The value of providing water for young calves on an early weaning system has been reviewed (ARC, 1980). When liquid milk diets were given at the rate of 4 kg/day the mean voluntary water intake of calves from 0 to 5 weeks was 6.5 kg with a coefficient of variation of 53%. There was a difference in consumption of water according to calf weight.

2.3.1.2. Pregnant Cows and Lactating Cows

Little research has been done specifically on water intake of pregnant cows (ARC, 1980; NRC, 1989). These workers reviewed the earlier research findings with pregnant cows and reported that heifers drank almost 50% less water on the day of oestrus than on the other days of the oestrus cycle, but the reason for this decrease is not known. Also, the voluntary water intake of heifers and cows in late pregnancy was, on average, 70 g water per kg live weight when offered water twice daily. Castle and Watson, 1973 working with dry Ayrshire cows reported that voluntary water intake was significantly reduced in proportion to the daily amount of rainfall, and major part of the daily water requirement of the animals was obtained from the herbage.

Lactating dairy cows require the greatest amount of water in proportion to their weight or surface area because water constitutes 85-87% of the milk. In addition, total body weight of most cows includes 55-65% of water (ARC, 1980). This shows that a lactating cow producing about 10 kg of milk per day loses 8.5-8.7 kg of water daily through milk alone. Experiments have shown that a Friesian cow in Europe would require 2.67 – 2.92 kg of water at ambient temperature range from 21.1 to 26.7°C for each litre of milk produced (Winchester and Morris, 1956). The Water intake of Friesian heifers throughout their stage of lactation has been recorded by Owen ***et al.***, 1968 (Table 1.1). Water requirements for lactating cows in relation to live weight; milk yield and environmental temperature are shown in Table 1.2. These estimates were obtained from experiments done in Europe for exotic cattle breeds.

The amount of body water in an average mature cow range from 50-70% (Macfarlane and Howard, 1972; Williamson and Payne, 1978) in which the variations depend largely on age and body fat content; young and thin animals contain more body water than older and fatter ones (NRC, 1978)

Table 1.1. Water intake of heifers according to stage of lactation

Successive periods pre- and post – calving (weeks)	Free water intake (kg)	Water from feed (kg)	Total water intake(kg)	Total water intake (kg/kg DM)	Total water intake (g/kg lwt per day)
Pre-calving	2285	100	2385	4.2	83
0-8	3262	120	3382	5.0	126
9-16	3547	148	3695	4.4	120
17-24	3356	139	3495	4.4	101
25-32	2956	130	3086	4.2	85
33-40	2590	126	2716	3.8	

Source: Owen *et al.* 1968

Table 1.2. Total water intake of lactating cows (kg/cow/day)

Milk yield (kg/day)	Live weight (kg)	Environmental temperature (^oC)			
		-17-+10	11-15	16-20	21-25
10	600	78	81	92	105
	350	52	54	61	70
20	600	88	92	104	119
	350	62	65	73	84
30	600	99	103	116	133
	350	73	76	85	98
40	600	109	113	128	147
	350	88	92	104	119

Source: ARC 1980

2.3.2. Ambient Temperature, Relative Humidity and Rainfall

Numerous experiments have shown a strong positive correlation between water intake and ambient temperature. Under controlled temperature Cattle tend to increase water intake as temperature rises above 81°F (Ensiminger *et al.*, 1990). Research reports by Winchester and Morris, (1956); McDowell and Weldy, (1967); Hyder *et al.*, (1968); McDowell, (1972); ARC, 1980; King, (1983); Murphy *et al.*, (1983); Martz *et al.*, (1989); Squires, (1988) and Barney (1992) dealt with relationship of water intake and ambient temperature. They showed that a very strong relationship exists between water intake, ambient temperature and dry matter intake, and an increase in air temperature will increase voluntary water intake. Also, a strong relationship exists between total water intake of lactating cows and environmental temperature, milk yield and live weight (Table 1.2).

Increase in humidity will result in decreased water consumption (NRC, 1978). Increasing humidity at high temperature results in decreased water consumption but increased frequency of drinking. It would seem that these changes reflect, in part, the lower intake of feed and the reduced vaporisation of moisture at high temperatures and humidities.

The amount of rainfall per day also influences the intake of water, while relative humidity and rainfall are of greater importance than temperature *per se* for grazing cattle. Season and rainfall are closely related. In the dry season, when grass pastures have high DM percent, cows drink a lot of water than in the wet season when pastures are lush (ARC, 1980).

2.3.3. Quantity and Composition of Diet Consumed

The water content of feed range from 10% in air-dried feeds to more than 80% in fresh, green forage (Ensiminger *et al.*, 1990). The water content of feeds is specifically important for animals, which do not have easy access to drinking water. Water on the surface of plants, such as dew, may serve as an important source of water for cattle, sheep and goats on the arid ranges, but this supply is rarely sufficient to meet their water requirements.

Voluntary intake of water increases with increasing DM intake (Winchester and Morris, 1956; Owen *et al.*, 1968; Paquay *et al.*, 1970; Kamal, 1982; Murphy *et al.*, 1983; Davis *et al.*, 1983; Stockdale and King, 1983 and Reid 1992), but for a given body size, the water intake per unit of dry matter eaten is higher for low DM intake than for high DM intake (Leitch and Thomson, 1944).

The presence of salts and high level of protein in the feed have been associated with high water intake (Hyder *et al.*, 1968; NRC, 1978; NRC, 1989; Reid 1992), because the water is required to flush out urea and salts from the body (Squires, 1988). In general, the higher the proportion of minerals in the diet the greater the excretion of urine and accordingly the larger the water intake. High intake of protein rich diet results in high levels of nitrogenous end products that require a larger urine volume for excretion (ARC, 1980). Diets high in pentosans and crude fibre result in increased losses of water in faeces, and, therefore, in increased water intakes (Paquay *et al.*, 1970). If animals are to tolerate moderate or high intakes of salt in their diets then an adequate water supply is essential (Challis *et al.*, 1987, Wang and Beede 1992). Animals were also found to be more tolerant to salt in the dry feed. provided they have unlimited water. than they are of salt in the drinking water.

Dairy cattle consuming typical air-dry (about 90% DM) diets consume less than 1 gallon of water from feed daily. depending on feed intake. This quantity is small compared with drinking. By comparison. when cattle consume pastures. silages. and liquid feeds. a substantial portion of water needs is provided. A typical diet for lactating cows containing 50% water would result in intake of 50 lb (6 gallon) of water if feed intake was 100 lb as-fed: this would be equal to about 17-23% of predicted drinking water intake depending on MY and average minimum temperature. based on equation of Murphy ***et al.***, (1983). In an equation developed from several pasture experiments. total water intake was affected negatively by DM content of the ration. and positively by DMI and mean temperature (Stockdale and King, 1983). Davis ***et al.***, (1983) investigating feeding value of wet brewers grains. showed that total water consumed (drinking water intake plus that derived from the ration) decreased about 26% as total ration moisture content increased from 30.7 to 53.6%. Drinking water intake. per se. declined 37% over this range of ration moisture content. However. this effect may have been more a function of actual DMI. because as total ration moisture content increased from 30.7 to 53.6%. actual DMI declined 24%. Substantial influence of DMI on drinking water intake was evident.

2.3.4. Metabolic Water.

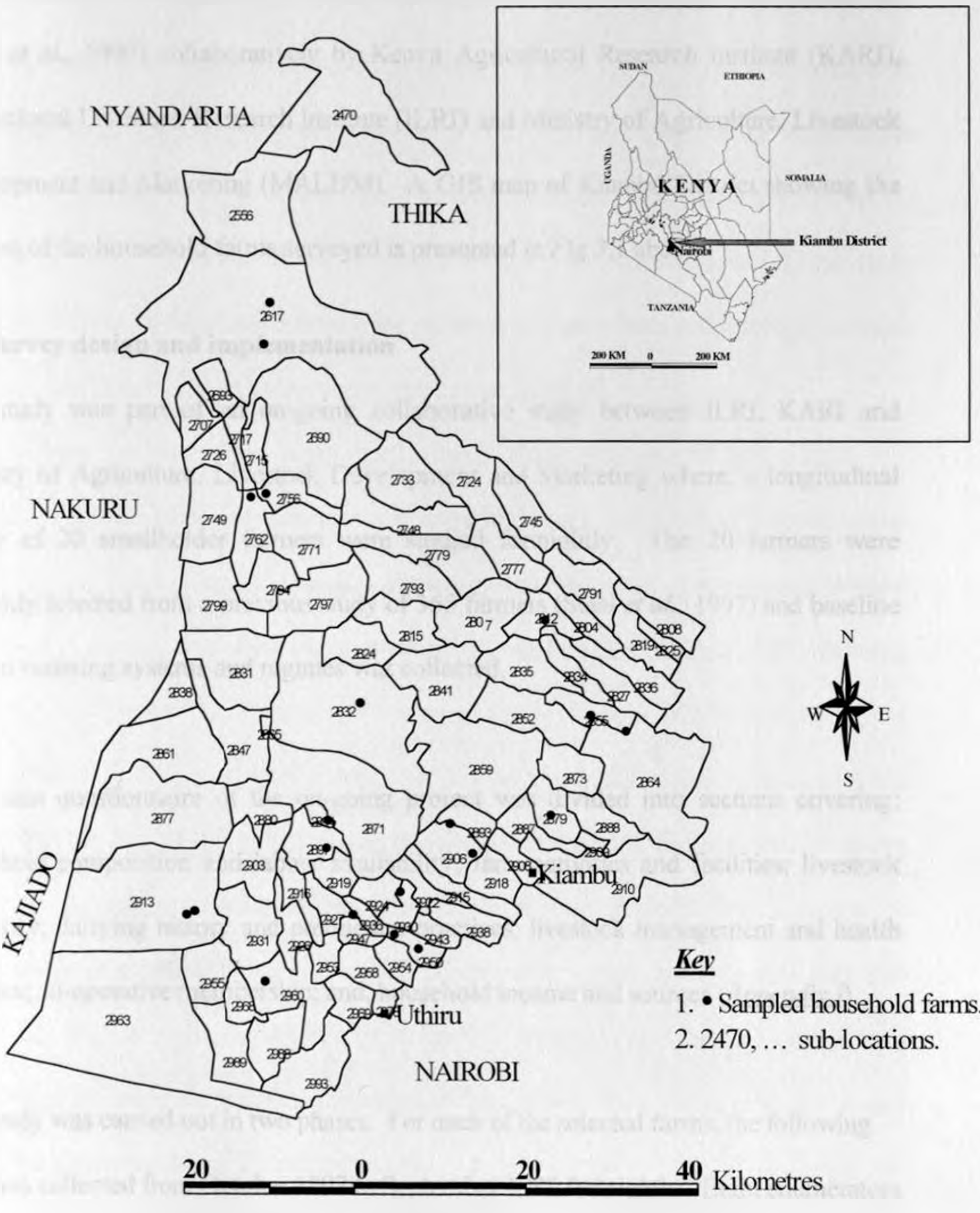
When organic compounds are oxidised by animals. hydrogen molecules go towards formation of metabolic water (Beede 1993). During metabolic oxidation. water yields (ml/g tissue) are 1.07 from fat. 0.40 from protein. and 0.50 from carbohydrate. This can account for as much as 15% of total water intake (Chew, 1965), which is substantially more than from consumption of an air-dry ration. Although oxidation (e.g., protein catabolism) contributes metabolic water, there also are increased demands for water for respiration, heat dissipation and urine excretion associated with oxidative processes. Thus, generation of metabolic water is not adequate to cover other demands associated with oxidation. Additional sources of water (e.g., drinking or feed-borne water) are required for metabolic oxidation.

CHAPTER THREE: MATERIALS AND METHODS

3.1 Study Area

Kiambu District is one of the seven districts in Central Province of Kenya and is generally of high agricultural potential. Kiambu lies between longitude 36°30″ and 37° 30″ to the east and between latitudes 0° 30″ and 1° 30″ to the South. Its altitude is 1200 – 2550m above sea level. Rainfall ranges between 600-2500mm per annum with an average of 1100mm. A bimodal type of rainfall is received with long rains beginning in late March. The rainfall decreases in intensity towards the end of May and early June. The short rains begin in mid October, end in late December, and are less reliable than the long rains. Temperatures range between 10 to 25°C. Soils are nitosols or alfisols (Kikuyu red loam soils) with acidity increasing with increase in altitude. Land tenure observed is a combination of freehold, rental plots and use of public roadside land. General land use is intensive dairy, maize, coffee, tea, beans, vegetable crops, sheep, poultry, and pigs. The mean farm size is 0.8 ha per family with an average of 3 dairy cows. More than 50% of the dairy cattle are high-grade cattle and the remainder are mainly dairy crosses, dominant breeds being Holstein-Friesian, Ayrshire, and Guernsey. Dairy production dominates over beef, the latter being mainly a by-product of the dairy process. Mean milk production per cow per day is 7.6 litres (Staal ***et al.***, 1997). Main feed resources are napier grass, crop residues and commercial concentrates, with most animals being stall-fed.

Figure 3.1. A GIS Map of Kiambu District showing the location of household farms surveyed. Inset: Map of Kenya showing location of Kiambu District.



Kiambu District borders the Nairobi metropolitan area and has a long history of smallholder dairy production. It is a major supplier of milk to the Nairobi market. A characterisation of dairy systems supplying the Nairobi milk market has been carried out (Staal ***et al.***, 1997) collaboratively by Kenya Agricultural Research Institute (KARI), International Livestock Research Institute (ILRI) and Ministry of Agriculture, Livestock Development and Marketing (MALDM). A GIS map of Kiambu District showing the location of the household farms surveyed is presented in *Fig* 3.1 above.

3.2. Survey design and implementation

This study was part of an on-going collaborative study between ILRI, KARI and Ministry of Agriculture, Livestock Development and Marketing where, a longitudinal survey of 20 smallholder farmers were studied fortnightly. The 20 farmers were randomly selected from a previous study of 365 farmers (Staal ***et al.***, 1997) and baseline data on watering systems and regimes was collected.

The main questionnaire of the on-going project was divided into sections covering: household composition and labour availability; farm activities and facilities; livestock inventory; dairying history and production practices; livestock management and health services; co-operative membership; and, household income and sources (*Appendix I*).

The study was carried out in two phases. For each of the selected farms, the following data was collected from October 1997 to September 1998 fortnightly. Eight enumerators were selected and trained to collect the data.

3.2.1. Phase I

The study involved a survey of factors affecting water offered to dairy cattle in selected farms in Kiambu District. From these farms baseline data on water sources, water types, distance to water sources, water availability, mode of water presentation and watering frequencies was collected. Water source was categorised into those farms with water source on the farm (on-farm) and those collecting and transporting water from outside the farm (off-farm). Water type (borehole, or tap or river) was recorded. Also the distance from the water source to the watering trough was recorded. Distance to water source was divided into 3 categories based on distance from water trough to water source: - 0 to 200 m, 200 to 1000 m and greater than 1000 m.

Means of water transport from its source to watering trough was recorded as either none needed (water piped directly to trough), manual (where water was ferried using 20-litre buckets by hand), or others (use of donkeys, bicycles, wheelbarrows) Watering frequency was defined as continuous (3 or more times per day) or non-continuous (<3 times per day). Type of watering trough/facility was recorded as either bucket (20-60 litres), half cut drum (100-150 litres), or brick-and-cement-built trough (180-300 litres). For analysis purposes, watering containers/facilities were grouped into 2 categories based on the volumes of watering troughs. These were: - small troughs (less than 100 litres) and large troughs (greater than 100 litres). Water storage facilities in the farm were either recorded as present or absence. When present these were either brick and cement-made tanks or iron sheet-made tanks.

3.2.2. Phase II

The study focused on data collection from 20 farms to determine effects of the factors identified in Phase I on amount of water offered and on milking cows' productivity. All farms evaluated had one or more cows in milk. Milk yields, body condition score; heart girth and water offered DM offered and types of feed on offer were measured in all farms.

3.3. Household Data Collection

3.3.1. Herd data and cattle performance

Cattle numbers, identification, breeds, sex, age and parity data was collected from each household farm for the dairy cattle. Number of cattle lactating, pregnant or both was recorded. Dates of the most recent calving and of the previous calving were recorded. Condition scoring of 1 to 5 (Edmondson ***et al.***, 1989) was done. Weight of the cows was estimated from the heart girth (cm) measurements. Weight of cows was standardised by 300-kg live weight because the average weight of cows was 338 kg live weight.

3.3.2. Water parameters

Data on source of water and distance from the farm, mode of presentation/offer was collected. Watering times/frequencies; defined as the number of times the farmer offers water to the cows was noted (continuous -more than 3 times) or non-continuous -less than 3 times) per day (*Appendix II*). Water offered per day (in litres) to dairy cattle was recorded. The volume of water offered was for the whole herd in each farm regardless of whether the cattle drank water from a centrally located communal trough within the farm or from a bucket brought to each cow separately.

3.3.3. Feed parameters and dry matter estimation

Type and condition (fresh-cut, wilted or chopped) of feeds on offer was recorded at each visit. Feed on offer (in kg), on as is basis, was measured by weighing both the feeds offered to the cows and the orts at the end of the day. Feed on offer measured was for all the dairy cattle in the farm. Amount of concentrates fed (in kg) was also recorded. If napier or maize stover were offered. condition (fresh. wilted) and form. (chopped or not chopped) and also the height at harvest were noted. All different types of feeds offered to the cows were recorded. Routine farm management practises were not altered during the study period. This information was collected fortnightly. Dry matter on offer was estimated using published values (Appendix III). The feeds were classified into five classes. These were 1). Napier and other green cut grasses (Rhodes grass. star grass, coach grass. etc (Appendix III)). 2). Dry maize stover. 3). Green and soaked maize stover. 4). Concentrates (commercial dairy meal. cotton seed cake. bone meal. maize bran. maize germ. wheat bran and poultry litter), 5). Other feeds banana (leaves. pseudo-stem. thinnings), bean leaves. congette leaves. kales. kitchen waste. sugar cane leaves and tops. weeds. wheat straw. barley straw. sesbania leaves. calliandra leaves. sweet potato vines and minerals commonly *macklic super* and mineral salt.

3.3.4. Milk records

Daily milk yield records for each lactating cow were kept during the study period.

3.4. Data analysis

Data collected was stored and managed using Microsoft excel. 1998 and dBase software. Data analysis was carried out using SAS (SAS, 1987) statistical package. Descriptive statistics and tests of significance using least square difference were carried out.

Stepwise selection procedure for all variables was carried out using SAS/STAT, 1987. Independent variables entered in the model were source of water. distance to water source, means of water transport, volume of water trough. water storage, type of watering facility, type of water and watering frequency with dependent variable being amount of water offered in litres/300 kg live weight.

The model used was: -

$$Y_{ijklmn} = \mu + \beta_i x_i + \beta_j x_j + \beta_k x_k + \beta_l x_l + \beta_m x_m + \beta_n x_n + \beta_o x_o + \beta_p x_p + \varepsilon_{ijklmnop}$$

where: -

Y_{ijklm} = amount of water offered litres/300 kg lwt/day

μ= mean amount of water offered per 300-kg lwt

x_i = Distance from water source to the watering trough (i =0-200 m. 200-1000 m. 1000-2500 m).

x_j = Water transport (j = none-piped to trough, manual, others).

x_k = volume of watering trough (k = Small, Large)

x_l = Watering frequency (l = continuous, non-continuous watering)

x_m =Presence or absence of water storage facility (m = Present, absent)

x_n = Source of water (n= on-farm, off-farm)

x_o = Water trough type (o = Bucket, half-cut drum or brick/cement made)

x_p= Type of water (p = Tap/roof catchment, borehole, river)

$\varepsilon_{ijklmnop}$ = residual error term.

Analysis of variance to determine the significance and contribution of the factors monitored to the observed milk yields was carried out using general linear model procedure (GLM). The statistical model used was:

$$Y_{ijklmno} = \mu + \beta_i x_i + \beta_j x_j + \beta_k x_k + \beta_l x_l + \beta_m x_m + \beta_n x_n + \beta_o x_o + \beta_p x_p + \varepsilon_{ijklmnop}$$

where: -

$Y_{ijklmno}$ = daily milk yield per 300 kg live weight

μ= Mean milk yield.

x_i=age (i = 3, 4,...., 11)

x_j = breed (1,2,3).

x_k = parity (1,2,3,....5)

x_l = Body condition score (1,2,3.....5)

x_m =weight (kg)

x_n = amount of water offered/300 kg live weight/day

x_o =stage of lactation

$\beta_p x_p$ = dry matter offered per 100 kg live weight per day.

$\varepsilon_{ijklmnop}$ = residual error term

CHAPTER FOUR: RESULTS

4.1. CHARACTERISATION OF WATERING PRACTISES OF DAIRY CATTLE IN KIAMBU DISTRICT.

Water on offer for dairy cattle in Kiambu was influenced by source of water, distance to water source, water storage, transport size and type of water trough and frequency of providing water to the dairy cattle. Sixty percent of all the farms surveyed had water source within the farm. Sixty percent of all the farms were located in the 0-200-m distance category, while 25% and 15% were located between 0.2 - 1.0km and 1.0-2.5km distance categories respectively. Twenty five percent needed no transport for water because water was piped directly to water trough, while 55% and 20% carried water by bucket and used either carts, donkeys or bicycles as water transport means respectively.

4.1.1. Distribution of Farms According to Water source, Distance to Water Source and Means of Water Transport

Table 4.1 shows distribution of the farms surveyed according to water source, distance to water source, watering frequency, trough size and means of water transportation. The survey showed that 60% of the farms had water within the farm. All farms with water on-farm were located in the 0-200m-distance category. Forty two percent of the farms with on farm water source needed no transport inputs because water was piped directly to the water trough, 58% ferried water by hand with use of 20-litre buckets, but the distance was short (less than 200m). Dairy cattle in farms with water on-farm did not experience water availability problems because water was easily accessible except for two farms where non-continuous watering of dairy cattle was practised.

Farmers sourcing water for dairy cattle from off-farm got water from distances ranging between 200m and 2.5 km. Of all the farmers with off-farm water source. 63% fetched water from a distance of 0.2 to 1.0 km. while 37% fetched water from distances ranging from 1.0 to 2.5 km. In the 0.2-1.0km -distance category of farms. 60% carried water by hand/back using 20-litre buckets while 40% used some means of transport (i.e. donkey drawn carts. donkeys or bicycles). Farms sourcing water from longer distances (1.0-2.5 km distance category of farms) relied more on either carts. donkeys or bicycles (67%), while the rest carried water by hand/back using the 20-litre buckets.

4.1.2. Size of Water Troughs

Large watering troughs (100 to 250 litres) were found in 75% of the smallholder dairy farms surveyed. These troughs were half-cut drums or brick-cement-made troughs and were centrally located in the cattle *boma* to water 2 - 4 dairy cattle. Small water troughs were found in 25% of all the farms surveyed. which were mainly 20-litre buckets. Farmers brought water to their dairy cattle at certain times of the day when using the buckets (small troughs). Use of large water troughs was dominant (92%) in farms with on-farm water source compared to those with off-farm water source (50%).

Table 4.1 Distribution of farms according to different water-source and watering management practises categories

VARIABLE	CATEGORY	Number of Farms ON-FARM	OFF-FARM
Distance	0-200 metres	12	-
	0.2-1km	-	5
	1-2.5km	-	3
Transport Used	None used	5	-
	manual (20-litre bucket)	7	4
	Transport (bicycles/carts/donkeys)	-	4
Watering Trough Size	Small (<100 litres)	1	4
	Large (100-250 litres)	11	4
Watering Frequency	Continuous	10	-
	Non-continuous	2	8

Table 4.2. Proportion of farms according to source of water by size of water trough

Source of water	Size of water trough Small	Large	Total
On-farm	1	11	12 (60%)
Off-farm	4	4	8 (40%)
Total	5 (25%)	15 (75%)	20 (100%)

To test whether the farmers' size of watering trough was determined by water source, the chi-square (x^2) test of dependency (Wonnacott & Wonnacott. 1977) was performed on the empirical data summarised on Table 4.2. at 0.1 significance level using SAS. The chi-square statistic gave a value of 4.44 at $P = 0.035$. The size of water trough a farmer has was found to depend on source of water for his livestock ($P < 0.05$). Most large water troughs were found in farms with on-farm water source.

4.1.3. Watering frequency practises

Fifty percent of the farms surveyed had water continuously available for their dairy cattle. i.e. water was available or presented to cattle more than three times a day. Farmers practising non-continuous watering presented water to dairy cattle less than 3 times per day.

Continuous watering was dominant in farms with on-farm water source where 84% of the smallholder dairy farmers had water continuously available for their cattle. In this category only 16% practised non-continuous watering. This was in contrast with farms in the off-farm water source category where all farms (100%) practised non-continuous watering of dairy cattle.

Table 4.3. Proportion of farms according to source of water by watering frequency

Source of water	Watering frequency: Continuous	Non-continuous	Total
On-farm	10	2	12 (60%)
Off-farm	0	8	8 (40%)
Total	10 (50%)	10 (50%)	20 (100%)

To test whether watering frequency of dairy cattle was dictated by source of water, the chi-square (x^2) test of dependence (Wonnacott & Wonnacott. 1977) was performed on the empirical data summarised on Table 4.3. at 0.1 significance level using SAS statistical package. The chi-square statistic gave a value of 13.33 at $P = 0.001$. This shows that watering frequency or number of times a farmer presented water to dairy cattle was significantly dependent on source of water at $P < 0.05$.

4.1.4 Descriptive statistics of farms

Average number of dairy cattle per farm was 4.2 with a minimum of 2 and a maximum of 10 animals (Table 4.4). Mean number of lactating cows per farm was 2.2. Mean body weight of heifers (non-lactating or lactating) and cows were 338 kg with a minimum weight of 226 kg and a maximum of 499 kg. Mean total weight of dairy cattle (heifers and adults) per farm was 1040 kg with a minimum of 349 and a maximum of 2361 kg. Age ranged from 3 years to 11 years with a mean of 5.7 years and a standard deviation of 1.9 years. Body condition scores of the dairy cattle fluctuated throughout the study period. Body condition score averaged at 2.4 with a standard deviation of 0.64.

Mean amount of water offered per farm per day was 134.5 litres. The minimum amount of water offered was 15 litres/farm/day and a maximum of 400 litres/farm/day. This appears to be high amount of water available to dairy cattle per farm. but when the total weight of dairy cattle per farm was accounted for. the mean amount of water offered was found to be very low (35.6 litres/300 kg lwt/day). Parity ranged from 1 to 5 with a mean of 2.6 and standard deviation of 1.3. The lactating cows surveyed were in different stages of lactation. ranging from 1 to 24 months.

Table 4.4. Descriptive statistics on smallholder dairy farms in 20 farms in Kiambu District

Variable	Mean	S.D.
Cattle numbers/farm	4.18	2.26
Lactating No./farm	2.19	1.32
Age of lactating cows (years)	5.70	1.92
Parity	2.63	1.34
Cattle weight/farm (kg)	1040	471.74
Average Weight (kg/cow)	338	47.74
Body condition score	2.43	0.64
Milk yield/cow/day (litres)	6.44	3.58
Amount of water offered/farm/day	134.00	122.8
Water offered/300 kg lwt/day (litres)	35.6	18.7

4.2. EFFECTS OF WATERING PRACTISES AND WATER SOURCES ON AMOUNT OF WATER OFFERED TO DAIRY CATTLE IN KIAMBU DISTRICT

Table 4.5 shows a stepwise regression procedure for the different factors affecting the amount of water offered per 300 kg Lwt to dairy cattle per farm per day. The analysis demonstrates a highly significant difference between the two water source categories, between the three distance to water source categories, between the two categories of volume of water troughs, between the 2 watering regimes, between the three watering trough types and between the 2 water storage categories in average amount of water offered to dairy cattle (P = 0.0001). Average amount of water offered to dairy cattle was also significantly different (P = 0.0015) between the three water transport means used. The high R-Square (0.63) observed implies that the model accounted for most of the variation in the amount of water offered to dairy cattle (P = 0.0001).

The regression model showed that when source of water is changed from on-farm to off-farm, amount of water offered to dairy cattle decreases by 25 litres. Also, changing distance category from lowest through to highest decreased the amount of water by 14 litres. Changing water transport means from direct piping to water trough to use of wheelbarrows or bicycles or carts decreased amount of water offered by 3.4 litres.

When water was offered using large troughs compared to small troughs, the amount on offer to dairy cattle increased by a significant 24 litres per day. Use of buckets as water troughs compared to brick-cement troughs decreased amount of water offered by 8 litres per day. A decrease of 10 litres of water on offer per day was observed in farms without water storage facilities.

The parameter estimate for watering frequency was negative 29 litres. This strongly indicated that practising non-continuous watering decreased amount of water offered to dairy cattle by 29 litres per day in relation to practising continuous watering.

Table 4.5. Stepwise regression procedure for variables affecting amount of water offered to dairy cattle in Kiambu District.

Source of Variation of the main Statistical model	Degrees of freedom	Sum of squares	Mean square	F-value	Pro>F
Regression Model	8	132187.9	16523.5	125.46	0.0001
Error	594	78231.2	131.7		
Corrected Total	602	210419.2			

Variable	Parameter Estimate	Std Error	Sum of squares	F	Prob>F
Intercept	63.71	8.87	6790.10	51.56	0.0001
Distance to water source	-13.56	2.57	3678.22	27.93	0.0001
Volume of watering trough	23.89	3.41	6461.83	49.06	0.0001
Watering frequency	-29.11	1.72	37803.74	287.04	0.0001
Water storage	-10.00	1.91	2924.95	22.21	0.0001
Water transport means	-3.38	1.06	1335	1014	0.0015
Source of water	-25.29	4.62	3948	29.98	0.0001
Water trough type	-7.84	1.74	2665.38	20.24	0.0001
Type of water	-2.10	1.41	290.20	2.20	0.1382

4.2.1. Effects of water source, distance and means of water transport on amount of water offered to dairy cattle in Kiambu District

Table 4.6 shows proportion of farms categorized according to distance from water source and water offered to dairy cattle within the different categories. Farmers with on-farm water source offered the highest amount of water (42.6 l/300 kg live weight) per day to their dairy cattle compared to those with off-farm water source (22.2 l/300 kg live weight) ($P < 0.05$). Farms having off-farm water either had to purchase and transport, or collect and transport water to water troughs.

Distance to water source had a significant effect ($P < 0.05$) on amount of water on offer to dairy cattle. Dairy cattle in 0-200-m-distance farms category were offered significantly higher ($P < 0.05$) amounts of water (42.6 l/kg live weight) per day. All these farms had on-farm water source. Categories of farmers fetching water from distances greater than 200 m had no water source on their farms. In contrast, farms drawing water for their dairy cattle from off-farm water sources of distances 0.2-1 km and 1-2.5 km categories offered very little amount of water (23.2 and 21.7 l/kg live weight respectively). These were not significantly different at $P < 0.05$.

Means of transporting water to watering receptacle varied among farms. These affected the amount of water on offer in different ways. Farms with water piped directly to the trough had significantly ($P < 0.05$) higher amount of water offered (52.3 l/300 kg live weight) to the dairy cattle per day compared to farms ferrying water manually by buckets or jerry cans (29.9 l/300 kg live weight). Other farmers ferrying water by either donkeys, donkey-drawn carts or bicycles offered the least amount of water (24.7 l/300 kg live weight) to their dairy cattle.

Table 4.6. Total number of cattle, lactating cows, and means of amount of water offered to dairy cattle in different categories of farms[1]

Variable	Category	Percent of Farms	Total Lactating Cows	WATER (litres/300 kg lwt/day) Mean
Source	on-farm	60	26	42.6*
	off-farm	40	10	22.2**
Distance	0-200 m	60	26	42.6*
	0.2-1 km	25	6	23.2**
	1-2.5 km	15	4	21.7**
Watering Frequency	Continuous	50	18	49.2*
	Non-continuous	50	18	21.2**
Volume of water trough	<100 litres	25	8	21.3*
	>100 litres	75	28	39.2**
Water Transport	None (Piped)	25	8	52.3*
	Manual	55	18	29.9**
	Means used	20	10	24.7**
Storage	Present	45	16	37.8*
	Absent	55	20	33.5**

[1] *Means with different number of asterix for the same variable within a column are significantly different at P = 0.05*

4.2.2. Effect of volume of water trough

Smallholder farms with small water troughs (less than 100 litres) offered the least amount of water per day (21.3 litres/day/300 kg live weight) compared to 39.4 litres/day/300 kg live weight offered in farms with large water troughs ($P < 0.05$). Most of the water troughs of less than 100 litres were 20-litre buckets. characteristically small in size/volume and with a narrow top.

4.2.3. Effect of watering frequency practices

Amount of water offered to dairy cattle was significantly influenced by watering frequency practices (i.e. the number of times a farmer presented water to dairy cattle). Smallholder farms practicing continuous watering (more than 3 times a day) had a lot of water (49.2 litres/day/300 kg live weight) available for the dairy cattle than those practicing non-continuous watering (21.2 litres/day/300 kg live weight). The amount of water offered in farms practising continuous watering was significantly higher than that of farms practising non-continuous watering ($P < 0.05$) (Table 4.6).

4.2.4. Effect of water storage

Water storage facilities found in the survey area were brick/cement tanks or iron made tanks for storing either rainy water (roof catchment) or piped water (bore hole or tap). Water storage facilities were found in 45% of the smallholder farms. Farmers with storage facilities offered significantly ($P < 0.05$) higher amount of water (37.8) than those without (33.5) litres/300 kg live weight per day.

4.3. AMOUNT OF WATER, DRY MATTER AND FEED TYPE ON OFFER TO LACTATING DAIRY COWS AT DIFFERENT WATERING REGIMES

A variety of feeds were offered to dairy cattle. Napier and other types of grasses were the main feeds constituting more than half (1.58/100-kg lwt) of the total feed offered to dairy cows per day. These other types of grasses commonly offered to cows were Rhodes grass, star grass, coach grass, etc (Appendix III). Dry maize stover was second to napier/grasses in importance with an average of 0.567 kg / 100 kg lwt per day. Some farms soaked dry maize stover in water overnight before offering to the cows. Green maize stover was also harvested and offered to dairy cows.

Other variety of feeds offered to dairy cows across the farms surveyed were banana (leaves, pseudo-stem, thinnings), bean leaves, congette leaves, kales, kitchen waste, sugar cane leaves and tops, weeds, wheat straw, barley straw, sesbania leaves, calliandra leaves, sweet potato vines and minerals commonly *macklic super*™ and mineral salt. But these feeds were offered in small scale (0.234 kg /100kg lwt/day). Concentrates were offered to cows in milk in all farms at an average of 0.4855 kg /100 kg lwt per day. These included commercial dairy concentrates, cotton seed cake, bone meal, maize bran, maize germ, wheat bran and poultry litter.

Table 4.7. Effect of watering systems and practises on means of amount of water and types of feed offered to lactating dairy cattle in Kiambu District[2]

Variable	Category	Water/ 300 kg lwt	DM/ 100 kg lwt	Napier/ grass	Dry maize stover	Green & soaked maize stover	Concentrates	Others
		Mean	Mean	Mean	Mean	Mean	Mean	Mean
Water source	On-farm	43.1*	3.11*	1.736*	0.524*	0.199*	0.573*	0.078*
	Off-farm	19.5**	3.01**	1.293**	0.643**	0.231**	0.317**	0.526**
Distance to source	0-200m	43.1*	3.11*	1.736*	0.523*	0.199*	0.573*	0.079*
	0.2-1km	19.0**	2.995*	1.177**	0.671**	0.252**	0.367**	0.528**
	1-2.5km	21**	3.057*	1.616*	0.564*	0.171*	0.177***	0.529**
Water Transport	None	52.2*	3.07*	1.546*	0.406*	0.26*	0.588*	0.27*
	Manual	28.1**	3.071*	1.709**	0.576**	0.174**	0.440**	0.172**
	Other	22.6***	3.111*	1.506*	0.854***	0.244*	0.404**	0.103***
Watering frequency	Continuous	51.1**	3.117*	1.700*	0.551*	0.191*	0.639*	0.035*
	Non-continuous	19.2**	3.038*	1.461**	0.583**	0.228**	0.332**	0.433**
Trough size	Small	17.9*	2.989*	1.206*	0.619*	0.218*	0.378*	0.568*
	Large	39.4**	3.102**	1.685**	0.553**	0.208*	0.509**	0.146**
Storage	Present	35.9*	3.047*	1.231*	0.553*	0.241*	0.435*	0.586*
	Absent	33.1**	3.107*	1.952**	0.447**	0.183**	0.525**	0.136**

[2] *Means with different numbers of asterix for the same variable within a column are significantly different at P = 0.05.*

Cows in farms with on-farm source of water were offered significantly higher amount of water (43 l/300 kg lwt/day), DM (3.11 kg/100kg lwt/day), napier and grass (1.736 kg/100 kg lwt) and concentrates (0.573 kg/100 kg lwt/day) compared to 19.5 l of water, 3.01 kg of DM, 1.293 kg of napier/grass and 0.317 of concentrates offered at farms with off-farm water source. Maize stover and other types of feeds were commonly used as feed in farms with off-farm water source (Table 4.7). Farms with water close to the water trough (0 –200 m) also offered significantly ($P < 0.5$) high amount of water (43 l/300 kg lwt/day), DM (3.11 kg/100kg lwt/day), napier and grass (1.736 kg/100 kg lwt) and concentrates (0.573 kg/100 kg lwt/day) compared to farms trekking 0.2 – 2.5 km to draw water for livestock (Table 4.7). Amount of concentrate offered decreased with increase in distance to water source with farms drawing water at 0 – 200 m, 0.2 – 1 km and 1 – 2.5 km offering 0.573, 0.367 and 0.177 kg /100kg lwt per day respectively. Farms sourcing water from distances 0.2 – 1.0 km offered less napier (1.177 kg/100 kg lwt) but more of dry maize stover (0.671 kg/100kg lwt) and green & soaked maize stover (0.252 kg/100kg lwt) compared to other category of farms.

Significantly ($P < 0.05$) high amount of water (52.2 litres) and concentrates (0.588 kg/100 kg lwt) were offered to dairy cattle in farms with water piped directly to the water trough compared to dairy cows categories 'manual' (28 l/300 kg, 0.440 kg/100kg lwt) and 'other' (22.6 l/300 kg, 0.404 kg/100 kg lwt) respectively. Highest amount of napier (1.709 kg/100 kg lwt) was offered in farms depending on manual means of transporting water compared to dairy cows in other farms. Average dry maize stover on offer to dairy cattle in farms using other (bicycles, donkeys, etc) transport means (0.854 kg/100 kg lwt) was significantly ($P < 0.05$) higher than in farms using no or manual transport (0.406 and 0.576 kg/100 kg lwt/day respectively).

Mean amount of concentrate, napier and water offered (0.639 kg/100 kg lwt, 1.70kg/100 lwt and 51.1 l/300 kg lwt respectively) was significantly ($P < 0.05$) higher in farms practising continuous watering than in farms practising non-continuous watering (0.332 kg/100 kg lwt of concentrate, 1.46 kg/100kg lwt of napier and 19.2 l/300 kg lwt of water). Average amount of dry maize stover (0.583 kg/100 kg lwt), green and soaked maize stover (0.228 kg/100 kg lwt), and mean amount other feeds (0.433 kg/100 kg lwt) offered was significantly ($P < 0.05$) higher in farms practising non-continuous watering than in farms practising continuous watering. DM on offer was higher in farms where continuous watering was practised than in the other category of farms but the difference was not significant.

Farms with large water troughs offered significantly ($P < 0.05$) higher amounts of DM (3.01 kg/100 kg lwt/day), water (39.4 l/300 kg lwt/day), napier/grass (1.685 kg/100 kg lwt/day) and concentrates (0.509 kg/100 kg lwt/day) to dairy cattle than in farms with small water troughs. Higher amounts of maize stover (dry, green and soaked) and other feeds were offered in farms with small water troughs than in farms with large water toughs (Table 4.7).

Farms with water storage facilities offered significantly ($P < 0.05$) high amounts of water (35.9 l/300 kg lwt), dry maize stover (0.553 kg/100 kg lwt), green and soaked maize stover (0.241 kg/100 kg lwt) and other feeds (0.586 kg/100 kg lwt) per day to dairy cattle than in farms without water storage facilities. But farms without water storage facilities offered higher amounts of napier/grass (1.952 kg/100 kg lwt) and concentrates (0.525 kg/100 kg lwt) lactating cows than in others.

4.4. THE EFFECT OF AMOUNT OF WATER ON OFFER AND WATERING REGIMES ON MILK YIELD, BODY CONDITION SCORES AND BODY WEIGHTS OF LACTATING DAIRY CATTLE

4.4.1 Watering frequency practices

The mean amount of water offered to dairy cattle with unlimited water supply was significantly higher (51.1 litres/300 kg live-weight) (Table 4.8) than that of dairy cattle watered non-continuously (19.2 litres) ($P < 0.05$.). The average amount of water on offer, milk yields, body condition scores and body weights of lactating cows in farms under different watering frequency practices are shown in *Fig. 4.1*. It was observed that cows having unlimited access to water were offered a higher amount of water than in farms where non-continuous watering was practiced.

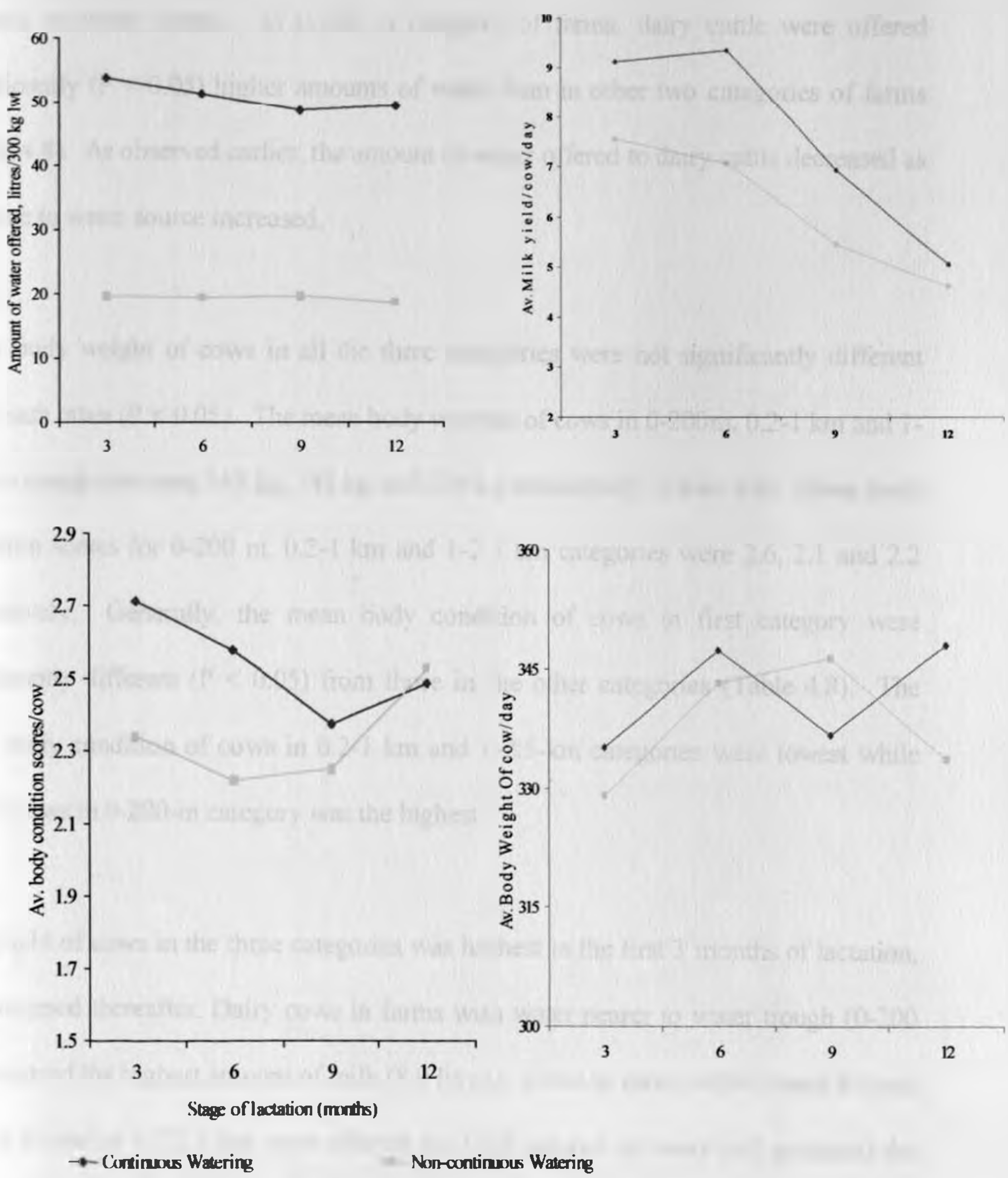
Milk yield was highest between 1st to 4th months of lactation, then dropped for both continuous and non-continuous watering regimes. Milk production of cows offered water throughout the day was higher than for cows getting water intermittently. The mean milk yield for dairy cattle watered continuously was significantly higher ($P < 0.05$) than that of cows watered non-continuously (the mean milk yields were 7.9 and 6.1 kg/300 kg lwt/cow/day respectively) (Table 4.8). Generally, body condition of cows in two watering regimes declined after calving, with dairy cattle offered water continuously had a significantly higher mean body condition score (2.6) than those watered less frequently (2.3) ($P < 0.05$). Generally, body condition of cows in farms practising continuous watering had high body condition scores throughout the lactation period. Average body weight of cows in the two categories of farms was not significantly different.

Table 4.8. Effects of watering systems and practices on means of amount of water offered, milk yields, body weights and body condition scores during the lactation period[2]

		WATER (litres/300 kg lwt/day)	MILK (litres/cow/day)	BCS	WEIGHT (kg/cow/day)
Variable	Category of cows	Mean	Mean	Mean	Mean
Source of water	on-farm	43.1*	8.0*	2.6*	345*
	off-farm	19.5**	5.2**	2.1**	328**
Distance to water source	0-200 m	43.1*	8.0*	2.6*	345*
	200-1000 m	19.0**	5.4**	2.1**	341*
	1-2.5km	21**	4.8**	2.1**	339*
Watering Frequency	Continuous	51.1*	7.9*	2.6*	335*
	Non-continuous	19.2**	6.1**	2.3**	343**
Volume of water trough	Small	17.9*	5.3*	2.1*	310*
	Large	39.4**	7.5**	2.6**	347**
Water Transport	None/piped	52.2*	8.0*	2.5*	352*
	manual	28.1**	6.7*	2.5*	335**
	Means used	22.6***	6.0**	2.2**	325**
Storage	Present	35.9*	7.7*	2.2*	350*
	Absent	33.1**	6.3**	2.6**	329**

[2] *Means with different number of asterix for the same variable within a column are significantly different at P = 0.05*

Figure 4.1 **Amount of water on offer, milk yield, body condition scores and body weights of lactating dairy cattle under different watering frequency practises**



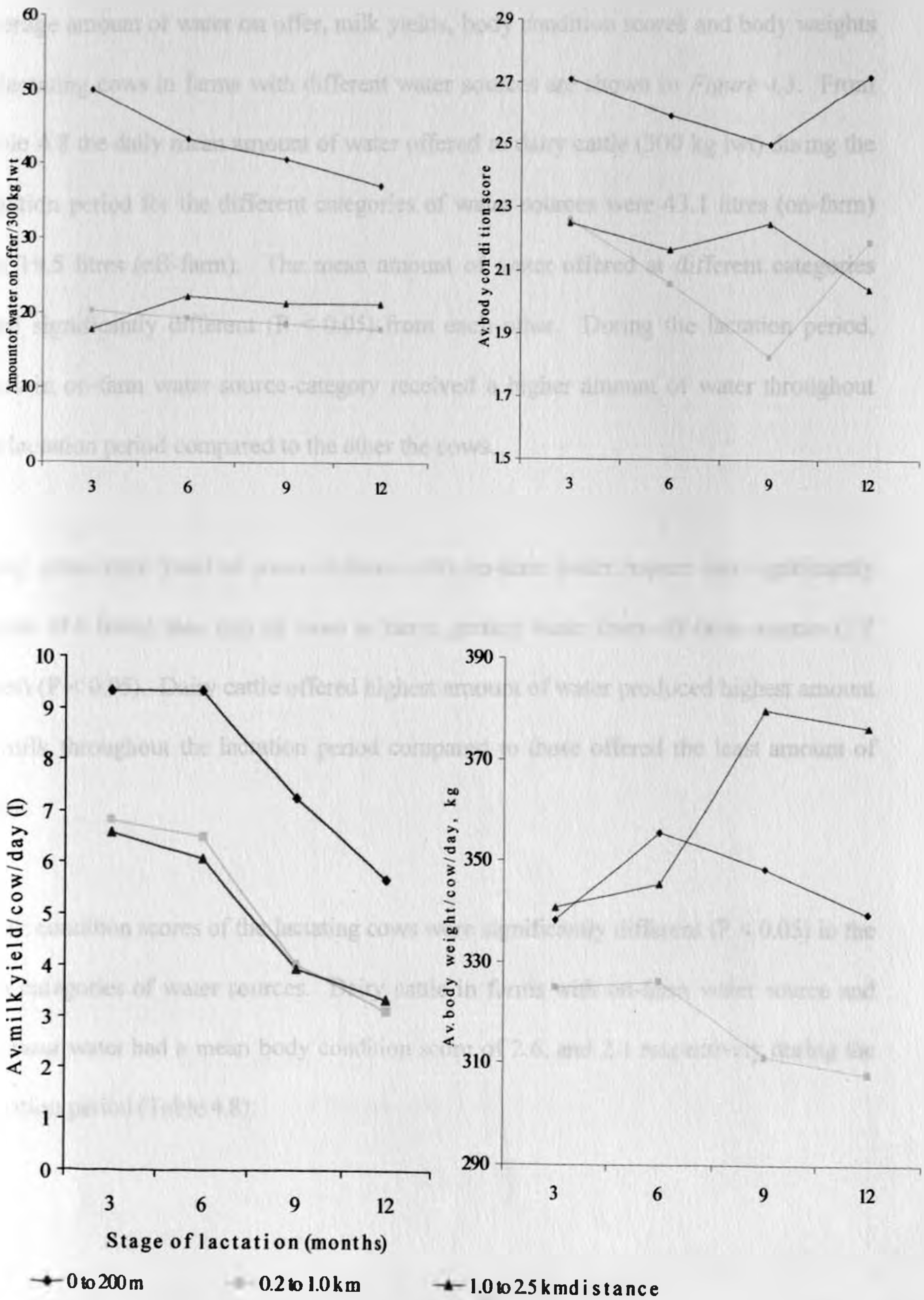
4.4.2. Distance to water source

Average amount of water on offer. milk yields. body condition scores and body weights of lactating cows in farms categorized according to distance to water source as shown in *Figure 4.2*. Performance of dairy cattle at different stages of lactation was affected by distance to water source. In 0-200 m category of farms. dairy cattle were offered significantly ($P < 0.05$) higher amounts of water than in other two categories of farms (Table 4.8). As observed earlier. the amount of water offered to dairy cattle decreased as distance to water source increased.

Mean body weight of cows in all the three categories were not significantly different from each other ($P < 0.05$). The mean body weights of cows in 0-200m. 0.2-1 km and 1-2.5-km categories were 345 kg. 341 kg and 339 kg respectively (Table 4.8). Mean body condition scores for 0-200 m. 0.2-1 km and 1-2.5 km categories were 2.6. 2.1 and 2.2 respectively. Generally. the mean body condition of cows in first category were significantly different ($P < 0.05$) from those in the other categories (Table 4.8). The mean body condition of cows in 0.2-1 km and 1-2.5-km categories were lowest while that of cows in 0-200-m category was the highest.

Milk yield of cows in the three categories was highest in the first 3 months of lactation. then dropped thereafter. Dairy cows in farms with water nearer to water trough (0-200 m) produced the highest amount of milk (8.0 litres). Cows in farms where water fetched from a distant of 0.2-2.5 km were offered the least amount of water and produced the least amount of milk during the lactation period. The mean milk yields of 0-200m. 0.2-1 km and 1-2.5 km categories were 8.0 litres, 5.4 litres and 4.8 litres respectively (Table

Figure 4.2 **Amount of water on offer, milk yield, body condition scores and body weights of lactating dairy Cattle in farms at different distances to water source**



4.8). The mean milk yield in 0-200m category was significantly different (P < 0.05) from those of cows in other categories.

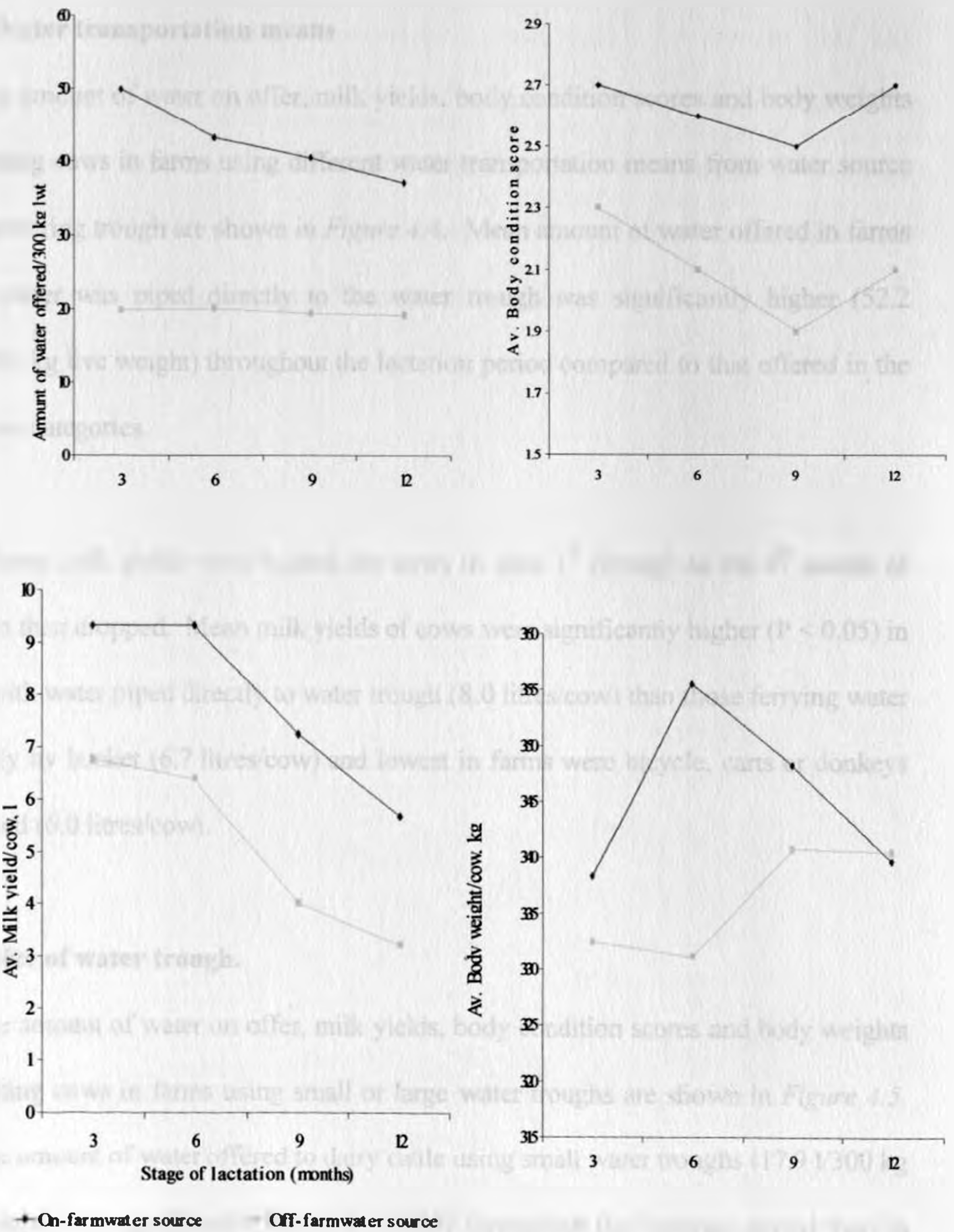
4.4.3. Water source

Average amount of water on offer, milk yields, body condition scores and body weights of lactating cows in farms with different water sources are shown in *Figure 4.3*. From Table 4.8 the daily mean amount of water offered to dairy cattle (300 kg lwt) during the lactation period for the different categories of water sources were 43.1 litres (on-farm) and 19.5 litres (off-farm). The mean amount of water offered at different categories were significantly different (P < 0.05) from each other. During the lactation period, cows in on-farm water source-category received a higher amount of water throughout the lactation period compared to the other the cows.

Daily mean milk yield of cows in farms with on-farm water source was significantly higher (8.0 litres) than that of cows in farms getting water from off-farm sources (5.2 litres) (P < 0.05). Dairy cattle offered highest amount of water produced highest amount of milk throughout the lactation period compared to those offered the least amount of water.

Body condition scores of the lactating cows were significantly different (P < 0.05) in the two categories of water sources. Dairy cattle in farms with on-farm water source and off-farm water had a mean body condition score of 2.6, and 2.1 respectively during the lactation period (Table 4.8).

Figure 4.3 **Amount of water on offer, milk yield, body condition scores and body weights of lactating dairy cattle in farms with different water sources**



Body weights of cows in on-farm water-source category were significantly higher ($P < 0.05$) (mean =345 kg), followed by those in off-farm water source category (mean = 328 kg) (Table 4.8).

4.4.4. Water transportation means

Average amount of water on offer, milk yields, body condition scores and body weights of lactating cows in farms using different water transportation means from water source to the watering trough are shown in *Figure 4.4*. Mean amount of water offered in farms where water was piped directly to the water trough was significantly higher (52.2 litres/300 kg live weight) throughout the lactation period compared to that offered in the other two categories.

Daily mean milk yields were highest for cows in their 1st through to the 4th month of lactation then dropped. Mean milk yields of cows were significantly higher ($P < 0.05$) in farms with water piped directly to water trough (8.0 litres/cow) than those ferrying water manually by bucket (6.7 litres/cow) and lowest in farms were bicycle, carts or donkeys were used (6.0 litres/cow).

4.4.5. Size of water trough.

Average amount of water on offer, milk yields, body condition scores and body weights of lactating cows in farms using small or large water troughs are shown in *Figure 4.5*. Average amount of water offered to dairy cattle using small water troughs (17.9 l/300 kg live weight) was significantly lower ($P < 0.05$) throughout the lactation period than in farms using large water troughs (39.4 l/300 kg live weight). Cows in farms watering from large water troughs had a significantly ($P < 0.05$) higher mean milk yield (7.5 l/cow) than that of cows watered from small water troughs (5.3 l/cow).

Average body weight for cows drinking from small water troughs (310 kg) was significantly lower than that of cows drinking from large water troughs (347 kg). Likewise, mean body condition score for cows drinking from small water troughs (2.1) was significantly lower than that of cows drinking from large water troughs (2.6). Major mean differences in body weights and condition scores between the two categories were observed in cows in 1st through to 12th months of lactation.

Figure 4.4 **Amount of water on offer, milk yield, body condition scores and body weights of lactating dairy cattle in farms using different water transportation means**

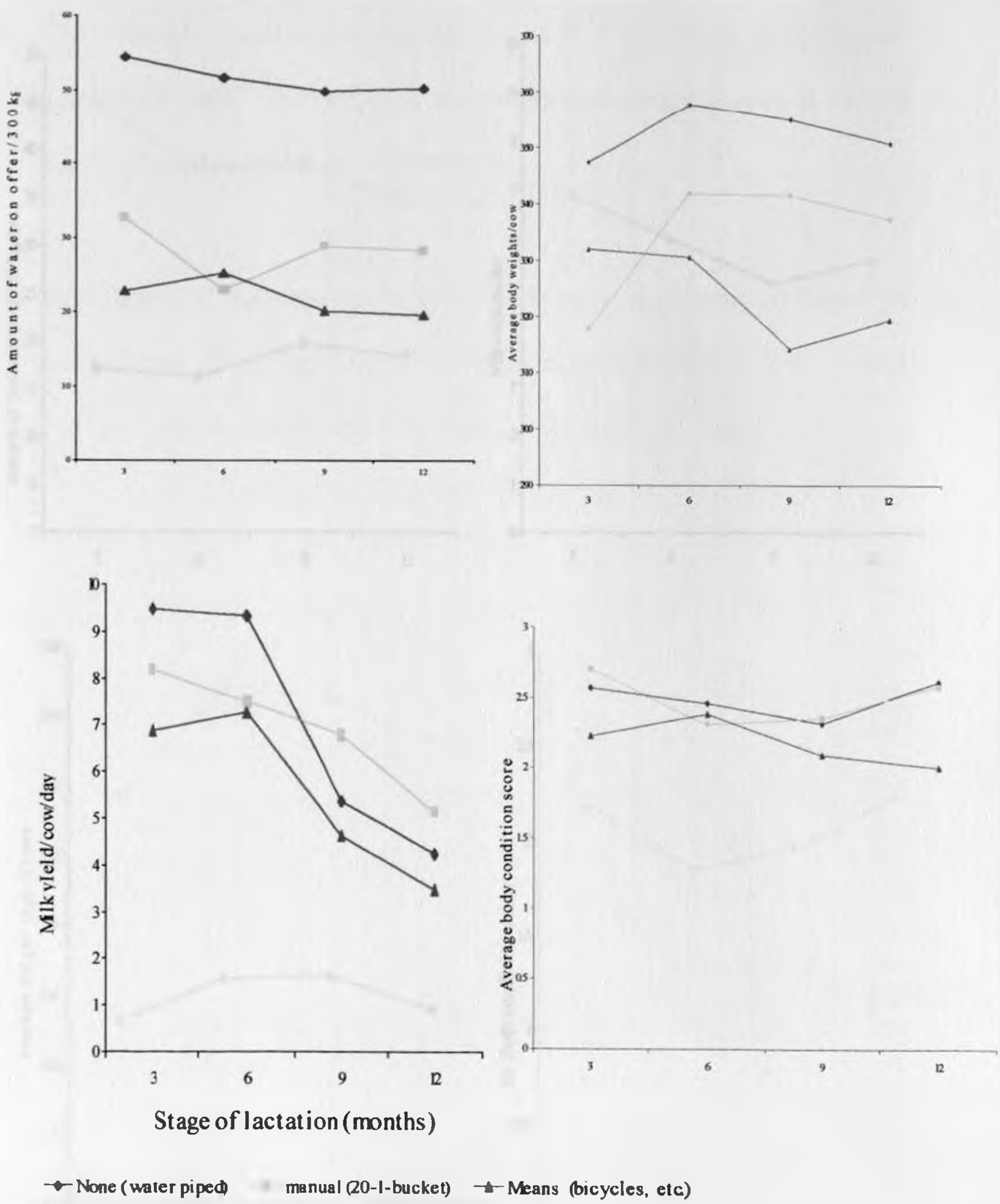
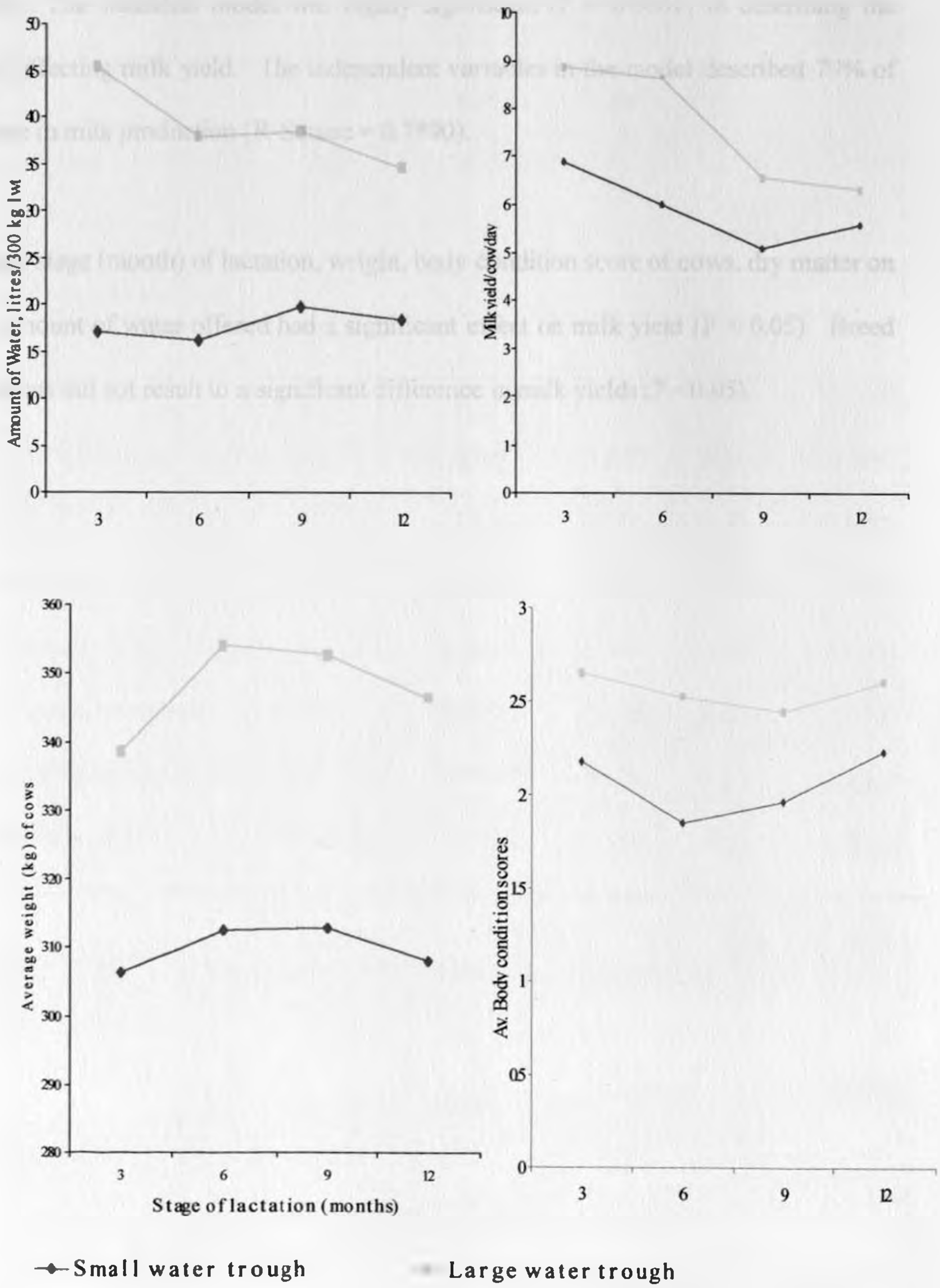


Figure 4.5 **Amount of water on offer, milk yield, body condition scores and body weights of lactating dairy cattle in farms with different sizes of water troughs**



4.5. ANALYSIS OF VARIANCE TO DESCRIBE FACTORS AFFECTING MILK YIELDS DURING THE LACTATION PERIOD.

Table 4.9 shows the analysis of variance (ANOVA) of the main statistical model to describe observed milk yield and ANOVA of variables affecting milk yield in Kiambu District. The statistical model was highly significant (P = 0.0001) in describing the factors affecting milk yield. The independent variables in the model described 79% of response in milk production (R-Square = 0.7890).

The age, stage (month) of lactation, weight, body condition score of cows, dry matter on offer, amount of water offered had a significant effect on milk yield (P < 0.05). Breed differences did not result to a significant difference in milk yields (P <0.05).

Table 4.9. Analysis of variance of the main statistical model to describe milk yield and ANOVA of variables affecting milk yields

Source of variation of the main model	Degrees of freedom	Sum of Squares	Mean Square	F Value	Pr>F
Model	325	6092.61	18.75	3.19	0.0001
Error	277	1629.23	5.88		
Corrected Total	602	7721.84			
Source of variation of the variables					
Age (years)	7	179.50	25.64	4.36	0.0001
Breed	2	26.54	13.27	2.26	0.1067
Parity	4	228.17	57.04	9.70	0.0001
Weight (kg/cow)	56	481.90	8.60	1.46	0.0253
Water offered/300 kg lwt/day, l	67	628.13	9.38	1.59	0.0051
Stage of lactation (months)	23	545.9	23.70	4.03	0.0001
Body condition score	6	109.46	18.24	3.10	0.0059
Dry matter on offer	158	1199.63	7.59	1.29	0.0328

R-Square = 0.789 C.V. = 37.65 Mean = 6.44 Root MSE = 2.42

CHAPTER FIVE: DISCUSSION

5.1. EFFECTS OF WATER SOURCES AND WATERING MANAGEMENT PRACTISES ON AMOUNT OF WATER OFFERED TO DAIRY CATTLE.

Majority of the farms (60%) in Kiambu District have on-farm water source, where farmers ferry water from short distances of between 0 to 200 m. The rest have problems in accessing water either due to long distances to water source, lack of water transportation means or due to hilly terrain. Where water source is off-farm, non-continuous watering of dairy cattle is practised. Non-continuous watering is also practised in a number of farms with on farm water source either due to lack of information on watering of dairy cattle or high labour requirements in drawing water from on-farm bore hole. Water trough technology (large brick/cement built troughs) has been highly adopted given that only 25% of the farms surveyed use buckets but some farms still use buckets even though they have brick/cement troughs probably because water is fetched using the buckets instead of being piped directly to the large troughs.

5.1.1. Effect of water source, distance and means of water transport on amount of water offered.

High amount of water was offered to dairy cattle in farms with on-farm water source. This may be attributed to a number of factors: firstly, some farms had water piped directly to the water trough and thus no labour was required to water dairy cattle. The rest of the farms were located within a radius of 200 m to the water source and labour requirements were minimal. Secondly, water transport was not required in farms with water piped directly to water trough, while in others, water was within easy reach. Thus water availability for dairy cattle in farms with on-farm water source may not be a constraint to cattle productivity.

Very low amount of water was offered to dairy cattle in farms with off-farm water source. This may be due to long distances to water point (0.2 km to 2.5 km), hilly terrain because some of these farmers had to trek and fetch water from rivers or lack of transport facilities because very few farms had transport means. In other cases where water was sourced from bore holes/water wells, a lot of labour was required to draw water and transport it to water troughs.

Farms with off-farm water sources needed a lot of labour to draw, transport and water dairy cattle. Bekure *et al.*, 1991 observed that, one of the most time consuming livestock management tasks is watering livestock in the boma. Also, it has been reported that, amount of labour required to water cattle depended primarily on water source and distance (Cossins and Upton, 1987; Swift 1981; Bekure *et al.*, 1991).

5.1.2. Effect of watering frequency on amount of water offered to dairy cattle

Watering frequency (the number of times a farmer presented water to dairy cattle) determined the amount of water offered. In continuous watering it was obvious that more water was offered to dairy cattle than in farms practising non-continuous watering. Water point/source and distance determined watering frequency. Farms with on-farm water mostly practised continuous watering because water source was within the farm and thus transport was not needed, labour was minimal and water was easily accessible. All farms getting water from off-farm sources practised non-continuous watering and offered the least amount of water to their dairy cattle. This may be due to the long distances to water source. Also, labour requirements for watering dairy cattle may have outstripped labour available within the farm. These findings agree with those reported by Bekure *et al.*, 1991.

5.1.3. Effect of type and size of watering trough on amount of water offered to dairy cattle

Low amount of water per day was offered to cattle in farms using small 20-litre buckets as water troughs. This may be because water buckets/bowls are small in size and volume and thus provided less amount of water per watering. Secondly, using them as water troughs may have required a lot of labour per watering.

Higher amount of water was offered in farms using large water troughs (half-cut drums and brick/cement built) to water dairy cattle. This can be attributed to their size and due to the fact that putting water into them does not have to be per watering but can be for a full day or days. Also, large troughs can act as water reservoirs. Thus labour requirements may have been minimal when using large water troughs.

Small water troughs could limit water on offer and thus intake. Large water troughs have adequate accessibility and provide adequate water. Also they are important because cows tend to drink in groups associated with other events (e.g. feeding, or after milking) and thus a bucket without automated filling would limit two or three cows drinking at the same time. MacLusky, (1959); Thomas, (1971); Castle and Thomas, (1975); Anderrson ***et al.***, (1984); Beede (1993) made similar observations.

5.2.0 EFFECT OF AMOUNT OF WATER AND TYPE OF FEED ON OFFER ON MILK YIELD OF LACTATING DAIRY CATTLE IN KIAMBU DISTRICT

In this study, it was found that increasing amount of water offered to dairy cattle resulted in an increase in milk yield. Dairy cows in farms offering high amount of water produced significantly higher amounts of milk. These farms had the following water sources and watering management characteristics: on-farm water source or short distance to water source, stored water, had large watering troughs and practiced continuous watering. In addition, these farms were offered high amounts of concentrates and napier grass. This may have been due to a number of reasons. Firstly, high amount of water on offer may have led to high water consumption. Castle and Thomas (1975) reported that cows having water continuously at their disposal consumed 18% more water than those offered water once or twice. Also, high amount of water offered, coupled with high amounts of napier and concentrates led to the high milk yields because napier and concentrates are feeds of high nutritive value than other feeds offered in Kiambu District.

This may mean that those cows offered high amount of water had higher voluntary water consumption than those offered less amount of water. Though amount of water drunk was not measured in this study, the amount of water offered to dairy cattle must have had a positive effect on water drunk as was observed by Castle and Thomas (1975). Cows offered smaller amounts of water might have drunk less than their requirements for milk synthesis and thermoregulation. And given that maintenance and thermoregulation are more crucial for the survival of the animals than milk synthesis (Holter and Urban, 1992), then most of the water consumed may have been channeled to maintenance and thermoregulation activities. Secondly, increasing the offer rate by increasing the amount of water in the troughs increased water intake and milk yields. Anderrson *et al.* (1984) and Reid (1992). had similar findings. Thirdly, dairy cows in milk require a lot of water because 85-87% of the milk is water (ARC, 1980). Thus cows in farms providing high amount of water had a corresponding high amount of milk yield.

Small troughs (20-litre bucket) provided small amount of water to dairy cattle in the boma. In addition, their small/narrow top would have restricted the cow's muzzle to enter completely into the bucket during drinking. This could result in a lot of water being left in the bucket and thus giving the farmer the impression that, the cow had enough to drink yet it still required more. On the other hand, one bucket would not cater for communal drinking yet it has been well established (Anderrson *et al.*, 1984; Beede, 1993) that, cows tend to drink at the same time.

Beede (1993) reported that type and size of water receptacle might affect drinking behaviour, which would in turn affect water consumption. Castle and Thomas (1975) also reported that water on offer and intake from bowls was lower than from large troughs even if automatic filling rate for both is the same. Anderrson *et al.*, (1984) reported that, increasing offer rate increased water consumption and decreased time spent drinking.

Severe drinking water restriction has been shown to lead to decrease in water intake by dairy cows and decrease their productivity because of changes in water balance (Little *et al.*, 1976; 1978). In this study, as in others (Castle and Watson, 1973; King and Stockdale, 1981), the cows restricted in their access to drinking water had less water available to them and thus may have consumed less. Since large differences in production were not observed, these cows maintained their water balance. Two probable reasons for this could be either, cows offered higher amount of drinking water may have consumed more and then excreted more water in the faeces and urine (Cowan ***et al.***, 1978) or cows with restricted drinking water could have consumed less and simply reduced the amount of water excreted. Thornton and Yates (1968) and Schlecht (1997) reported that, cows consuming less water excreted drier faeces and concentrated urine less frequently than cows consuming *ad libitum* water.

Milk yield was highest in farms offering high amount of concentrates and water. Also in farms offering high amount of napier and maize stover, high milk yields were realized. This may be due to the fact that, cows offered high amount of water consumed more water and took in more feeds of high protein content like concentrates and napier. This may have increased digestibility of feeds. These findings agree with Coppock and Sovani (1999). He observed that, cattle receiving supplemental water consumed 27% more of feed offered and their overall productivity increased. It is worthy to note that, the researcher did not measure the actual water and feed intakes.

In farms where high amount of dry maize stover was offered to dairy cattle, coupled with low water on offer, low milk yields were realized. This was observed in farms with small water troughs, off-farm water source and without piped water. Dewhurst ***et al.***, 1998 reported that free water intake increases with increased DM in the feed and free water intake is positively correlated with milk yield. Thus, high amount of dry maize stover on offer to dairy cattle (with high DM content) coupled with low water on offer led to low milk yields.

5.2.1. Amount of water offered to dairy cattle in the 20 farms surveyed compared to the recommended water requirement of dairy cattle.

From the survey, there was a wide range of performance with a mean milk yield that reflects low milk production (Table 5.1). The average daily milk yield in the survey sample was 6.44 litres/cow (SD = 3.58) and 5.7 litres/300 kg live weight (SD = 3.05) on an average daily amount-of-water-offered of 35.6 litres (SD = 20.32) per 300 kg live weight. These low milk yields are consistent with performance when the nutrition of lactating cows is inadequate, a conclusion in line with low amount of water offered in majority of dairy-cattle owning households in the survey.

Table 5.1. Voluntary water intake for dairy cattle in Europe compared with amount of water offered to dairy cattle in the studied 20 farms in Kiambu District

Water offered (litres)/day	Voluntary Drinking Water (litres)/day	Climate	Live Weight (kg)	Milk yield (litres)	Source
-	60**	Temperate (Europe)	350**	10.00**	ARC (1980)
40.1	-	Tropical (Kiambu)	338	6.44	This study
35.6	-	Tropical (Kiambu)	300	5.7	This study

Note: ** =*voluntary water intake of dairy cattle as recommended by ARC 1980*

Dairy cattle in colder regions like Europe get high amount of water than their counterparts in the hotter tropical climate (e.g. Kiambu). Owen ***et al.*** (1968) reported that dairy cattle voluntarily drank an average of 60 litres per day during their lactation stage. Water on offer was broadly below the literature values (Murphy 1992) and ARC (1980) tables of water requirements for dairy cattle. However the range across category values (17.9 – 43.1 litres/300 kg lwt), despite varied feed types, highlights the importance of identifying sources of variation, which relate to watering management characteristics and watering regimes. The free water intake in temperate regions is by far higher than what dairy cattle in Kiambu are offered. For example, free water intake of cows offered different silages ranged from 20.1 to 89.9 litres/day as reported by Dewhurst ***et al.,*** 1998. Given that temperatures in the tropics are higher and feed types are more varied, water requirement and thus water on offer is expected to be higher than in temperate regions. This high water requirement is necessary for body temperature regulation (Hyder ***et al.***, 1968). Apart from the low amount of feed on offer and the low nutritive value, the low water on offer, and thus low water intake may be one of the factors contributing to the low milk yield observed by different authors working with dairy farmers in Kiambu District (Table 5.2).

Table 5.2. Daily mean milk yields in Kiambu district reported by different authors.

Mean Milk yield (litres/cow/day)	Authors
6.40	Gitau ***et al.***, 1994
7.60	Staal ***et al.***, 1997
6.44	This study

The differences in the above mean milk yield may be attributed to different sample sizes, different seasons and years during which the particular survey was conducted, use of different household farms and aims of the different studies.

CHAPTER SIX: CONCLUSION

Source of water. distance to water source. storage of water. size and type of watering trough. means of water transport to water troughs. watering frequency (number of times water is presented to dairy cattle) are factors that affect amount of water on offer. The application of this work is limited by the fact that it was conducted using water on offer and not water intake. assuming that water offered was drunk which might not have been the case. Nevertheless. the findings indicate the effects of various factors on amount of water on offer. when different types of feeds are offered. and their effects on milk yields. Free drinking water on offer was high with high milk yields. Furthermore. high amount of water. concentrates and napier/grass on offer resulted in high milk yields. These results highlight the increasing importance of ensuring adequate provision of drinking water as milk yields in dairy cows increase. Therefore. the amount of water on offer may be strongly related to water intake of dairy cows. and thus to productivity.

In this study, cows were offered far much less water than what cows in colder areas voluntary drink in a day. This is also the case in dry matter on offer. Therefore dairy cattle in Kiambu are not only under-nourished in terms of feed on offer but also. are offered inadequate drinking water. In conclusion it is felt that the results of this study provide a sound basis for giving advice on water provision to dairy cattle under zero-grazing management in Kiambu District to maximise production.

CHAPTER SEVEN: RECOMMENDATIONS

1. On a practical basis, an abundant, easily accessible supply of drinking water must be available at all times to dairy cattle.
2. Smallholder dairy farmers in Kiambu District should be advised to increase the amount of water offered to dairy cattle from the average 35 litres/300 kg LW/day currently offered to at least the recommended 60 litres per day.
3. If a herd or group of dairy cattle is not performing to expectations, one of the first factors that should be evaluated and monitored is the drinking water on offer.

CHAPTER EIGHT: REFERENCES

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Appendix I

NOTES on forms

Parameter	Original	Change
FARM ID CODE		
Name of House-hold head (sex)		
Total adults >21		
Children 15-21		
Children < 15		
Cluster		
Division		
Location		
Sub-location		
AEZ		
Total Area of land (acres)		
No. of plots		
Area planted with Napier		
Member of co-operative		
Cash crop grown		
Wealth group		
Active Co-operative member		
Cluster: Specialist/Co-op resource poor		

Appendix I

NOTES on forms

House-hold head	

Visit date	

Location	

PLOT INFORMATION

Plot number	Plot size (acres)	Distance from homestead	Patch	Crops grown (code)

Crops grown

FOOD CROPS	CASH CROPS	FORAGES
1 = maize 2 = sorghum/millet 3 = beans 4 = Irish potatoes 5 = Sweet potatoes 6 = Cabbage, cauliflower 7 = Kale 8 = Tomatoes 9 = Onions 10 = French beans 11 = carrots 12 = bananas 13 = arrow roots 14 = other vegetables for market	15 = coffee 16 = tea 17 = cut flowers 18 = fruit/tree crops 19 = pyrethrum	20 = napier grass 21 = desmodium 22 = lucerne 23 = oats 24 = fodder beet 25 = vetch 26 = fodder trees 27 = other (specify below) 28 = sugarcane

Appendix I

NOTES on forms

House-hold head	

Visit date	

Animal ID	Name/Identification	Sex	Age at entry		Date of entry	Date of disposal
		M/F	Years	Month		

Appendix I

NOTES on forms

House-hold head	

Visit date	

	ANIMAL ID No.								
r	01	02	03	04	05	06	07	08	09
Animal Identification (Name/description)									
Pregnant (yes/no)									
Lactating (yes/no)									
Condition score (1-5)									
Weight (from weigh-band)									
LACTATING ONLY									
Time suckled (mins) [?time grazing]									
Unit used to measure milk production (code)									
First milking									
Time started									
Quantity produced									
Second milking									
Time started									
Quantity produced									
Third milking									
Time started									
Quantity produced									

Sex of person milking (M/F)	

Status of person milking (code)	

Unit used for measurement of milk production
1 = Litre
2 = Kg
3 = Grams
4 = Treetop bottle (750ml)
5 = Large Cup (500 g)
6 = Small Cup (350 g)
7 = Other unit (specify conversion rate)

Status of person milking
1 = Household head
2 = Spouse of household head
3 = Adult (>21 years) other than head
4 = Youth (15-21 years)
5 = Child (<15 years)
6 = Casual labourer
7 = Long term labourer

Appendix I

NOTES on forms

House-hold head	Visit date		Event time	

Sex of person feeding (M/F)		Status of person feeding (code)	

FEED ADDED

Name of Feed added	Form offered (code)	Source (code)	Weight of feed offered (kg)

ANIMALS INVOLVED IN FEEDING EVENT

Animal ID						
Animal Name/ Identification						

Form:	Source:	Status of person feeding
1 = As gathered 2 = Chopped 1-5 cm 3 = Chopped 6-10 cm 4 = Chopped > 10 cm 5 = Machine chopped 7 = Collected and left to wilt 8 = Other (specify how feed offered here)	1 = On-farm (cultivated and harvested) 2 = On-farm (stored) 3 = On-farm (collected) 4 = Off-farm (purchased) 5 = Off farm (collected) 6 = Off farm (exchanged) 7 = Other (specify source here)	1 = Household head 2 = Spouse of household head 3 = Adult (>21 years) other than head 4 = Youth (15-21 years) 5 = Child (<15 years) 6 = Casual labourer 7 = Long term labourer

Appendix I

NOTES on forms

House-hold head		Visit date	

Sex of person feeding (M/F)		Status of person feeding (code)	

FEED ADDED

Name of Feed added	Form offered (code)	Weight of feed refused (kg)	Remove feed refused Y/N

ANIMALS INVOLVED IN FEEDING EVENT

Animal ID						
Animal Name/ Identification						

Form:	Source:	Status of person feeding
1 = As gathered 2 = Chopped 1-5 cm 3 = Chopped 6-10 cm 4 = Chopped > 10 cm 5 = Machine chopped 7 = Collected and left to wilt 8 = Other (specify how feed offered here)	1 = On-farm (cultivated and harvested) 2 = On-farm (stored) 3 = On-farm (collected) 4 = Off-farm (purchased) 5 = Off farm (collected) 6 = Off farm (exchanged) 7 = Other (specify source here)	1 = Household head 2 = Spouse of household head 3 = Adult (>21 years) other than head 4 = Youth (15-21 years) 5 = Child (<15 years) 6 = Casual labourer 7 = Long term labourer

Appendix I

NOTES on forms

ORIGINAL DATA

This sheet was pre-pared from the original characterisation survey (Staal., *et al.*, 1997). The enumerator was to check these data during the first few visits and record any changes

BACKGROUND DATA

This sheet will be the front of each days records and will provide a guide to the different plots owned by the farmer which can be used in completion of the feed event sheets for allocating source of feed. Once this data is recorded, printed sheets containing the information will be prepared for the enumerator to refer to.

HERD DATA

Data for this sheet was collected during the first visit and subsequently only used to record changes. Information on cattle only was recorded. *[It was useful to know what other animals were on the farm.*

Name/Identification: Name was recorded if there was one the farmer commonly used. Otherwise, brief information allowing easy identification of the animal was entered e.g. all black, broken horn, white socks etc. etc This was to avoid confusion later when animal codes were used again. Animals were later tagged to further assist in identification.
Sex: M = Male, F = Female
Age at entry: Age of the animal in years and months on the date of entry into the data collection exercise. This was normally during the first visit, except where a new animal was introduced into the farm at a later date.
Date of entry: The first day data was recorded for an animal. This was normally during the first visit, except where a new animal was introduced into the farm at a later date.
Date of disposal: If the animal was no longer on the farm and therefore not included in the data collection exercise for any reason, e.g. if it died or was sold or stolen etc

PERFORMANCE

There was one of these sheets used on each visit

Pregnant (yes/no): Y = Yes N = No
Lactating (yes/no): Y = Yes N = No
Condition score: Assess condition of animal using 1-5 scale
Weight: Weight was determined using the weigh band taken round the animals girth

Time suckled: If the calf suckled, the length of time it spent suckling, if released only for the purpose of suckling. If the calf spent more time with the mother, length of time spent with the mother recorded.

Unit used to measure milk production: codes given below were used. If no appropriate code was available, a 7 was put in the box and at the bottom of the page it was noted the type of container used to collect milk and the volume it contained

First and second milking
Time started: Time at which the person milking actually started to extract milk (i.e. not when the animal was taken from the pen to be milked) was recorded
Quantity produced: The number of containers that are filled was recorded
Sex of person milking: M = Male, F = Female
Status of person who milked: Codes given were used.

NOTES on forms

FEED REFUSED: (1/feeding receptacle)

There was a separate sheet for each group of animals fed together from the same receptacle

This sheet was similar to that for feeding events but was only to record the refusals remaining in the trough before the first feed was added. These refusals were from the feed offered the day before. but was to give some idea of whether animals were eating all the feed they are offered. or whether they were being fed in excess. Source of feed was not important in this case since it was very difficult to determine.

FEED EVENTS: (1/event)

There was a number of these sheets depending on how the farmer offered the feed to the animal.

Definition of a feed event: Each time that an amount of feed (single feed or mixture) was offered to the same animal or group of animals in the same place at the same time.

Examples of 'feed events':

- A load of a mixture of Napier and weeds put into in a trough to which 2 animals had access at 0715 (these animals were then both recorded as having been involved in the feed event at the bottom of the sheet)
- A smaller load of Napier put into a different trough to which a different 3 animals had access at 0715 (i.e. although feed was offered at the same time. they were offered to different groups of animals and therefore constitute a separate event)
- A 2 kg kimbo tin full of dairy meal offered to a milking cow in such a way or in a place where no other animal had access. N.B. A 2 kg kimbo tin did not hold 2 kg. It was important to weigh the amount contained in the tin and the amount entered.

N.B. If one cow was removed and fed dairy meal during milking while feed was put in the trough it shared with another animal. but returned before all the feed put in the trough at that time was gone. then it was considered to have participated in the feeding event.

Event time: Time at which feed/water actually offered to animal. i.e. put in trough or in front of animal

Name of feed: A list of feeds was given and was referred to. If the feed the farmer was using did not appear on the list the actual name was noted. The list was then up-dated.

Form offered: Use codes. Where no suitable code was available. 6 was entered and at the bottom it was specified how the feed was treated before offering

Source: Where did the feed come from. i.e. on farm. purchased etc. Where no suitable code was available. 7 was entered and specified below where feed was obtained from

Plot no.: If the feed was obtained on farm. from which plot did it come.

Weight offered: Always kg used If a standard container was used. it was ensured that the weight recorded is actual weight of feed. not the weight the container is presumed to hold (e.g. a 2 kg kimbo tin does not hold 2 kg of maize bran or dairy meal..Water was entered in litres

Weight refused: The refusals of different feeds offered was distinguished and weighed separately.

Refusals removed: Are the refusals removed from the trough or left in front of the animal and new feed put on top?.

Animal ID and Animal name: Using the herd data sheet correct code and name (or description) was entered. The name/description was important and was used to avoid mistakes in animal code numbers

NOTES on forms

ON-FARM TRAINING SESSION

Equipment: Balance. Watch. Tape measure

Training

- Where to do measuring of girth and weight
- Condition scoring
- Recording
- How to distinguish feed events
- Weighing (taring)
- Standard containers (of concentrate etc.)
- How to deal with grazing animals
- How to deal with suckling animals
- How to deal with 3 times daily milking
- How to deal with grazing
- What feeds to include on the list
- How to deal with animals separated for part of the day (e.g. in milking)
- Are the codes for form offered/source of feed sensible or ?needs amending
- Order of animals in record sheets
- Specify type of bran

CHECKING: Was done by front-line extension staff responsible for supervision of the enumerators:

- Did plot nos. on feed events match plot description, if not why not
- were there feeds not listed being fed, if so, co-ordinators needed to amend list
- Had enumerators noted height of napier grass
- Were there a lot of places where no suitable codes are available. If so then new codes and sheets were generated
- Check data makes sense, e.g. no milking data recorded for male or non-lactating animals. Animal involved in feeding events in different groups at the same time (except where cow temporarily removed for milking)
- Did animal names and codes entered on the feed event sheet match up

ASCERTAINING WITH FARMERS

Front -line extension staff visitED listed farmers to ascertain whether they were prepared to be involved in the monitoring exercise

During these visits they would also ascertain the following from the farmers:

- Did they milk at night
- Did they graze, if so was there a lot of stall feeding, were they moved around
- Did they suckle (partially or totally)
- Did they milk more than twice daily

List of feeds entered under 'feed added'

- Naier grass 6 inches
- Napier grass 1 ft
- Napier grass 2 ft
- Napier grass 3 ft
- Napier grass 4 ft
- Water
- Green maize stover at harvest
- Green maize thinnings
- Dry maize stover at harvest
- Dry maize leaf from stover
- Dry maize stover at harvest soaked in water overnight
- Dry maize leaf from stover soaked in water overnight
- Dry maize stover at harvest soaked in water containing salt overnight
- Dry maize leaf from stover soaked in water containing salt overnight
- Hay *(?different types of hay)*
- Straw *(?different types of straw)*
- Banana pseudo stem
- Banana leaf
- Banana thinnings
- Weeds
- Cut grass
- Cut Rhodes grass
- Sugar cane leaves
- Sugar cane tops
- Leucaena leaves
- Leucaena branches
- Gliricidia leaves
- Gliricidia branches
- Sesbania leaves
- Sesbania branches
- Calliandra leaves
- Calliandra branches
- Sweet potato vines
- Dairy meal
- Maize bran
- Wheat bran
- Maize germ
- Poultry litter

Appendix II.

Questionnaire: Characterization of watering systems and practises.

Division	________	
Location	________	
Sub-location	________	
Farmer's Name	________	
Date	________	
Filled by	________	
Water Source	________	(1=On-farm, 2=Off-farm purchased, 3=Off-farm collected)
Distance to water source, Metres	________	
Water lype	________	(1=tap, 2=River, 3=Bore hole, 4=dam, 5=rain)
Mode of tranport from source to trough	________	(1=none needed, 2=man-20-l-bucketload, 3=cart drawn by donkey, 4=motorisedtranport)
Type of watering facility	________	(1=water trough, 2=half-cul drum, 3=bucket, 4=others)
Volume of watering facility	________	
Are there any water storage tanks	________	(1=yes, 2=no)
Volume of water storage tanks	________	
Frequency of watering	________	(1=once, 2=twice, 3=thrice, 4=continuous)

Appendix III.

Feeds on offer and their percentage nutritive value/100 g of DM

Feed type	Class of feed	Dry matter (%)	Ash (%)	Crude protein(%)	Energy (kilo joules
Calliandra leaves	Tree fodder	25	4.3	26.3	9.00
Banana leaf	Crop residue	12.2	8.8	9.9	8.95
Banana pseudostem	Crop residue	5.1	14.3	2.4	8.95
Banana thinning	Crop residue	13	13.1	6.4	8.79
Bean leaves	other	89	8.7	8.5	9.20
Bone meal	concentrate	75	49	6	8.33
Coach grass	Grass	30.2	7.4	8.8	8.20
Colostrum	other	10	52	23	8.16
Commercial dairy meal	concentrate	86	6	12	7.74
Cottonseed cake	concentrate	92	7	21.8	8.37
Courgette leaves	Crop residue	20	11	12	0.00
Cut grass	Grass	28	7	10	8.16
Fish meal	concentrate	92	21.4	64.3	9.04
Kales	Vegetables	20	11	12	9.25
Kitchen waste	other	20	11	12	7.74
Macklick super	other	96	96	0	8.20
Maize (green thinnings)	Crop residue	25	4.5	6.2	8.28
Maize bran	concentrate	85.4	2.2	9.4	7.74
Maize germ	Concentrate	88	4.2	22.6	8.08
Maize stover (dry)	Crop residue	85	7.2	3.7	2.19
Maize stover (green at harvest)	Crop residue	13	8.5	7.7	2.2
Maize stover (soaked overnight)	Crop residue	20	7.2	3.7	2.19
Maize stover (soaked overnight/salt)	Crop residue	20	7.2	3.7	2.19
Maize waste	Crop residue	86	1.4	10.2	3.16
Mineral salt	other	96	97	0	0
Napier grass	Grass	15	13	6	2.18
Napier grass (1ft)	Grass	12.1	12.1	9.2	2.18
Napier grass (2ft)	Grass	12.6	12.4	7.4	2.15
Napier grass (3ft)	Grass	13.4	12.6	7	2.15
Napier grass (4ft)	Grass	14.4	13.1	6.5	2.15
Napier grass (5ft)	Grass	15.5	13	6.2	2.14
Napier grass (6 ft)	Grass	18.7	12.9	6	2.14
Napier grass (>6ft)	Grass	24	13	5	2.1
Pig finishers	concentrate	86	7	15	2.2
Poultry litter	concentrate	87	14	22	1.99
Rhodes grass	Grass	90	9.1	6.3	1.96
Star grass	Grass	30	11.6	11	1.95
Sugar cane leaves	Crop residue	25.6	6.2	6.3	1.85
Sugar cane tops	Crop residue	30.5	9.1	5.9	2
Water	other	0	0	0	0
Weeds	Weeds	25	12	10	1.95
Wheat bran	concentrate	88	2.4	17.8	2.16
Calf pallets	concentrate	85	9	13	2.21
Grazing	other	28	7	10	1.85
Wheat straw	Crop residue	86	9.4	3.8	1.96
Barley Straw	Crop residue	86	8.2	3.9	1.98
Sesbania leaves	Tree fodder	28	4.5	28.2	1.85
Sweet potato vines	other	25	9.4	19.2	1.93