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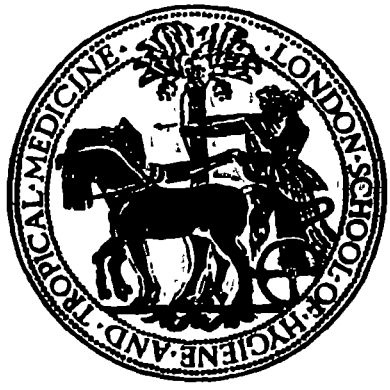

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MEASUREMENT OF THE ELASTICITY OF DOMESTIC WATER DEMAND

A study of water vendors and their clients, in urban Sudan

by

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CONTENTS

SUMMARY

Many millions of people in the developing world do not have reasonable access to safe water. If a significant increase is to be achieved in the rate at which water supply coverage is extended, there is little option but to require that those who benefit should pay for at least some of the cost. However, a rational cost recovery policy requires a knowledge of the elasticity of demand - the degree to which payment for water affects consumption. Many poor urban residents, who are unserved by water supplies, buy their water from vendors in the informal sector. This report describes a study of the elasticity of demand for water and the economics of water vending in urban Sudan.

The fieldwork focussed on two squatter communities in Khartoum - Meiyo and Karton Kassala - where households at various income levels, paying different prices for water, were studied by observation and by questionnaire. The average household in Meiyo spent 17% of its income on water, while the corresponding figure in Karton Kassala, where the price was nearly four times higher, was 56%. However, water consumption in Karton Kassala was no lower than in Meiyo. Households within these communities also showed no tendency to use less water when paying a higher price for it, or when their income was below average. Thus, there was no detectable price elasticity or income elasticity of demand.

One consequence of this is that the poorest households devote the greatest percentage of their income to the purchase of water. The only item in the household budget which can be sacrificed to make this possible is food. There can be little doubt that the high price of water in urban Sudan is a major cause of the malnutrition which is rife in the squatter areas.

Another consequence is that a low income household's consumer surplus for domestic water is higher than had ever been imagined, and close to the

household's total income. This has important implications for the economic appraisal of urban water supply schemes It also follows that wealthier households with private connections would be willing to pay at least as much for water as that currently paid to vendors by the poor.

A study of the micro-economics of water vending showed that, while profits were negligible in Meiyo, they were considerable in Karton Kassala and in Port Sudan. There was no evidence of a monopoly or cartel to fix the price of vendors' water, but it appeared that certain ethnic groups could exert some indirect control over prices, by restricting access to the credit necessary to buy donkey carts, and to the sources of water.

This is in accordance with the theoretical consequences of the low elasticity found in the household surveys; that quite a small change in the supply of water can have a major impact on its price. Thus, a quick and cost-effective measure to improve the material wellbeing of the urban poor would be to reduce water vendors' prices by improving the availability of water. This could be achieved by making water more available for vendors to load their carts, or by a revolving fund offering credit to those seeking to buy a donkey and cart and take up water vending as a trade.

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I THE CONTEXT

1.1 INTRODUCTION THE INTERNATIONAL WATER DECADE

In 1972, little more than 13% of the rural population of the developing countries was considered to have reasonable access to safe water. In that year, the World Health Assembly resolved that by 1990 this proportion should be increased to 25%, implying provision for over one billion people. Many sceptical analysts doubted that the target would be reached (Feachem 1977). In the event, the World Health Organization's figures indicated that it was not only reached but surpassed. They also showed considerable progress in extending the coverage of urban water supply systems, in spite of the rapid growth of the urban populations of most developing countries. The precision of the figures is open to debate, but few would dispute that the 1970s saw an impressive advance in coverage.

Perhaps this experience inspired the optimism of the United Nations Water Conference in 1977, which declared 1981-90 as the International Drinking Water and Sanitation Decade, and set the goal of supplying safe water to everyone by 1990. This time, unfortunately, the target really was overambitious, and many countries have since set more modest goals for the Decade (WHO, 1987). The progressive increase in the percentage of the population in developing countries with reasonable access to a safe water supply is shown in Table 1.

Table 1. Water supply coverage in the developing countries, 1970-85.

	1970	1980	1985
Urban	65	73	75
Rural	13	32	42

These figures represent a considerable achievement, but owing to population growth the absolute number of people without access to safe

water has barely changed since 1980. In urban areas, it has even increased

Most of the investment funds for the Decade and practically all the maintenance funds have come from the developing countries themselves. In the present conditions of economic austerity there is little likelihood that their hard-pressed government budgets can stretch to the greatly increased rates of investment which would be required to meet even the revised Decade targets. Nor can aid donors, for all their generosity, be expected to increase their support for water supply out of proportion to their assistance to other sectors. They have not done so hitherto (Anon, 1987). This leaves the consumer as the only other likely source of funds. In the circumstances, it is hardly surprising that the two constraints to achievement of the targets ranked as most severe by the countries reporting to WHO (1987) are

(i) funding limitations, and

(ii) inadequate cost-recovery framework.

The establishment of a policy for cost recovery in the water sector requires an understanding of the demand for water and the factors which influence it, particularly the level of water tariffs and the way they are levied. The degree to which water demand is affected by tariffs is known as the price elasticity of demand. This report is an account of a field study of the elasticity of demand for water for domestic use among low-income communities in Khartoum, Sudan.

1.2 ELASTICITY OF DEMAND

In economic parlance, the demand for a product is the amount which people are prepared to buy under the prevailing conditions. The demand for some products is heavily dependent on the price, falling steeply whenever there is a small price increase but rising substantially if the price is reduced. In this case, the demand is said to be elastic. When price changes exert relatively little influence on demand, it is said to be inelastic. Examples of goods with elastic demands would be those for which there is a ready substitute at a comparable price. Inelastic demand, on the other hand, is a characteristic of essential goods such as staple foodstuffs, whose consumption is determined by people's dietary needs and habits more than by price.

Economists illustrate the relationship between price and demand for a good by drawing a graph of the quantity which is bought (the demand) against its price (the unit purchase price). This is known as the demand curve. Figure 1 shows how the demand curve slopes more steeply when demand is inelastic, and is flatter for elastic demand. The price elasticity of demand is a measure of the degree of this elasticity. It is a number, for which the Greek letter ϵ is often used. If a change in price from P to P $+\delta P$ causes a change in demand from Q to Q $-\delta Q$ (see Figure 2), then

$$\epsilon = \frac{\delta Q}{Q} \cdot \frac{P}{\delta P}$$

Put another way, the elasticity ϵ is the percentage increase in quantity divided by the percentage reduction in price which produces it.

The elasticity is an indication of the slope of the curve, but it is not an exact one; constant elasticity does not correspond to a straight line with constant slope, but rather to a curve whose slope varies in order to keep the percentage changes in the same ratio.

The area A of the rectangle formed on the demand graph by the axes,

the ordinate and the abscissa (the rectangle a b c d in Figure 2) is equal to the total revenue generated by sale of the good, because

$$A = P \times Q.$$

Note that when demand is elastic (that is, when $\epsilon > 1$), the total revenue can be reduced by an increase in price. This paradox corresponds to the fact that the area a' b' c' d in Figure 2 is less than the area a b c d.

The consumer surplus

There is another way in which areas under the demand curve can be understood. Consider a reduction in price from $P_1 + \delta P$ to P_1, bringing about an increase in consumption from $Q_1 - \delta Q$ to Q_1 (Figure 3). By deciding to buy the additional quantity Q at a price of P_1, but not more, consumers have shown implicitly that they value it at that price; that is, its total value to them (price times quantity) is $P_1.\delta Q$ which is the area of the strip shaded in Figure 3.

This implicit valuation has meaning even if the price is really (or subsequently) fixed at a lower figure such as P_2, so that consumers buy a larger quantity Q_2. Contemporary economists refer to it as "utility". Adam Smith termed it "value in use", to distinguish it from the actual price, or "value in exchange". If Q_2 is the quantity purchased, it can be considered as being the sum of a large number of small quantities δQ. The utility of each of these to the consumers is the maximum price at which they are willing to buy it, and this may be greater than the price they actually pay. The total utility to the consumers of the total quantity actually purchased can be seen as the sum of the area of a series of strips such as that shown, lying between Q_2 and the vertical axis of the graph. In the limit, as the strips become imperceptibly small, this is the area of the trapezium e b c d in Figure 3.

Now, it has already been shown that the total amount paid when the price is P_2 will be $P_2\ Q_2$, the area of the rectangle a b c d in the Figure

3. Thus, the difference between the value of the product to the consumers and the amount they pay for it is represented by the difference between these two areas - that is, the area of the triangle e b a. This difference is known as the consumer surplus. When demand is highly elastic, the graph is relatively flat so that the area of the triangle is small compared with that of the rectangle. In other words, the consumer surplus is small in relation to the amount paid. On the other hand, in an inelastic market the demand curve slopes steeply, and the consumer surplus may be very large. In that case, the value of the product to the consumers may be much greater than the amount they actually pay for it.

Income elasticity

The foregoing discussion has focussed on price elasticity, which expresses the relationship between price and demand. However, the demand for a product is also influenced by the incomes of those who may wish to buy it. Generally, those with higher incomes will tend to purchase more. If they purchase much more, there is said to be a high income elasticity of demand. Income elasticity can also be represented graphically, on a graph of demand against income (see Figure 4).

1 3 THE OBJECTIVES OF WATER SUPPLY

Any rational policy for the provision of water supply must be based on a clear definition of the objectives which it is desired to achieve. This is not as easy as it might seem, as the question is complicated by several factors.

First, the experience of the industrialised countries, in which the consumer is willing and able to pay the full cost of a very high level of service, has encouraged many of those active in the sector to perceive the provision of the highest possible level of water supply service as an objective in itself. This tendency has been exacerbated by the setting of goals for the Water Decade which are often unrealistic and usually couched in terms of the numbers of additional people to be supplied. This has led to distortions such as inappropriately high standards and to undue emphasis on the construction of new water supplies, to the neglect of those already existing (Briscoe and de Ferranti, 1988).

Second, some of the most important potential benefits, such as improved health, are in practice very hard to measure (Blum and Feachem, 1983). Others, such as industrial development, may be more easily observed, but are not necessarily attributable to improvements in water supply (Saunders and Warford, 1976). The practical difficulties of measuring and attributing benefits means that there is a lack of objective knowledge about the kind of water supply programme most likely to bestow them.

Third, the different parties involved in building, financing and using water supplies may have very different perceptions of the objectives of a water supply programme, and political considerations often loom large. In most developing countries, there is a strong public demand for water supplies, so that for politicians, the promise to provide them may be an effective vote-catcher, and the allocation of resources in the sector often

forms an important part of political patronage systems, or an adjunct to politically-motivated schemes to direct or control patterns of settlement (Cairncross, 1988). To international aid agencies, on the other hand, water supplies have different attractions. They are a tangible contribution towards meeting the basic needs of the poor and improving their quality of life; water supply construction requires no major changes in land ownership or in the local balance of power; moreover, the sector can often benefit from the foreign technical expertise and foreign equipment which aid agencies can provide.

For the economist, however, water supplies offer two benefits which are concrete enough to be considered as objectives. Both of them accrue to the users. The first is improved health, and the second is a saving in time (or, in many cases, money) which would otherwise be expended in water collection. These are considered in turn.

Improved health

In the past, the general expectation has been that water supply improvements will, by preventing the water-borne transmission of a wide range of enteric diseases, lead to significant health improvements. To a considerable degree this perception has been based on the historical experience of major water-borne epidemics of cholera and typhoid in the industrialised countries, and the success of sanitary engineering interventions over the last 100 years in preventing them.

More recently, some studies of the health impact of water supplies in developing countries have failed to detect the expected health benefits, leading to a certain amount of disillusionment (Feachem, 1985). However, the Bradley classification of water-related diseases (White, Bradley and White, 1972) provides an explanation for these sometimes puzzling findings, as will be shown in the following discussion. Bradley drew the important distinction between the strictly water-borne transmission of infections,

directly related to poor water quality, and transmission by "water-washed" routes such as the contamination of hands, food and utensils due to a lack of water in sufficient quantity to maintain adequate standards of personal and domestic hygiene.

Water-borne transmission is best controlled by the provision of drinking water of high microbiological quality, whereas the control of water-washed transmission requires the provision of water in quantity, irrespective of its quality, and with sufficient convenience and ease of access to encourage its plentiful use for hygiene purposes. The relative priority to be attributed to quality or to quantity in the provision of water supply depends on the relative importance for public health of the two types of transmission route. Clearly, the relative importance of water-borne and water-washed transmission is of great significance for water supply policy.

However, the question is not easily answered because the faeco-oral enteric infections can potentially be transmitted in both ways. These are a major cause of child mortality and constitute the most important group of all the water-related diseases. They include the paediatric diarrhoeas which cause so many child deaths, and also typhoid, cholera and other enteric diseases which afflict poor communities in the developing world. The exact modes of transmission of these infections among low-income communities have been the subject of considerable debate (Briscoe, 1978; Shuval et al., 1981; Cutting and Hawkins, 1982,; Esrey, Feachem and Hughes, 1985). Water-borne transmission has been demonstrated to occur in some well-known epidemics. However, there is an accumulating body of evidence that most of the endemic transmission of these faeco-oral diseases is by water-washed routes.

This evidence includes the comprehensive review of the published studies by Esrey and Habicht (1986) who found that in most of the cases

where water supply improvements were shown to have brought about a reduction in diarrhoeal disease, these improvements had included an improvement in access to water in quantity. Further evidence is provided by a major ODA-sponsored evaluation of village water supplies in Lesotho (Feachem et al., 1978), which found that neither diarrhoeal disease nor typhoid was primarily water-borne.

A graphic illustration of the two transmission routes is provided by Elzubier (1977), who studied a typhoid epidemic in the town of Kosti in the Sudan. The epidemic curve is shown in Figure 5. The epidemic was found to have been caused by water-borne transmission, due to an interruption in the disinfection of the town's water supply, which lasted from July 1st to 19th, 1976. The cause of the epidemic was identified by a Ministry of Health team on July 20th. Disinfection was immediately restored and the water quality was meticulously monitored thereafter. However, the graph shows that typhoid had been endemic in the town before the epidemic, and typhoid cases continued to be reported long after the restoration of disinfection and the expiry of the 10-day incubation period for the disease. These additional cases were clearly not water-borne, and must therefore have been water-washed. The increased incidence of water-washed disease after the epidemic can be explained by the existence of a greater number of temporary carriers in the town. The number of cases in the epidemic was large, but still more endemic, water-washed cases must have occurred in the town during previous and subsequent years.

In this example, and indeed it would seem in many other cases, the water-washed transmission of an enteric infection is in the long term of greater public health importance than the occasional episode of water-borne transmission. Moreover, some diseases are water-washed, but clearly can never be water-borne. This includes eye infections such as trachoma, whose relationship with poor water supply is well documented (Marshall, 1968;

Taylor et al., 1985, Cairncross and Cliff, 1987), some skin infections (Jancloes and Jancloes-Diepart, 1981), and two infections transmitted by body lice (Feachem, 1977). The failure of some water supply programmes to have a detectable impact on any of these health problems can be explained by the fact that, in spite of providing water of greatly improved quality, they did not bring about an increase in the quantity of water used for hygiene nor an improvement in specific hygiene habits, sufficient to reduce the water-washed transmission of faeco-oral and other diseases.

In this context, the factors affecting water consumption among low-income populations take on an added significance. In particular, if the cost of water, whether in cash or in valuable time spent collecting it, deters consumers from using it in desirable quantities, this could vitiate the important health benefits which investments in water supply seek to achieve.

There is one important infection which, contrary to the general rule, is exclusively related to water quality, and that is guinea worm, which can only be caught by drinking infected water. The eradication of guinea worm disease has been declared a goal of the International Drinking Water Supply and Sanitation Decade (WHO, 1986). The disease is only found in the Sahel region, the Indian subcontinent, and in one or two foci between those areas. Recent studies in the Sudan (Cairncross and Tayeh, 1988) have found that apparently minor disincentives to the use of improved supplies may lead people to continue to drink from sources of water infected with the disease. a water tariff could potentially be a disincentive. The elasticity of demand for water is therefore relevant to this case also.

Time saving

The provision of water closer to the home permits significant savings in time spent in the chore of water collection. Since the task of collecting water generally falls to women, this saving is an important

contribution to their emancipation, and a significant improvement in their quality of life. In many low-income communities, both rural and urban, in developing countries it is typical to find women spending over an hour each day collecting water. The avoidance of this drudgery through better water supply is a benefit more immediately perceptible to the users than health improvements, and is the principal reason for the popularity of water supply programmes in the developing world.

Women may use the time saved in a variety of ways, many of which may promote secondary health benefits. For example, there is evidence that women who have more time for child care, particularly for feeding their children, have children who are better nourished (Popkin and Solon, 1976; Tomkins et al., 1978). A great deal of women's time in most communities is spent in the tasks of cleaning, sweeping, scrubbing and washing, which are essential for the maintenance of good hygiene. More time to perform those tasks effectively could lead to health improvements.

Surprisingly little research has been devoted to the ways in which women use the time freed by improved water supply, but the few such studies which have been carried out (Feachem et al., 1978; Cairncross and Cliff, 1987) suggest that much of it is devoted to other household tasks and to social activity. Whatever the use to which it is put, there is evidence that it is highly valued. Women in many low-income communities are prepared to pay as much as 10% of their household income to water vendors who deliver water to their door (Zaroff and Okun, 1987).

Studies of queuing behaviour in the United States (Deacon and Sonstelie, 1985) have found that most people implicitly value their time at a rate similar to their net hourly wage rate, which is a not irrational estimate of its opportunity cost. There is no reason to believe that low-income communities in developing countries are any less rational in this regard, but so far there has been very little research on the willingness

of such communities to pay for water, and no studies have used the information to make an empirical assessment of the value the consumers implicitly set on their time.

It is nevertheless justifiable to include a valuation of time savings in cost-benefit calculations for water supply investments, in the same way as time savings are used to justify investments in road construction in the industrialised countries. A reasonable rate to use for this purpose would be the average wage rate for unskilled labour. On that basis, a detailed desk study by the World Bank (Churchill, 1987) led to the conclusion that, irrespective of any potential benefits to health, rural water supply investments could usually be justified on the basis of time-savings alone. A more remarkable conclusion was that in many cases, the provision of individual connections was more cost-effective in securing time savings than the installation of public standpipes, in spite of its greater per capita cost.

The World Bank study referred to rural water supplies, but it is likely that similar conclusions could be drawn for many urban systems, especially when time spent queuing at the water source is included. In urban areas the savings are as likely to be in money as in time, since large sums are often paid to water vendors. Money paid to water vendors is generally drawn from that part of household income which is at the disposal of the housewife for domestic expenditure. Payments to water vendors mean that expenditure on other items in the household budget, particularly food, is likely to suffer. If water is provided close enough to the home to enable households to collect their own, additional funds are made available to the housewife and diet is likely to improve.

A study in Stockton-on-Tees, UK, in the early 1930s (M'Gonigle, 1933) offers a dramatic illustration of the way in which sacrificing expenditure on foodstuffs can be prejudicial to good health. M'Gonigle found that

working class households which were moved to new housing estates with better water supply, sanitation and other facilities had higher mortality rates than their neighbours who remained in the slums, because their increased expenditure on rent had caused their diet to suffer. Very little is known about the ways in which low income households in developing countries adapt their expenditure to respond to demands on their resources such as payments for water. However, it is well established that resource allocations made within such households do not usually favour vulnerable groups such as women and children (Golladay, 1983), so that these may be the first to suffer from increased water prices.

1.4 THE CASE FOR COST RECOVERY

The figures collected by WHO (1987) and shown in Table 1 above suggest that the proportion of the urban population served by safe water supplies is advancing by some 7% every 10 years, while in rural areas, each decade sees an increase in the coverage rate of some 20%. At these rates, the original target of the Water Decade will not be reached before 2020,and meanwhile many millions of people will have to go without this basic need being met. There are four ways in which the rate of progress can be improved:

i. reduction of unit costs

ii. increased investment from external sources

iii. increased investment by national governments

iv. increased recovery of costs from the users.

These are discussed in turn.

i. Reduced unit costs

Reducing the cost per capita of water supply construction through the use of appropriate technology is attractive, and has been used with success in some countries to permit an accelerated rate of water supply provision (Arlosoroff et al., 1987). However, in rural areas there are limits to the reductions which can be achieved by these means without prejudice to the reliability of the water supplies, and in urban areas the technology is so well developed that there are few opportunities for cost reduction. On the contrary, the increasingly large cities of the developing world, many of them located in semi-arid or coastal regions deficient in fresh water resources, are having to look ever farther afield for suitable water sources from which to abstract. The high construction cost of long distance pipelines and the energy cost of pumping will thus tend to increase the unit costs of urban water supply in the future. Moreover, the unit costs of oil-based products which as polythene pipe, of energy-

intensive goods such as cement, and of some other items required to build water supplies, have tended to rise and will probably continue to do so in the future.

WHO (1987) found that urban water supply construction costs per capita had increased from 1980 to 1985 in all 5 regions of the developing world, roughly in line with the rate of inflation in the industrialised countries. Rural water unit costs were less consistent, falling in some regions and rising dramatically in others, but the general trend was still upwards Thus no marked overall reduction in unit costs was achieved in the first half of the Decade, in spite of this period being considered by many as one of widespread adoption of low-cost technology (Feachem, 1980). It would therefore be unwise to count on such a reduction in the immediate future.

ii. Increased investment from external sources

It has been estimated that some US$ 2 billion are invested annually in the water sector by international agencies, development banks and non-governmental organizations (Dietrich, 1983). However, there is no evidence that these external donors and lending agencies have responded to the Water Decade by significantly increasing their assistance to the sector. For example, the proportion of World Bank funds disbursed for urban water and sanitation projects remained roughly constant over the ten years 1975-85, at less than 5% of the Bank's total lending. Only 0.5% of total lending has been for rural water supply (Churchill, 1987). Great efforts were made at the start of the Decade by UNDP, WHO and several major bilateral donors to assist developing countries with the preparation of Decade Plans and of project documents for submission to donors, and to mobilise donor support for water projects. Even were these initiatives to be repeated, there is no reason to believe they would be more successful the second time around.

Some regions, and some countries in particular, are already heavily dependent on external funding for water supply investments. In Africa,

external funds accounted for some 75% of sector investment in 1985, and a similar figure applied to the least developed countries in the world as a whole (WHO, 1987). This dependence is likely to continue, but donor funds are unlikely to meet the increasing requirement for recurrent expenditure, to maintain and operate the increasing numbers of water supplies which they have helped to build. If the necessary funds to meet recurrent costs are not raised from local sources, they are unlikely to be raised at all.

iii. Increased investment by national governments

The tide of monetarist thinking which has swept through the capitals of Europe and North America did not stop at the Tropic of Cancer. As the high oil prices and ready loans of the 1970s gave way to the high interest rates of the 1980s, they precipitated severe foreign exchange crises in most of the developing countries, and the strict tutelage of the IMF has taught many of them the hard lesson that the linkages between public spending and the foreign exchange deficit are closer than they had imagined. Austerity and retrenchment are evident in the budgets of most developing countries today. Capital expenditure is the first to suffer, particularly in social sectors such as health, education and water supply. Increased government investment in water supply is indeed a remote prospect in all but a privileged few developing countries.

iv. Increased cost-recovery

From the foregoing it is evident that the recovery of at least a part of water supply costs from the users is practically the only option offering a possibility of increasing the funds available for the sector, whether to permit an increased rate of water supply construction or to meet the increasing recurrent expenditure requirements of operation and maintenance.

There is also an important equity argument for cost recovery, which has been succinctly stated by Laugeri (1987). It is often concealed

beneath polemical statements that access to water is a right and should be free. Laugeri suggests that the premise should be re-phrased, to state that safe water as a public commodity should by rights be available to all, in most developing countries, where full coverage is far from being attained, the supply of free water to any given consumer implies that the service will not be extended to others who have equal right to it.

1.5 HOW MUCH TO CHARGE?

To concede that there is a need in principle for cost-recovery in the water supply sector is far from a definition of policy. There is ample room for debate, and there is far from a clear consensus, on how much should be charged for water. Reasonable arguments can be made for at least five broad policy options in this regard.

(a) recovery of operation and maintenance (O&M) costs

(b) recovery of O&M costs plus amortization of past investments

(c) full marginal cost pricing

(d) tariffs sufficient to guarantee liquidity of the water enterprise

These options are considered below.

(a) Recovery of operation and maintenance costs

When water supply construction costs are met by donor grants earmarked for that purpose and not subject to a country ceiling, it might be argued by the recipient government that the opportunity cost of these moneys is nil and hence that there is no economic case for their recovery.

A more general argument rests on the important externalities of the sector. These are the benefits of water supply which do not accrue solely to the consumer, such as the availability of water for firefighting. To these may be added those benefits, particularly health benefits, which although accruing to the consumer, are not perceived as such, or given their true value (Briscoe, 1985). Consumers may not be prepared to pay at full cost for consumption at the level required for full achievement of these benefits, so that marginal cost pricing would produce a less than optimal consumption pattern.

A more extreme position was taken in 1986 by the House of Commons Select Committee on Transport in its report on toll bridges in the United Kingdom (Cooper, 1986). It argued that, once an investment had been made in an item of public infrastructure, and as long as spare capacity was

available, any charge for its use would tend to deter the public from using it as fully as they might, and so diminish its cost-benefit ratio. Water supplies, like toll bridges, are a "lumpy" investment and in many cases are not used to full capacity after they have been built or extended, so that the same argument might be deemed to apply to them.

(b) Recovery of O&M costs, plus amortization of past investments

In developing countries, however, and particularly in urban areas, water supply capacity is often the principal constraint on demand. Roughly half the urban water supplies in the Third World function intermittently (Cairncross and Feachem, 1983) because they have insufficient capacity to maintain pressure for 24 hours a day. Excessive use of cheap water is then at the cost of sacrifices by other consumers.

Moreover, the opportunity cost of investment funds is rarely zero. The availability of external grants and loans is frequently subject to intersectoral country ceilings, so that investment in water supply is at the cost of other sectors. Whether or not this applies, even soft loans must eventually be repaid.

In these circumstances, it could be argued that the cost of these investments should be passed on to the consumer. However, this argument implies a responsibility of the consumer to pay for the service provided, and not as it will be provided to other consumers in the future, so that amortization levels would be based on historic and not future levels of investment. This, after all, is the price which would obtain under conditions of free market competition (Laugeri, 1986).

(c) Full marginal cost pricing

Neither of the two previous options can be expected to generate significant funds for a more rapid extension of water supply coverage, the case for which was set out in Section 1.4 above. For this it would be necessary that the charge for each household served or for each cubic metre

of water supplied should be related to its marginal cost. That is, the cost of serving each additional household or supplying each further cubic metre of water. It is the policy of several financing agencies, particularly the World Bank, to encourage such full marginal cost pricing.

There are difficulties in defining the marginal cost for a given water supply system because a large component of it depends on investments which may not have to be made for many years. The form such investments will take (and hence their cost) may not yet be known, and there is room for debate regarding the interest rates which should be used to discount them to a present value. The problem is further discussed by Saunders et al. (1977). The view that marginal cost pricing will encourage "economically efficient use" (World Bank, 1980) begs the question of economic efficiency for a commodity which, for those most likely to waste it, has an almost imperceptible cost, but which provides significant externalities for those who can least afford it (Carruthers, 1972). Nevertheless, the economies of scale in water supply systems mean that water tariffs based on long-run marginal costs usually generate substantial cash flows, which are then available for further investment.

(d) Tariffs to guarantee liquidity

In practice, water charges are not usually paid directly to Governments, but to public or private bodies which often enjoy a certain degree of financial autonomy. The level of charges may be subject to governmental approval or control, but in the first instance it is normally the water supply agency which proposes the level of charges which it hopes to recover. Its position may lead it to have rather different objectives in this matter from the central government, but the practical question of its financial viability, once its constitution has been determined, is certainly of public interest. Thus there is often a strong case for setting water rates at a level adequate to guarantee the financial

viability (and, in many cases, the liquidity) of the water supply agency.

A water charging policy based purely on costs assumes that savings accruing to the water agency are not lost by inflation, nor to irretrievable accounts such as the Treasury, although in practice such losses frequently occur. In addition, there is normally a certain percentage of consumers from whom charges are not collected, however diligent the water agency may be. Moreover, some allowance must be made for the length of time it takes for increases in water charges to receive government approval when the old rates have been overtaken by inflation.

These factors will in many cases cause a water tariff based on costs to provide less revenue to the water supply agency than it requires to meet its financial obligations. In many countries, borrowing by water supply agencies is difficult or (as in the United Kingdom) subject to stringent government controls. In such cases, water revenue must be adequate to guarantee not only the viability of the agencies in the medium term but also their liquidity in the short term. In one case, it was found that this implied a level of charges 10-30% higher than one based strictly on costs (van der Mandele, 1987).

1 6 MEASURING THE DEMAND FOR WATER

Whatever the policy option chosen for cost recovery, there are clearly strong reasons why communities should pay a large proportion of the cost of their water supplies. However, the cost of a water supply depends on the level of service provided and the quantities of water consumed, so that the most appropriate design of water supply for a given community will depend on its willingness to pay for it; that is, on the demand for the various levels of service and consumption, each at the corresponding price. The choice at the margin between one level and another will thus depend on the elasticity of that demand. As Briscoe (1984) has shown using a simple, idealised model, the elasticity of demand is the item of information which must be known most precisely in order to select an appropriate and affordable level of water supply.

A decision on the gross proportion of costs to be recovered still begs several important questions. Large (and usually wealthy) consumers may be charged more than the average rate, to prevent waste and so that the surplus can be used to cross-subsidise the poorest members of the community or those using a minimum "lifeline" level of service. Water charges may be based pro rata on the measured quantities of water supplied, or alternatively the cost of water may be recovered in the form of a flat water fee, possibly based on the level of service, the house value, or some other assessable indicator of likely water consumption. For these decisions also, an understanding of the elasticity of water demand is an important input.

Demand, in the context of water supply, can be understood in two senses. On the one hand it can refer to the number of households choosing a given level of service (for example, house connections or standpipes), but it can also be understood to mean the quantity of water consumed at the prevailing service levels and prices.

Some data exist on the proportions of households in low-income communities opting for particular levels of service, and on the way this demand is affected by price Much of this "willingness to pay" information has been collected by development banks and others in the context of feasibility studies for water supply projects. The effect of water metering, and of different unit prices, on water consumption has also been studied, but only in the context of industrialised countries such as the United States or the United Kingdom. However, the effect of the water price on the quantity of water consumed by low-income populations in developing countries has not previously been studied, in spite of its importance for cost recovery policy. A comprehensive literature search by the World Bank (D M de Ferranti, personal communication) brought to light not a single field study of this kind.

In the few published studies from developing countries where separate consumption figures are presented for groups paying different prices for water (e.g. Bannaga, 1977; Adrianzen and Graham, 1974) it is not possible to derive an estimate for demand elasticity because the groups are not comparable; they have different income levels or different types of water supply service.

Assessments of willingness to pay, and hence of the elasticity of demand, can be made in two ways. The first, the "conditional" approach, is to ask potential consumers how much they would be willing to pay for different levels of service. An obvious difficulty with this method is that the answers may be biased in several ways; the respondents may not be accustomed to answering hypothetical questions, may answer in such a way as to finish the interview as soon as possible, or may give deliberately false replies with a view to pleasing or impressing the interviewer, or to obtaining a water supply at the cheapest possible price (Whittington et al., 1987a). A decade ago, the World Bank (1976) concluded that such

surveys were "less than useless". In recent years, the conditional approach has been used in industrialised countries to assess the benefits of public services, and the method has been somewhat refined (Birdsall and Chuhan, 1983). However, it is not suitable for assessing the affect of price on quantity consumed, because most consumers are unable to state accurately how much water they use at present, and still less how much they would use under hypothetical circumstances.

The second, "empirical" approach involves the investigation of existing arrangements and practices. This requires the collection of data on who has actually chosen to install house connections, who has opted to use standpipes, and so on, and at what cost. The method can be extended to include measurements of the quantities of water used.

The chief weakness of the empirical approach is that a given level of service or price may not exist in the community or that two levels to be compared do not exist in comparable groups. However, the existence of water vendors in many low-income communities creates an opportunity which is absent in the markets for many other goods. The price charged at the consumer's door by these water sellers of the informal sector is usually related to the distance over which they have to transport the water. Thus households at different distances from the water source often pay different prices for water, although there may be no other difference between them.

The present study was designed to take advantage of this opportunity Low-income households were interviewed and observed, in order to analyse the effect of water vending on their consumption and expenditure. In particular, the effects of price and other factors on their water consumption were studied, with a view to making an assessment of the elasticity of their demand for water for domestic purposes.

1.7 WATER VENDORS

The practice of water vending is very common in developing countries and is a subject worthy of study in its own right. In a brief survey, Zaroff and Okun (1984) found it to be prevalent in rural and urban areas throughout Asia, Africa and South America, and to serve an average of 40% of the households in the 12 low-income communities which they studied in detail. In half of these communities, the cost of water amounted to one fifth or more of the income of a typical household. Briscoe (1985) has estimated that water vendors serve 20 to 30% of the urban population of the developing world.

It has been estimated that, in a variety of settings, money paid to water vendors accounts for a large share of the sector's income (Laugeri, 1987). In one of the few detailed field studies of water vending, Whittington et al. (1987b) found that the total sum paid to water vendors amounted to twice the revenue accruing to the water agency. Their existence is an indication of a demand unsatisfied by the formal sector provision, which the water supply agency could very probably meet at lower cost and to the benefit of both consumers and suppliers. For example, it was the observation of water vendors in Abidjan, Cote d'Ivoire, which led the city's water supply agency to improve its service to compete with them, and hence increase its revenue (Lewis and Miller, 1987).

Some have gone further, and advocated the study of the constraints under which vendors operate, with a view to providing assistance to render their service more efficient (Briscoe, 1985) or more hygienic (Antoniou, 1980; Zaroff and Okun, 1984). It might appear that the water vending systems of the informal sector involving transport by truck, by animals or on people's backs, are hopelessly inefficient by comparison with formal water supply systems using pipelines. However, the fact remains that, for all their efficiency, the formal systems still fail to serve a quarter of

the population of a typical tropical city, and the shortfall in service is largely made up by vendors. Compared to further funding for formal water supply construction, an intervention to increase the number and efficiency of these vendors might produce a more rapid and replicable improvement in the standard of service provided to their clientele. Since this clientele consists mainly of the urban poor, they would be the ultimate beneficiaries. The intervention could thus be an effective form of aid to the poorest. However, the engineering, financial, economic and social aspects of vending systems have hardly been studied at all (Okun, 1982). It is therefore impossible to judge the feasibility or most suitable means of providing support for them, without first studying them in the field.

A secondary objective of the present study, then, was to document the working of informal water vending systems in the Sudan, particularly regarding their financial and social aspects.

II THE STUDY

2.1 WATER IN SUDAN; RURAL AREAS

Sudan, with an area of 967,500 square miles, is the largest country in Africa (Figure 6). The North has a very arid climate, with an average annual rainfall of only 160 mm in Khartoum, and 110 mm in Port Sudan. The humidity falls progressively to very low levels during the first six months of the year, while temperatures of 45°C are common during the summer months of April to June. The result is a high evaporation rate that reduces the yield of open reservoirs and increases the water requirements of the country's 21 million population, and of the animals they keep. The country's total drinking water requirements for human and animal populations have been estimated at nearly one million cubic metres each day, of which only 20% were met by existing water supplies (Mohammed, 1981).

The low rainfall and poor water yields of the prevailing geological formations make alternative water sources hard to find or develop, so that it is hardly surprising that 60% of the population live along the banks of the Nile. Where river water is not accessible, water sources include shallow wells, irrigation channels and natural and man-made storage areas in addition to boreholes, usually referred to as water yards. A water yard consists of a borehole with pump and an elevated water tank surrounded by a fence and fitted with taps.

The operation and maintenance of rural water supplies, in addition to the siting and drilling of new boreholes, has recently been made the responsibility of the National Council for Rural Water Resources Development (NCRWRD). Previously left to the Regional Governments and Rural Councils, water yards have fallen into disrepair.

For the determination of the eligibility of individual communities to receive water supplies, the country is divided into three broad regions

taking into consideration the availability of natural resources as well as social and economic factors (Mohammed et al., 1982). These are:

(i) areas under irrigation,

(ii) semi-desert rainland,

(iii) savannah region.

Villages in need of a water supply are rated on a points system, the total points gained by each site determining its priority and the possibility of its being included in the annual programme. Points are allocated as follows:

	%
number of people	40
number of livestock	30
nearest water source	10
capability of area	10
season of study	10

Spatial and managerial problems in administering the water yards in Sudan have led to problems with operation and maintenance. Running costs, particularly fuel and repair costs, are seen by most rural dwellers as the responsibility of the Government. However, active local councils or water committees can ensure the continued running of a water yard, once the confidence of the people is gained. Contractors are often employed to control the administration of water yards, the conditions being that the contractor provides petrol and collects water rates, while the Government pays the salary of the pump operator and carries out maintenance.

Water is purchased by volume at a water yard, according to a water tariff which varies according to the region. At the water yards in Kassala region, for example, the NCRWRD charges an average of LS 0-55/m^3 (ie. LS 0-01 per 4 gallon tin). Water vendors are charged LS 0-02 per tin and livestock as follows: horses and donkeys - 0-03/head/day, cows -

0-04/head./day, sheep and goats - 0-02/head/day, camels - 0-08/head/day. It has recently been calculated (personal communication, O.M.Taha, Executive Director, NCRWRD) that the present water charges in Gedaref area are enough to cover operation and maintenance costs of the 40 water yards in the region. However, the actual amount of revenue collected will depend on many factors including: the location of the water yard; the mechanical condition of the pump and engine; the availability of fuel and oil; the density of population and domestic animals around the water yard, and, of course, the yield of the borehole.

Continuous pumping for 24 hours, producing an average of 400 gallons/hour (12,000 gallons/day) provides the financial justification for installing a water yard at a borehole (Mohammed et al., 1982). However, in the rainy season, the existence of natural depressions and other water sources which are accessible free of charge reduces the demand for water at the water yards. This can lead to their closure, and complete loss of revenue, for 3 to 4 months of the year (Personal communication, Hashim Youssef el Hag, NCRWRD Director General).

The proportion of the rural population served for at least part of the year by water yards varies from region to region, but it is clear that, on the whole, it is only a minority. This is illustrated by data collected by Mohammed (1981), and presented in Tables 2 and 3 below. Three communities were studied with regard to water collection, use and management: Khartoum Province, Gezira and East Kordofan, representative of riverine settlements, irrigated areas and traditional communities, respectively.

Table 2. Percentage of households using different types of source in the dry season (n = 1000)

Source	Khartoum	Gezira	E. Kordofan
Boreholes (wateryards)	22	10	70
Shallow wells	20	9	23
Filters	-	14	-
Hafirs (wet season)	5	-	7
House connections	34	31	-
Canal (wet season)	2	12	-
Standpipes	20	24	-

Table 3. Percentage citing each reason for using the main source (n = 1000)

Reason	Khartoum	Gezira	E. Kordofan
Only source	8	23	44
Near to the house	36	13	39
Easy to get water	15	13	9.5
Cheap	22	-	7.0
Clear (healthy)	18	35	2.5

Table 2 shows that while large numbers of households use improved sources, a substantial number also resort to canals and shallow wells which are unimproved. Reasons for using the various sources are varied (see Table 3).

35% of consumers in Gezira chose their main source because it is clean and healthy, reflecting their greater awareness of the relationship between diseases and water. In most other areas, however, there is in practice no

opportunity for choice between sources or, if there is, choice is made for reasons of convenience and accessibility (especially proximity to the house) rather than water quality or health considerations.

Perceptions of water quality vary according to the sources available in the region; communities whose main source is a muddy hafir (open reservoir) or rahad (natural depression) are less likely to be concerned with such qualities as colour and taste as it is often their only source and so their expectations are low. Moreover, as Jahn (1981) has found, such communities in Sudan have developed a sophisticated knowledge of water treatment methods over the years. Jahn also noted, looking at water use along the Nile in Sudan, that wells are often avoided because of fluorosis and other problems associated with the high concentrations of mineral salts in groundwater in many parts of the country.

Water consumption and use in North Kordofan has been studied in detail by Mohammed et al. (1982). In their study area the water source most used was the wateryard (39%) followed by shallow wells (27%) and hafirs (20.8%). In the wet season, the picture is slightly different. During this season other sources can be used, such as ponds and shallow open wells (jamams) dug in stream beds, but still the wateryard is the dominant source used by 34.9% of the respondents, followed by ponds (24.1%) and the artificial open storage areas known as hafirs (18.4%). The wateryard retains its dominance in this region because most of the area is covered with sandy soils which are too permeable for natural ponds to form.

In another survey in the region, Mohammed et al. (1982) found that 28% of their respondents reported buying water from water vendors. Water vendors in North Kordofan are of several types. Lorry owners transport water to cisterns in the villages. Cistern owners, usually local merchants, sell it directly to consumers or to the owners of donkey carts who in turn sell the water door-to-door. The cisterns are of concrete,

built underground and can hold 10 to 60 m^3 of water. The water to fill them is transported by lorry, each lorry capable of carrying 30 drums of 200 litres. A survey by Cafod/Sudanaid (1986) in three villages in the region found that the prevailing prices were as shown in Table 4 below. The water had originally been purchased for LS 0-75 a drum at a borehole in a nearby village, controlled by a local Water Committee.

Table 4. Water prices in three villages in North Kordofan

Price in LS	Village		
	Mineim	Hineibat	Talib
Per drum, from lorry	4-50	5-00	7-00
Per drum, from cistern	5-00	7-00	8-00
Per safiya*	0-59	0-70	0-70

* (1 drum = 12 safiyas, approx.)

These water charges are often paid in kind - cereals, groundnuts and gum arabic are examples. In the dry season, water prices are said to rise to LS 2-00/safiya, and in some areas farmers estimated as much as 50% of their cash income would be spent on water. Their dependence on vendors has increased of late, as a result of the recent drought. Because of the high cost of water to the consumer from vendors, the amounts bought are rather small. Respondents gave many reasons for buying water from vendors. The most common reason cited was lack of transport, and that no family member was available because the children went to school.

2.2 WATER SUPPLY IN SUDAN: URBAN AREAS

Sudan, like most other African countries, has seen very rapid urban growth in recent decades. In the last few years it has been further increased by the civil war in the South, the drought in the West, and by refugees from famine and war in Ethiopia and Eritrea. Most of this growth has been concentrated in the three cities which together constitute Greater Khartoum. separated by the Blue and White Niles above and below their confluence, these are Khartoum North and Omdurman, in addition to Khartoum itself. Since 1980, their combined population has grown from just over one million to over 1.8 million (Khaddam and Salih, 1986).

Water supply has benefited relatively little from investment, a situation reinforced by the priority accorded to power by the Public Electricity and Water Corporation which, until recently, was responsible for both commodities in the Three Towns (Lusk, 1982). The piped water supply dates from 1925, when the first treatment plant opened at Burri. Four more plants followed in 1930, 1953, 1964 and 1979. The design capacity of the five water treatment works is 160,000 m^3/day. Water is drawn from all three Niles, treated and chlorinated at 0.5 - 1.00 ppm. In addition, there are 40 boreholes, which are designed to provide about a third of the capital's supply. These have now been improved, with a total target capacity of 80,000 m^3/day. These boreholes, ranging from 105-120 m in depth, are fed by the Nubian Aquifer underlying the whole area.

Problems with water quality arise from ancient pumps, silting and rusty filters, as well as lack of maintenance of the automatic chlorinators. Quantity is more of a problem. Since May 1982, the amount supplied has increased from 110,000 m^3/day to 260,000 m^3/day, but potential demand is increasing and has been estimated at 500,000 m^3/day (El Sammani et al., 1986). As a result, daytime pressure is so low in some areas that a ground-level mains tap will often be without water. Ironically,

electricity shortages are one of the main causes of low pressure, as most of the Water Corporation's pumps are driven by electric motors.

The supply was designed for a single storey city, but high-rise buildings, depending entirely on pumps connected directly to the mains, have distorted projections and reduced flow to the poorer areas. Unforeseen urban migration has added to water demand. Future potential supplies are thought to lie in ground water resources, being cheaper than treatment plants. However, reliance on septic tanks and pit latrines as sanitation disposal methods may lead to contamination of the ground water since Khartoum's municipal sewerage system serves only 5% of the urban areas.

There is a large deficit in the City Council's annual budget due to the inadequacy of present sources of revenue to meet the needs. The Electricity and Water Corporation has been split into two corporations, responsible for urban water supply and for electricity respectively. However, the Urban Water Corporation is currently running at a loss. Water charges are often not collected and the tariffs are often so low as to be of little or no use in contributing toward the upkeep of the system.

The water tariffs currently charged to domestic consumers with house connections in planned urban areas vary from region to region. They are shown in Table 5 below, in Sudanese pounds.

Table 5. Water tariffs charged by the National Urban Water Corporation.

Region	Khartoum	Central	Darfur	Kordofan	Eastern	Northern	Southern
Fixed monthly charge	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Rate/m^3	0.25	0.25	0.50	0.40	0.25 - 0.50	0.25	0.35

Even the fixed charge is not as constant as might appear from the table. For example, in Gedaref, a town in the Eastern region, the fixed rate varies from LS 2-50 to LS 10-00 according to the class of housing and size of connection.

With a view to increasing the revenue of the Urban Water Corporation, it is proposed to introduce new tariff rates which will apply throughout the country, but which will be related to the class of housing area in which they are charged. These new rates are shown in Table 6. In addition, since many water meters are broken, it is proposed that standardised monthly consumption figures be used to calculate charges. This should also reduce administration costs and the number of uncollected charges. These figures, based on previous experience, are also shown in Table 6.

Table 6. Proposed new urban water tariffs (LS).

Class of housing area	1st	2nd	3rd/4th
Fixed monthly charge (up to 15 m^3)	20-00	15-00	10-00
Rate/m^3			
15 - 50 m^3	1-00	0-75	0-75
>50 m^3	1-00	1-00	0-75
Standardised consumption (m^3/month)	60	40	15-20

It is noteworthy that the lowest of the assumed consumption figures, for 3rd and 4th class housing, is equivalent to 100 litres per person per day in a five person household. This is not much less than the average per capita domestic consumption of households in the United Kingdom. The higher figures, applied to households of normal size, imply that the

majority of water consumed in 1st and 2nd class housing areas is used for "luxury" purposes over and above normal domestic use, such as the watering of gardens and washing of cars.

On the other hand, the proposed rate of LS 1-00/m^3 for 1st class housing is low by the standards of industrialised countries. It is equivalent to roughly £0.15 sterling per cubic metre, at the rate of exchange prevailing during the study. This is roughly half the average rate charged in the United Kingdom, and lower than that of any country in Western Europe. In view of the much richer water resources of European countries and the difficulty of treating the turbid waters of the Nile, one might have expected Sudanese rates to be higher, not lower.

The current charge per m^3 from public standpipes is LS 0-50/m^3. About one in ten of these is operated by the Urban Water Corporation, which often leaves them unattended so that consumers collect water without charge (Antoniou, 1979). The majority, however, are run by private contractors who pay a LS 100-00 deposit for a licence to operate. It is proposed to increase the standpipe rate to LS 0-75/m^3.

The new tariff scheme was due to come into operation in January 1987, but at the end of our field work in March 1987 it was still awaiting approval from the Council of the Urban Water Corporation. Even when water charges are increased, and if they are collected more effectively, the Urban Water Corporation will need Government finance to provide services to new areas. It has been estimated that some 60% of the cost of infrastructure investments in Sudan is in foreign exchange.

2 3 SQUATTER AREAS

Among the chief sufferers from the inadequacies of urban water supply in Sudan are the urban poor. Antoniou (1980) defined urban poverty groups as those in households earning less than LS 500 per annum, and estimated that they constitute 24% of the population of Greater Khartoum. He found that 70% of these lack reasonable access to water and are thus dependent on water vendors. Their poor access to water is largely due to the fact that a substantial proportion live in squatter areas.

A squatter locality is defined as an area whose inhabitants have no legal right to the plots on which they live. Development by illegal settlements in Khartoum began in 1960, with over 30,000 squatters in Greater Khartoum by 1969 (Taha, 1987). This number increased during the early 1980's due to the increasing migration to the capital, particularly from Western and Southern Sudan. In 1982 there were 96 squatter areas in Greater Khartoum with a total population of 600,000. Figure 7 shows the locations of the principal areas where squatters are found.

All but a tiny fraction of the land in Sudan is state owned. The provision of plots for housing development for the rich as well as the poor, throughout Sudan, remains exclusively a Government responsibility. People obtain their leasehold plots from the Government (in the case of lower income housing, paying a nominal fee for a 30 year renewable lease) in new subdivisions or extensions on the outskirts of urban centres, where infrastructure and community facilities will be provided over a period of time. Only Government has the right to develop new plots. However, due to the limited funds available in recent years, site development has been severely constrained. Consequently, artificially high prices are obtained for plots on a resale basis, and many people seek plot allocation in order to speculate (Antoniou, 1980). To gain access to a residential plot in a planned area, an applicant must fulfil certain criteria. Eligibility is

determined by a points system This system was liberalised slightly in 1986 but it is still biased towards applicants born in the Khartoum area (Taha, 1987).

Illegal occupation of new areas of land is explicitly prohibited by the Unregistered Land Act 1970, and gives the City Engineer's Department the right to evict unlawful occupiers. Since 1975, a document certifying legal ownership of the land is required by each householder for access to facilities in unplanned areas. Settlers are sometimes given permission to build on land but this does not necessarily entitle them to any facilities.

The lack of legal land tenure in illegal housing areas excludes residents from receiving urban public services such as piped water, electricity, health, transport and security services. However, if local leaders (often tribal sheikhs), and community groups or councils are active, they may be able to influence decisions regarding the provision of these facilities. The upgrading of settlements to "planned" status, often achieved for political reasons, is another possibility. In some cases, self-help committees have, through their efforts, enabled squatter populations to gain access to municipal services. Water supplies have sometimes been obtained by lobbying the Urban Water Corporation, or by the intervention of non-governmental organizations and external donors. However, the formation and action of local committees have been restricted in the past by the Government. When the Nimeiri Government came to power in May 1969, political parties were banned and the powers of elected local councils were suspended. The system of native administration introduced by the British in the 1920s, by which powers were granted to tribal sheikhs, was also abolished in 1969.

During the field work for the present study, in early 1987, the newly formed "Sakan Al Ashwai" (Administration for Squatter Areas) in Khartoum had plans to move 50,000 families of illegal squatters to 3 new

"adsorption" areas served with electricity and water supplies. More than half of these would be resettled in Omdurman. The operation would be vast by comparison with the resources and capacity available for it, but would still affect only a fraction of the total squatter population of Greater Khartoum, estimated at 600,000 in 1982.

On payment of LS 140, each family is allowed to build its living accommodation on the land allocated - a plot of 200 m^2. Those eligible must have lived in Khartoum for a defined length of time, be Sudanese nationals in employment, and inhabit unsatisfactory accommodation. Those who are not Sudanese nationals are the responsibility of the Commissioner for Refugees or the Aliens' Office. Many settlers, however, do not meet either of these criteria. Thus, most people inhabiting squatter areas have no real possibility of obtaining a legal title to land.

People living in unplanned areas are not supplied with water by the NUWC (National Urban Water Corporation) since they fall outside the Corporation's jurisdiction. Facilities cannot officially be provided. Even if a community managed to collect enough money for the drilling of a borehole, it would not normally be allowed to go ahead within the unplanned area, although a few communities have successfully got around this rule by arranging for a borehole to be drilled for their exclusive use in an adjoining area with 'planned' status. In general, however, anything that might encourage settlers to stay longer, or attract more newcomers, is discouraged.

Generally speaking, squatter areas are served by vendors using donkey carts. They sell water by the jerry can, at a price which depends on the difficulty of obtaining and transporting it. Typical prices in Greater Khartoum range from LS 7-50 to LS 30 per cubic metre, altough in practice the water is sold in smaller quantities. These prices are 30 to 120 times the rate per cubic metre paid by Khartoum residents with private connections, and 10 to 40 times the proposed new rate for 3rd and 4th class

housing areas (Section 2.2).

Without this informal distribution system, however, the inhabitants' water requirements would not be met. Each donkey pulls a cart consisting of 2 oil drums welded together as one, to give it a capacity of roughly 400 litres. This is supported by a framework attached to the wheel base (Figure 11). Occasionally donkeys can be seen pulling only one barrel. This may be in areas where distances are very great, so that the donkey is not physically able to pull a full load over the distance involved. In some cases, less common in urban than in rural areas, the donkey and cart may be owned by and used for one family, one drum being adequate for an average family's daily requirements.

In February 1987, the Sakan Al Ashwai issued a directive to the water vendors supplying an area in Omdurman, prohibiting the sale of water to the inhabitants. Police were ordered to arrest any vendors contravening this law. Under the 1961 Building Ordinance (revised in 1973), water cannot be sold in such an area since it is held to promote the illegal building of new houses on land designated for other planned uses. The main construction material is mud, which dries in the sun. Water is therefore an essential part of the process.

However, there is no evidence that restriction of the provision of water supplies to unplanned areas has limited the growth of Khartoum's population or of the unplanned areas. Many migrants to Khartoum, interviewed during our fieldwork, stated that their first place of residence was in an established area of the city where facilities are already available although rents are high. The subsequent move to the urban fringe enables a family to build its own house and join people of the same ethnic origin, although the saving in rent is counterbalanced by the high cost of water. Water for house construction, if not available locally, is purchased from vendors.

2.4 STUDY LOCATIONS

Two survey areas were selected in squatter settlements in Greater Khartoum. They were chosen as communities with low but comparable average incomes, unserved by house connections, largely reliant on the services of water vendors and with comparable ethnic composition. In order to be able to study the price elasticity of demand for water, they were also selected as areas where water is sold at widely differing prices. These two locations were Meiyo, on the southern fringe of Khartoum proper, and Karton Kassala, in Khartoum North

In addition, two visits were made to Port Sudan to study water vending there.

Meiyo

Established in the early 1970s, Meiyo is situated ten kilometres south of central Khartoum beyond the Green Belt, an area planted with trees to reduce the effect of dust storms on Khartoum. Its current population is estimated at 70-80,000 with an annual rate of increase of 4.8%. Westerners (from Darfur and Kordofan) make up the majority of the inhabitants, 80% of whom are Muslim. However, a significant proportion have come from areas far to the South of Khartoum, as is shown by the results of a survey carried out by GOAL, an Irish agency involved in maternal child health in the community.

Province or country of origin	Percentage of population
Kordofan	27
Darfur	27
S. Sudan	14
E. Sudan	14
Nigeria	15
Chad	3

The results of the same survey indicate that 20% of the population have been there for over 12 years, that only 12% of the population have settled in the 1st 3 years, and that only 10% of the total have any intention of returning to their place of origin (GOAL, 1987). Possibly due to the long-term nature of this settlement, the Government upgraded the area to 3rd class in February 1987.

Figure 8 is a map of the area, with an overlay showing its division into neighbourhoods and indicating the locations of clusters of survey households.

There are four boreholes in Meiyo, each with an adjacent water tower. One of these had been out of operation for several months at the time of the survey. Of the other three, one is operated as a private concern, providing water for irrigation. Some vendors use this water to serve Hyal Fellata since it is nearer than the alternative, the church-run borehole. The second, drilled by the Islamic African Relief Agency, a local NGO, serves public standpoints (shown in Figure 8). Water vendors do not have access to this source. The water is considered salty and is therefore used mainly, if at all, for washing clothes.

Drilled in 1976 by the Sudanese for the Dutch Government, responsibility for operation and maintenance of the third well (Figure 9) was subsequently handed over to the Comboni Church. Water is sold to vendors at the price of LS 0-50 per donkey cart load of 400 litres. Income from the sale of water at the well is used to pay the overseers (who work in shifts from 6am to 6pm), and also to employ teachers to work in the school. The balance sheet for an average day works out roughly as follows.

Income		LS
1200 carts per day at LS 0-50		600-00
Daily running costs		
Oil	60-00	
Diesel	62-00	
Wages	120-00	
Total		242-00
Net revenue		LS 358-00

The demand for water, and hence the net revenue, varies from day to day, being highest on Fridays, and increases in hot weather.

The church has never used any of its revenue from water for maintenance of the system. However, when GOAL obtained a grant of LS 24,500 from the Netherlands Government to improve it, each of the 18 sheikhs (local leaders) in Meiyo contributed LS 50 to pay for the labour costs.

The constant queue of vendors' donkey carts for filling means that a considerable amount of water is wasted and spilled on the ground, as the valves on the dispenser pipes are left open as they are moved from one cart to the next. After much discussion with the community, it has been decided to fit reducing valves on the tank and to expand the drainage system into a series of canals so that the wasted water can be used to irrigate land for donkey fodder production.

Water delivered to the consumer's door in Meiyo is sold for LS 1-50 per drum of 200 litres, or LS 0-25 per "jos" (One jos is the contents of two four-gallon jerry cans, which together hold 36 litres. One jos is therefore about one-sixth of a drum). The price of water in Meiyo does not vary between parts of the area, nor with seasons of the year.

GOAL has found that diarrhoeal disease is the most common cause of child mortality in Meiyo, accounting for 64% of deaths among children of 5

years and under. Malaria and measles, the next most common, come far behind, causing only 16% and 14% of child deaths, respectively. Diarrhoeal disease was also found to be the most common cause of morbidity. The breakdown of diagnoses among children attending the GOAL clinic in Meiyo in 1986 was as follows:

Diarrhoeal disease	49%
Respiratory infections	27%
Malaria	19%
Measles	4%.

The virulence of all these diseases, and the likelihood that they will lead to death, is greatly increased by malnutrition. In July 1986, half the children attending the clinic were under 85% weight for height, and many were marasmic. Breast feeding is practised by 93% of mothers, but many of them claim that they have insufficient or no breast milk. This may result from the mothers' own poor nutritional status. It sometimes leads them to bottle feed their babies with poorer substitutes such as powdered milk or sugar water. Prepared in unhygienic conditions, these can be a further cause of diarrhoea.

Karton Kassala

Little research had been carried out in this area before the present study, but the high price of water and the ethnic and socio-economic composition of its population, broadly similar to that of Meiyo, made it suitable for choice as the second study area.

About 5 miles from the centre of Khartoum, Karton Kassala is situated near the Eastern extremity of Khartoum North. In 1970, the settlement consisted of about 5,000 houses, built of cardboard, which gave rise to the first part of its name. At that time these housed around 35,000 people, but current estimates put the population at nearly 70,000, with continuing expansion towards the East. A large percentage of the inhabitants are from

the South of Sudan, but there are also significant contingents from other regions. 50% of the households surveyed in Karton Kassala were Christian. In common with the people of Meiyo, many inhabitants of Karton Kassala first live in Khartoum itself on reaching the metropolis, moving to the outskirts to avoid high rents and build their own homes, which are now mostly of mud construction.

Unlike Meiyo, the people in Karton Kassala have not been given permission to build on the land and their houses are thus liable to be bulldozed at any time. The Municipality may authorise the City Engineer's Department to demolish squatter dwellings; this can occur 2 or 3 times a year. Influential speculators have the power to avoid demolition of their properties. This allows them the opportunity of increasing rents, partly due to the fact that other houses in the vicinity have been destroyed and, therefore, demand has increased, and partly because protection from demolition can be virtually guaranteed.

Figure 10 is an aerial photograph of the area, with an overlay showing its division into neighbourhoods and indicating the locations of the clusters of households included in the survey.

There is now no source of water within Karton Kassala, so that the inhabitants are entirely dependent on water transported by donkey cart from one of several sources on the periphery. The canal running along the southern edge of the settlement served as a convenient source until July 1986, when it was shut off. Later in the year, and shortly before the commencement of the survey in the area in early 1987, the borehole servicing Karton Kassala was also shut down, ostensibly to prevent further house construction. The logic of this measure is not clear, as the borehole water was not used for building, being twice as expensive as water from the nearest canal. However, some informants spoke of police preventing access to the canal on occasion.

Wahida, an adjoining settlement, is "planned" by the local authorities, and some house connections to the municipal water distribution network have been provided there. Apparently, there was some local resistance to this measure, presumably from a few prominent figures with a vested interest in the water vending trade. Nevertheless, some households with these connections sell water to vendors who deliver it to Karton Kassala. The other existing sources for Karton Kassala are boreholes to the North and West, some 2 km from most households, and an irrigation canal to the East, a similar distance away. Long queues of water vendors' carts build up at these boreholes, because the demand exceeds their capacity (Figures 11 and 12).

The effect of the closure of the canal to the South, and particularly of the area's borehole, was that the price of water doubled, and many people spoke of not being able to eat adequately because there was no water to drink or with which to prepare food.

The progressive escalation of the price charged by vendors for water in Karton Kassala is shown below.

Year	Price per drum (LS)
1984	1-25
1985	1-50
1986	3-00
1987	5-00 - 6-00

Canal water is priced at LS 2-50 - 3-00 per drum. Water prices are not constant over the whole area, but vary slightly, depending mainly on the distance over which the water must be transported.

Port Sudan

A credit scheme for small enterprises is run in Port Sudan by Acord, a consortium of European donor agencies. One in five of the loans is made for the purchase of donkeys and carts for water vending, and this provided an opportunity for further study of the economics of this activity. Two

visits were made to Port Sudan to conduct interviews with vendors and with male and female residents of low-income areas in this city, but time did not permit a detailed survey such as those carried out in Meiyo and Karton Kassala.

Port Sudan's water supply is piped from the abstraction works at Khor Arbaat, 40 km away. The Khor is a seasonal stream, and so reservoirs have been built at the site to provide storage during dry periods. However, the supply is inadequate to meet the demand, especially in summer.

Standpipes, often operated by licensees, therefore provide water for only one or two hours each day, if at all. Many standpipes have a concrete storage area attached for periods of water storage, but most of these are out of use. In fact, most of the standpipes have been closed as the water pressure is never sufficient to reach them.

Those with house connections face similar problems. Many of the wealthier households have built storage tanks beneath their houses, but most of those in squatter areas do not have sufficient capital to do this, or do not receive any water even in the rainy season. One resident interviewed in the squatter settlement of Salalab had a private connection which had provided no water for two years.

There are some boreholes in the town, but the water from these is salty, and is normally only used to wash clothes. Local surface water sources are not a feasible alternative, as the rain, when it does come, washes down from the Red Sea Hills in a torrent which it has not so far been possible to contain in any way, following a flow path which varies from year to year and frequently destroying large numbers of squatter houses.

Thus, most of the low-income areas of Port Sudan are entirely dependent on water vendors selling water from the few functioning standpipes. Most vendors use donkey carts similar to those in Khartoum but

some men also sell water which they carry for limited distances in a pair of 20 litre containers suspended on a yoke. In the outlying settlements, water is sold from privately-constructed concrete reservoirs filled by tanker trucks, which bring water from the standpipes in the town. Canals are also used, water being carried in skins.

The price of water sold by vendors in Port Sudan varies during the year. It increases considerably in the dry season because of the higher price of donkey fodder and the increased queuing time at the standpipes. When the town was visited in March 1987 the prevailing price was at the lower rate of LS 6-00 per drum of 200 litres. Salty water from boreholes is sold at a constant, much lower price, but is not distributed by vendors.

2.5 SURVEY METHODS

In addition to a large number of informal interviews conducted in Arabic, two methods were used to conduct systematic surveys in Meiyo and Karton Kassala These were:

- household observation, and
- questionnaire.

Household observation was used to collect reliable information regarding water consumption, water prices, and the number of people per household. Detailed questionnaires were used to ascertain levels of income, and thus the percentage of income spent on water, and the division of water use within the home, as well as several other variables. For example, questions were also asked regarding household size and total water consumption in order to check for consistency between the results of the two survey methods. Field workers were initially trained to identify and assess the capacity of the various vessels commonly used for water (Figure 13).

Observers were employed on a daily basis for the morning (6 am - midday) or evening (midday - 6 pm) shifts, noting down quantities, costs and times for each group of 5 households. Each household was observed over 2 days. Meanwhile, the female heads of one or two out of each group of 5 households were interviewed. The questionnaire was split into morning and afternoon visits, with a second day being used in particular to provide extra data apertaining to water use in total, and its subdivision between the various purposes for which water is used.

Based on the experience of similar surveys elsewhere, a sample of 100 household-days of water consumption (that is, 50 households observed over 2 days each) is needed to provide an adequate indication of consumption levels (Cairncross et al., 1980). In Meiyo, 116 households were observed, giving 232 household-days of observation data. In Karton Kassala,

observation throught the day was not possible as it was not possible to live within the study area during the survey. Since the interview results from Meiyo showed good agreement with the questionnaire responses, only the questionnaire was used in Karton Kassala, but an increased number of households was interviewed.

Questionnaires (Appendix A) were administered in Arabic with the help of local women. This worked well since they were indigenous to the areas surveyed, and even information on sensitive topics, such as levels of income, was freely given. 27 women were interviewed in Meiyo, and 45 in Karton Kassala. For 15 of the latter, a shorter questionnaire was used so that income data were sought only from the initial 30. A summary of the principal data collected by the questionnaire surveys is presented in Appendices B and C.

2.6 HOUSEHOLD ECONOMY IN THE SURVEY AREAS

Income

Wage levels in Sudan are very low, as can be seen from the examples in Table 7, based on responses by our interviewees. Many households therefore have more than one source of income. Foreseeing some difficulty in collecting reliable information on all these, the questionnaire included questions relating to the type, size and ownership of the house, and to the possession of items such as radios, bicycles, and livestock, as indicators of the socio-economic status of each household. In the event, direct information regarding all of the sources of income was readily forthcoming so that there was no need to use the proxy indicators to study income elasticity of demand.

Table 7. Typical wage levels in Khartoum

Occupation	Wage (LS)
shop assistant	150/month
driver	150/month
janitor	150/month
factory worker	80-150/month
machine operator	180/month
merchant	500-1000/month
soldier - newly joined	190/month
soldier - average	200/month
soldier - in war zone	350/month

Some of the survey results indicating the relative socio-economic status of the two communities are summarised in Table 8.

Table 8. Comparison of the two survey sites with regard to socio-economic indicators.

	Meiyo (n = 27)	Karton Kassala (n = 30)
Percentage of households:		
- receiving remittances	32	76
- owning radio or cassette	62	33
- owning bicycle	31	30
- renting accommodation	38.5	20
- with latrines	85	57
Average household income (LS/month)	309	393
Average household size	7.3	8.3
Average number of children under 14	2.9	3.8

Many of the men in both study areas had been unable to find work locally. A few join the army, but many travel abroad to Saudi Arabia or Iraq in search of employment, and send remittances to their households in Khartoum. Small scale commerce provides another source of income. The selling of coffee and tea, once the costs of charcoal, sugar etc. have been accounted for, yields only a few Sudanese pounds a day. Women selling peanuts, peanut butter, vegetables and kisra (a pancake made with dura flour) can make LS 10 - 20 per day. Some men sell sugar cane, water melons and other items.

However, a more important local source of income is the brewing or distilling of alcoholic drinks for sale. In spite of the Sharia law currently in force in Sudan, these are widely produced (mainly by women) and consumed (mainly by men), and their production accounts for a considerable amount of water consumption. The principal products are 'marisa' which is a flour-based beer, and 'aragi' which is a distilled spirit based on sugar and dates.

(a) Marisa. The ingredients are mixed, heated over wood or charcoal in a 200 litre drum and allowed to ferment before sale. The cost of a brew

varies from LS 20 - 30 per drum. A typical breakdown is as follows.

Item	Cost (LS)
flour	10-00
yeast	7-00
water	5-00
wood	3-00
Total	25-00

This is sold for LS 25 - 55 per drum, yielding a profit ranging from LS 5 - 25. Most women in both survey areas reported that, due to the limited market, they brewed only 2 or 3 times each month. Net monthly incomes reported from sales of marisa ranged from LS 40 to a maximum of LS 200 a month, the latter requiring the production and sale of two drums a week. Marisa is also frequently used by the Southern Sudanese as payment for the building of a new house. Kanimoroo (Sesame beer) is also brewed, albeit very occasionally.

(b) Aragi. One 200 litre drum of water is required to fill a jerry can with 18 - 20 litres of aragi. Aragi can bring a greater profit margin than marisa, but is often sold outside the area through middle men, so that much of the potential monetary gain is lost to the producer. A typical cost breakdown for one jerry can is as follows:

Item	Cost (LS)
10 lbs sugar	25-00
2 tins dates	24-00
yeast	35-00
water (1 drum)	5-00
wood	12-00
Total	101-00

With a sale price of LS 180-00 per jerry can, the typical net profit is about LS 80-00. Aragi is distilled typically once to four times a month.

An example of the use of multiple sources of income was provided by a young woman in Karton Kassala. Her husband, a soldier, earned a larger than average salary of LS 500/month. She supplemented this as follows, to help support the five members of her household:

Marisa Profit LS 26 per brew of 300 litres.
Brews twice monthly, giving LS 52/month.

Aragi: Profit LS 150/distillation (Once monthly).

This brought the household's total income to LS 700/month.

Expenditure

House rents in both Meiyo and Karton Kassala ranged from LS 20 - 30 per month for one room to LS 50 - 60 for 2 - 3 rooms. However, as shown in Table 8, the majority of households in these areas owned their own accommodation so that most paid no rent. Unfortunately this saving was offset by the high cost of water, which accounted on average for 17% of household income in Meiyo, and a remarkable 56% in Karton Kassala. The vast majority of the remainder was spent on food, and on the fuel to prepare it.

This is illustrated by the case of Harim, a woman in Karton Kassala, most of whose income came from the sale of fish, lentils, bread etc. from a shop in her compound. Thanks to the skills she had acquired through her trading, she was able to compile for us an account of the expenditure of her household of 6 during one week (Table 9) In this case, food and fuel accounted for 68% of household expenditure and water for over 26%, leaving less then 6% available for any other items. Nor was this an unusually poor household; the total weekly expenditure of over LS 130 implies a monthly income of over LS 500, above average for Karton Kassala.

Table 9 Typical weekly expenditure for a family of 6 in Karton Kassala

Item	Unit cost (LS)	Quantity	Total cost (LS)
Food:			
flour	15-00/tin	1 tin	15-00
"sharmoot" (dried meat)	13-00/kilo	500 g	6-50
onions			8-00
"salsa" (tomato paste)	1-00/tin	6 tins	6-00
sugar	30pt/1b (from coop) 3-00/1b	1 lb 3 lb	0-30 9-00
oil	2-50/1b	3 lb	7-50
"weka" (dried okra)	4-00/measure	1 measure	4-00
salt			1-00
"chattah" (dried red chilli peppers)			3-00
cumin			1-00
coriander			1-00
black pepper			1-00
tea	6-00/lb	8 oz	3-00
bread	15-20pt/loaf	20	3-50
lentils	6-00/kilo	1 kilo	6-00
rice	3-00/kilo	1 kilo	3-00
tomatoes	3-00/kilo	1 kilo	3-00
Fuel:			
charcoal	1-00/bag	7 bags	7-00
Water:	5-00/barrel	7 barrels	35-00
Others:			
nursery school	1-50/month/child	1 child	1-50
soap	50 pt (laundry)	4	1-60
	1-50 (toilet)	3	4-50
TOTAL WEEKLY EXPENDITURE			LS 131-40

The dominance of food, fuel and water in household budgets is borne out by data collected from three households in squatter areas of Port Sudan (Table 10). Since other items of expenditure are frequently incurred by the male heads of households, this dominance becomes even stronger when attention is focussed on that part of the household income which is at the disposal of their wives.

It is to be expected that the wives of male breadwinners in Khartoum do not receive all their husbands' earnings, and it is certain that they do not always receive them immediately, or when they most need them. Only a minority of favoured zabuun customers obtain credit from a water vendor, so that most women must have ready cash and storage capacity available at the moment the vendor calls if they are to buy water. The vendor's visits are not always predictable, and there are times when a vendor is not to be found. Thus the need to keep money ready ties up household funds which could otherwise be used for different purposes.

In the circumstances, it is not surprising that 30% of the women we interviewed considered that the biggest problem with their water supply was the inconvenience of not being able to buy water when they wanted it. On the other hand, practically all of them said a tap in the home would solve their problems. The chief advantage attributed to house connections was the ability to pay monthly for them at a lower rate, and thus avoid the need to find money daily to pay a vendor

Many women said that, if water were available more cheaply, they would spend the money saved on food, particularly milk for their children, and indeed the only major item in most household budgets which could be sacrificed to make room for the increasing cost of water is the household's expenditure on foodstuffs and, to a lesser degree, on the fuel required to prepare that food. Moreover, a household's income is the principal limitation on its diet. Several women stated that they would prefer to

cook more than one meal a day, but could not afford to do so.

The majority of families eat once a day at about 3 pm, making do with bread and tea, without milk, for breakfast. Thus, money saved from expenditure on water is likely to be used to improve the family's diet.

Table 10. Household expenditure for three households in squatter settlements in Port Sudan

Occupation	Monthly income (LS)	Family size	Percentage of income spent on each item							
			Food & perish-ables	Fuel	Water	Cloth-ing	Recre-ation	Trans-port	Health	Educ-ation
Daily labour in docks	180	4	56	8.3	8.3	4.4	5.6	5.6	3.9	2.8
Retail shop	150	8	57	8.6	17	2.6	-	4.3	-	5.7
Mobile worker	200									
Total	350									
Water vendor	200	5	75	11.25	7.5	3.5	4.5	-	-	0.004

(Source: Acord credit scheme client notebooks)

2 7 WATER HYGIENE, QUALITY AND SOURCE CHOICE

Water treatment

The interviewed women gauge a water's quality according to its taste and level of turbidity. Where no contamination is obvious, the water is considered clean. Salty water sources are generally only used for washing of clothes. In general, though, the women surveyed in this study found no fault with their main source of water as regards quality. However, in Karton Kassala, where canal water was also available at half the price of "tap" water, many households were purchasing this in preference. All the women said it was dirty, most only buying if for building purposes and for washing clothes. It is considered dirty because of the visible particles suspended in it. Some women use a coagulant ("shaff") for this water. It is sold in shops and also hawked around the streets. Using a spoonful a day, a teacupful lasts 10 days at a cost of LS 0-50. It therefore adds little expense to the family budget.

Jahn has researched in detail the use of natural coagulants by Sudanese women to clarify water. In one survey (Jahn 1977), she found that on average, coagulant adds 7 - 10% to the cost of water purchased from vendors. She concluded from her field work that this treatment is not carried out for health reasons but because clear water is aesthetically more pleasing, evil smells and visible turbidity being perceived as bad. Religious beliefs that stress cleanliness as part of worship may also influence the degree of purification carried out.

Both "zirs" (porous clay pots) and oil drums are used for water storage, the zir water being used for drinking only. Zirs are also used in houses with private connections, in order to keep the water cool. Each household generally has at least one of each type of storage vessel. 25% of the survey population bought water every 2 days. However, those households tended to be smaller than average with a mean of 5.7 members. In larger

households, the frequency of purchase is often greater due to the limited storage capacity available. It has been suggested that there may be a relationship between the capacity of a dwelling's storage vessels and the water consumption of the household (De Wolfe Miller, 1984).

When water is distributed by donkey, there is a considerable potential for contamination both at source and in the process of transfer to domestic consumers. Contamination within the home is also possible. The longer the water is stored, the greater the chance of contamination within the home, especially where zirs and barrels are not kept covered. The zir water is normally used for drinking only, and is usually protected by placing a tray over the top. The barrel water, used for bathing, washing clothes and dishes, and often for cooking too, is usually left uncovered. However, when the zir water runs out, it is often topped up from the barrel. Utensils used for extracting water from the storage containers may be dirty, and the process often involves contact between the hand and the bulk of the water. Anal cleansing with water after defecation is practised by the Muslims in Sudan. This increases the chance of contamination of food and water, especially if hands are not washed thoroughly.

Straining (through muslin or other cloth) into the zir and leaving water to stand were also practised in Karton Kassala in order to reduce the turbidity of the canal water. The extent to which purification methods are employed is likely to depend to a large extent on the household's place of origin and the quality of water there. For example, the Fur, from Darfur in West Sudan, leave a cloth over the mouth of the zir specifically for the purpose of straining.

Water source choice

In Meiyo, there are alternatives to buying water from the vendor. For those consumers living near a standpipe, water may be collected from that source, but it is generally used only for the washing of clothes since the

water has a salty taste. However, women seldom fetch their water from the main source, the church run borehole. Questioned why this was so, women living within a few hundred yards of the borehole said it was not acceptable to do this in the community; delivery of water at a price is the accepted norm. It was not possible to ascertain whether this norm was enforced by pressure from water vendors, seeking to protect their market. However, it did not seem likely, as young children were frequently seen carrying small containers from the tapstand at the well. The frequency of their visits and the size of containers they use may change in the summer when demand for water increases. Some people, mainly young boys, also wash their legs and arms at the tapstand.

It is surprising that more women do not collect water at source, especially since it is free to individual consumers, but convenience appears to be rated highly. Also there are often no children available to fetch the water, and the men of the house may leave early for work in the city so that the woman relies on vendors for delivery.

In Karton Kassala, where water prices have recently risen dramatically to LS 6-00/barrel, the alternative source (the canal) is becoming more and more attractive to the consumer, although it is much dirtier, because it is sold by vendors at half the price. 10 of the 30 households for which the full questionnaire was employed stated that they used canal water partially or fully. These appeared to be poorer than average, with a mean household income of LS 285 per month compared with LS 424 per month for those exclusively using borehole water. However, the four households using only canal water had a mean monthly income of LS 394. There was no significant difference is household size, with a mean of 8.7 members in households using canal water wholly or partially, compared with 8.1 members in the remainder.

It was perhaps more indicative of the reason for their using canal

water that 7 of the 10 were among the 11 households interviewed in Hila Shiluk and Hila Moroo (Figure 10). An additional 15 households were therefore interviewed in Hila Moroo with a shortened version of the questionnaire. 8 of these were found to use canal water partially, and a further 5 used it exclusively. It would seem that it was not only the lower price that encouraged women to buy the dirtier water. The recent closure of the normal source for the community had forced vendors to collect water from already over-subscribed sources in areas to the North. They were therefore less inclined to deliver in areas far away, being able to dispose of their water closer to the source and so fit in more journeys per day. Many women currently using canal water in Hila Moroo simply said that tap water was no longer available, because the donkey boys were no longer operating in their area. This in fact appeared to be the main reason for using the canal water, since few households in the other parts of Karton Kassala used canal water to any great extent, except for washing clothes.

2.8 WATER CONSUMPTION AND DEMAND ELASTICITY

This Section presents the data whose collection was the principal objective of the study. They permit an estimation of the elasticity of demand for water in three different ways. First, it is possible to compare water consumption in the two communities of Meiyo and Karton Kassala, in which vastly different prices are paid for water, after allowing for the small difference in average incomes between their respective populations. Second, the evidence in the previous Section suggests that most of the households using canal water in Karton Kassala do so because the alternative is not available, rather than to save expense; thus their water consumption can be compared with that of households which use the more expensive borehole water. Both of these should yield estimates of the price elasticity of demand for water. Third, by comparing the consumption of individual households with different income levels, it is possible to estimate the elasticity of demand with respect to income.

Reliability of questionnaire responses

However, before questionnaire results can be used for this purpose, it is first necessary to compare them with data collected by household observation to confirm that they are reliable. The observed "household" units did not always correspond with residents' own perceptions of what constituted a household, as more than one family was frequently found to share a single compound. Observers standing outside a compound could not distinguish between the quantities of water purchased by the different households living there. Nevertheless there were 14 households whose individual water consumption was measured by questionnaire. The results of the two survey methods in assessing overall water consumption of these households are compared in Figure 14. The agreement is reasonably good, both in terms of the aggregate consumption of the households as a whole and that of the individual families. Such discrepancies as appear are within

the range of difference between observed water collection and stated water consumption which is likely to arise from overnight storage of water.

Comparison between Meiyo and Karton Kassala

In Meiyo, where water cost a uniform price of LS 1-50 per drum, the average water consumption for the 27 households interviewed was 24.2 litres per capita per day (l.c.d.). This is a fairly typical figure for standpipe users in urban areas in Africa (White et al., 1972). Observation of 96 households with a total population of 957 people gave a slightly lower figure of 19.2 l.c.d. The difference can be explained by the larger mean household size in the observation sample, 10.0 members, compared with 7.3 in the households interviewed. It is well-known that, as a result of economies of scale in water use, larger households tend to consume less water per capita. Each household's monthly expenditure on water may be estimated by multiplying the daily consumption figures by 30, to obtain an estimate of monthly consumption, and then multiplying by the price of water. Of course, any given household's consumption on the day of the survey may not be representative of its water use over an entire month, but daily variations are likely to even out when the results are taken together over a number of households.

By comparing monthly expenditures on water with household incomes, it is possible to arrive at an estimate for the average proportion of household income spent on water. Complete income data were obtained from 22 households in Meiyo, and from these it can be estimated that the average household spends 16.5% of its income on the purchase of water from vendors.

In Karton Kassala, the majority of borehole water was purchased for LS 5-00 a drum, although 2 out of 30 households interviewed paid LS 6-00 and one paid LS 4-00. As discussed above, 10 households supplemented or substituted the borehole water with cheaper water of lesser quality brought by vendors from a canal. Thus, the average price paid per drum of water

was LS 4-64 per drum.

Remarkably, the mean water consumption for 30 households in Karton Kassala was 27.0 l.c.d. - higher, not lower, than the figure for Meiyo where water cost one third the average price. This difference cannot be accounted for by a smaller household size; the average size of the 30 households in Karton Kassala was 8.3, larger than that of the families interviewed in Meiyo. Repeating the procedure described above for Meiyo gives an estimate that the average household in Karton Kassala pays a staggering 55.6% of its income for water.

It might be argued that averaging the percentage on a household basis gives an exaggerated figure for this mean, as it will be inflated by some very large percentages arising from occasional peaks of consumption by certain households on the day of the survey. An alternative algorithm would be to divide the total estimated expenditure on water by the total income of the community. On this aggregate basis, the percentages spent on water are 11.4% in Meiyo and 34.8% in Karton Kassala. On the other hand, these latter figures are strongly influenced by the very high incomes (and consequently low percentages paid for water) of a few wealthy households in each survey area, who earn 10 to 20 times the incomes of the poorest. A truly typical figure for the proportion of its budget which a poor household must reserve for water would therefore be somewhere between the two types of average.

By either reckoning, the residents of Karton Kassala pay three times more for water than the people of Meiyo in relation to their incomes, but this does not reduce their consumption (see Table 11). That is to say, the price elasticity of demand, judged from these data, is effectively zero.

Table 11. Comparison of prices and water consumption in Meiyo and Karton Kassala.

	Meiyo	Karton Kassala
Number of households fully interviewed	22	28
Mean household size	7.3	8.3
Mean household income (LS/month)	309	393
Mean price of water (per 200 litre drum)	1.50	4.64
Mean water consumption (l.c.d.)	24.2	27.0
% spent on water (averaged by household)	16.5	55.6
% spent on water (aggregate for sample population)	11.4	34.8

Users of borehole and canal water in Karton Kassala

It was mentioned in Section 2.7 that 10 out of the 30 households fully interviewed in Karton Kassala used canal water partially or fully, and that this practice was particularly common in Hila Shiluk and Hila Moroo. A further 15 households were interviewed in Hila Moroo using a shortened version of the questionnaire, and 5 of these were found to use canal water as their sole source, with a further 4 using it for the majority of their needs. Combining the two sets of households produces a total sample of 45 households, of which half (22 households) used only borehole or tap water. 20 of these paid LS 5-00 per drum for their water, while one household paid LS 4-00 and one paid LS 6-00 per drum. All of those using canal water partially or exclusively paid LS 3-00 per drum for it to be delivered by vendor.

Income data were not collected for the supplementary sample of 15 households, but for the original 30 it was possible to estimate the mean percentage of income spent on water (averaging by household). The result was 59.8% for those using only borehole or tap water, 63.6% for those also using canal water, and 26.1% for those using canal water alone. In other

words, the saving in expenditure resulting from the partial use of canal water was offset by the lower household incomes of this group; those using canal water as their sole source, however, and paying half the price for it, spent a percentage of their incomes roughly half as great as those who used the more expensive water from boreholes. There was no reason to believe that this pattern was markedly different among the further 15 households interviewed, or that their their average income differed significantly from that of the original sample of 30.

Since there was evidence, presented in Section 2.7, that the lower price of canal water was not the chief reason, and certainly not the only reason for using it, a comparison of the quantities of water used by the households in the categories could yield some information on the elasticity of demand. There are of course some advantages in comparing consumption between households within a single community as in this case, rather than between the two communities of Meiyo and Karton Kassala, because the potential impact of extraneous confounding variables is reduced.

However, the result was the same. The mean household consumption of the three groups was not significantly different. The results are summarised in Table 12. The small difference between the three mean consumption figures are of the some order as the standard error of each of them (± 3 l.c.d.), and no consistent relationship can be seen between water consumption and the price or the percentage of income spent on water.

Table 12 Comparison of water consumption among households using water bought at different prices in Karton Kassala

Source of water	No of households	Mean household size	Typical price of water (LS/drum)	Mean water consumption (l.c.d)
Borehole or tap only	22	7.8	5-00	30.1
Borehole and canal	14	8.1	5-00 and 3-00	26.5
Canal water only	9	7.2	3-00	27.7

Income elasticity of demand

Before the relationship between income and water consumption can be examined, it is necessary to assess the impact of one potential confounding variable; the number of people in each household. It has already been mentioned that larger households tend to consume less water per capita. This is illustrated by Figure 15, which shows the relationship between per capita water consumption and household size in all of the households interviewed in both Meiyo and Karton Kassala. The tendency for per capita consumption to fall with increasing household size is significant, although not as marked as that found in several similar studies (White et al., 1972; Feachem et al., 1978).

However, it is clear from these data that larger households are likely to have a higher overall consumption, as shown in Figure 16. If, as commonly occurs, household size were also correlated with household income, this could produce a spurious apparent relationship between income and water consumption. In the present case, the problem does not arise, because no relationship was found between household size and income. The average number of members in households shows no consistent varation over the full range of income levels. This is shown for Meiyo and for Karton

Kassala in Figure 17.

Thus an opportunity arises to examine demand elasticity from another point of view. The foregoing discussion considered the impact on water consumption of differing prices. The alternative is to consider the impact of differing household incomes and hence, presumably, of differing capacity to pay a given price.

Figure 18 shows the mean total water consumption for the households at each level of income, with the results presented separately for Meiyo and Karton Kassala. Both present the same picture, with a marked uniformity of consumption over the full range of incomes encountered in the surveys. There is no tendency for the wealthier families to purchase more water, even if their incomes are ten times those of their poorest neighbours. In other words, the income elasticity of demand, like the price elasticity, is effectively nil.

An important consequence of this finding is that the poorer households pay a higher percentage of their income for water. Not only do low-income communities pay water vendors several times more for each litre of water they consume than those who have house connections (Section 2.3). Within those communities, the percentage paid for water out of each household's budget will on average vary in direct proportion to the inverse of its income (Figure 19). Households with half the mean income will spend twice the average percentage on water, while those with twice the mean income will pay half, and so on. Indeed, it is expensive to be poor in Khartoum.

2.9 THE USES OF WATER

In the expectation of detecting a measurable elasticity of demand for water, a considerable amount of data were collected regarding the amounts of water used for different purposes, with a view to identifying those uses which suffered most if water consumption was reduced in response to high prices or low incomes. In the event, as discussed in the previous section, water consumption proved to be practically inelastic, with no significant tendency to be lower in households paying higher prices or with lower incomes. It would thus appear that the residents of Meiyo and Karton Kassala had already reduced their water consumption to the minimum level acceptable. It is nevertheless of interest to know how those minimum quantities were used.

The results are shown in Figure 20. It is noteworthy that personal hygiene, in the form of bathing and washing clothes, accounted for some 60% of the total in both study sites. Typically, one bucket of water, holding about 18 litres, was used for bathing every day by each adult, and about half a bucket for each child under 14. The frequency of bathing was sometimes reduced to every second day in winter. Women were also observed to wash their feet before leaving the home. A further 2 litres per person per day were used in Muslim households for the ritual washing of face, forearms, hands and feet which must precede prayer, up to five times a day. 21 of the 27 households interviewed in Meiyo, and 12 of the 30 in Karton Kassala, were Muslims the rest being Christians.

Most of the reminder of the available water was used for the washing of food and utensils - another hygienic purpose - and for cooking and drinking. Other uses, amounting to less than 10% of the total, included the watering of gardens and livestock, and anal cleansing after defecation. For this last purpose, mainly found among Muslims, about half a litre was used on each occasion.

These data refer to the first use of water. In addition, a considerable amount of water was re-used in order to minimise consumption. Freshly-purchased water only was used for drinking, cooking, bathing and washing food, but grey water was often saved for washing and rinsing clothes, and might even be used a third time on the garden or to dampen the ground in the compound to keep down the dust.

It was mentioned in Section 2.6 that an important economic activity in the survey areas was the production of alcoholic drinks. This occurred infrequently, but could require large quantities of water on a brewing day. It was not recorded in the interviewed households, but was seen to occur in 12 of the 96 households observed in Meiyo during the two days of observation. Their observed consumption per capita was seen to be 44 l.c.d. higher on a brewing day, compared with that of non-brewers. This corresponds to an additional 320 litres in an average Meiyo household of 7.3 members, or roughly one and a half drums.

2.10 WATER VENDING IN KHARTOUM AND PORT SUDAN

In Sudan as in many other developing countries, water vending helps to satisfy a vast unmet need for water for domestic use. However, its cost to the consumer, and particularly to the poorest consumers, as documented in Section 2.8, is extremely high. Is this due to exploitation by unscrupulous vendors or donkey cart owners? Is it due to a shortage of donkeys or carts? Given the extremely low elasticity of demand found in this study, economic theory would indicate that only a slight improvement in supply could provoke a very large fall in price before a corresponding rise in demand would result. Could access to water be improved by government assistance to the vending sector, and would this cause prices to fall?

For any agency seeking to improve access to water in the squatter areas of Khartoum, and the living standards of the urban poor in general, support to water vending presents an attractive possibility. However, it is essential that the present operation of the system be understood before any attempt is made to change it. This Section presents an overview of water vending in urban Sudan, based on informal interviews with vendors and their customers conducted during the survey in Khartoum, and during two visits to Port Sudan.

Market control

There is no evidence of monopolistic or oligopolistic control of donkey carts. Most donkey cart owners have only one or two carts, although they do tend to belong to a limited number of ethnic groups. In both Khartoum and Port Sudan, the vast majority of the owners are Northern "Arab" Sudanese. In Karton Kassala, most of them lived outside the area. The same goes for those who operate the carts, roughly half of which are driven by the owners themselves. The usual arrangement, when the owner does not drive his own cart, is for the driver to pay 75% of his net

takings to the owner, who will usually feed the donkey himself although he may make allowance for the cost of donkey fodder and leave this expense to the driver. The water requirements of the owner's household may also have to be provided free of charge.

The donkey market in Port Sudan appears to be controlled by the Beja tribes, nomadic people who bring livestock from the North and from Tokar in the South, by train and lorry. The Halab people, who originated in Syria, buy up most of the donkeys and in this way control the prices to a certain extent. One of the Beja tribes, the Beni Amir, is also very much involved in the buying and selling of donkeys. There is an auction every Friday morning where both donkeys and carts can be bought. The auctioneer takes 10% of the price, so that most interested parties will in practice try to come to an agreement privately.

It is perhaps no concidence that most water vendors in Port Sudan were also from the Beni Amir and other Beja tribes, although Nigerian Fellata and Western Sudanese were also involved. This was said to be because it was an unskilled job, inferring that the Beni Amir were inferior in the eyes of the majority of other Sudanese. However, further investigation showed that there was a more rational explanation.

For may years, the Beni Amir have worked seasonally in Port Sudan, leaving their families to farm the land. This was done in order to buy certain goods such as coffee, sugar and clothing, for which cash was needed. Suitable employment and remuneration was gained from water vending, carrying a pair of jerry cans hung from a yoke. This involved little capital expense, was not binding - they could work how and when they wanted - and the equipment could be left for a relative to use afterwards. As the shanty towns grew in size after the drought in the 1970s, and the problems of water distribution increased, it became necessary to carry water by donkey. In this way it was a natural progression for the Beni

Amir to become involved in this new development, having long years of experience in the trade.

Many other reasons have been given to explain the lack of involvement of other tribes in this type of employment. It should not be surprising to find that the majority of vendors in Port Sudan are Beja people, since they make up the main populace of the East of Sudan. However, the Southerners who do live in the squatter areas of the city do not appear to be involved in water vending at all. In Khartoum it is also striking that hardly any Southerners participate in water vending, although they make up a sizable proportion of some of the squatter communities, such as Meiyo, or Hila Moroo in Karton Kassala (see Sections 2.4 and 2.7).

Water vending with a donkey cart requires a substantial capital outlay, more than half of which represents the cost of the donkey. In Port Sudan, a donkey costs LS 600 - 1000, depending on its quality, and prices in Khartoum appear to be slightly higher.

One mechanism by which water vendors appear to exercise a degree of control of their market is by limiting access to water sources. In 1986, Oxfam ran a project to facilitate the purchase of donkeys and carts for water vending among the southerners living in a part of Hag Youssef, a squatter area in Khartoum North. The aim was to offer them a source of income as well as alowing them to exercise a certain amount of control over the price of water. However, these men were effectively barred from using the water source, which was controlled by northern Sudanese. Another example is the case of Wahida North, mentioned in Section 2.4, in which the local water vendors lobbied (unsuccessfully) against the extension of the piped water distribution network, as it would reduce their market.

The degree to which a cartel operates among vendors to regulate prices is unclear. In Port Sudan, water prices increase in summer when queues are longer and donkey fodder is more expensive. The water price increase, and

the subsequent drop in price later in the year, occurs in a single jump simultaneously throughout the city. However, even those who know the market well are unable to point to any single group or forum in which the decision is taken. The sudden jump may be a consequence of the difficulty of charging anything other than multiples of 25 pt for a single jos (8 gallons) of water. News of the price change appears to travel by word of mouth once one or two of the more astute vendors have judged that it is what the market will bear. Similar price changes follow increases in the price charged for water at the source. However, the slightly differing prices charged by various vendors in Karton Kassala (LS 5-00 and 6-00 per drum) demonstrate that, if any attempts are made to control the price, they are not completely successful.

Many vendors have some regular customers, known as zabuun, who may be charged a slightly reduced price for the convenience of regular delivery, since this saves the vendors from the time-consuming task of searching for custom. The vendor will sometimes extend short-term interest-free credit to these customers, so that they can pay when money is available. However, at times when water demand increases - in Port Sudan, for instance, when fewer standpipes function and for shorter times, so that queues begin to grow - the vendor may reduce the number of customers to whom he will extend these benefits. In this way he can keep his income up, since the higher price charged to casual customers can compensate for the reduction in the number of journeys he can make each day.

Government control

The Government does exert some control over the prices charged to water vendors at its standpipes and boreholes, the official price being LS 0-50/m^3 (Section 2.2). Nevertheless, at boreholes operated by private licensees, consumers have complained of being overcharged by as much as 70% (Antoniou, 1979).

No attempt is made by the authorities to control the price of water resold by vendors. Legal powers exist for the issue of vendors' licences, but in practice their possession is not normally enforced, and in any case they were introduced for public health reeasons rather than to control the market. Some vendors in Meiyo reported that they had obtained licences, known as Certificates of Hygiene, in 1983 at a cost of LS 3-00 from the Public Health Department of the Khartoum Council, after passing a health test. Licences were reportedly required by law 20 years ago in Port Sudan, but their use has lapsed over the years.

Costs and profits

The first major outlay for a water vendor is the purchase cost of a donkey and cart. This ranges from LS 1,000 to over LS 1,500 in Port Sudan, while in Khartoum the prices quoted were relatively uniform at around LS 1,600 - 1,700. Roughly two thirds of the cost is for the donkey. Allowing a 10 year working life for the donkey under the hard conditions of urban life and a 5 year useful life for the cart, this can be expressed as a depreciation rate of a little over LS 100 per year. Including the costs of lubricant and minor running repairs would suggest an overhead cost for the cart of about LS 10/month.

The major running cost is fodder for the donkey. In Port Sudan, the daily cost of fodder was made up as follows:

	LS
grain	1-00
dry grain	1-00
dura	1-25
TOTAL	3-25

In Khartoum, the daily cost of fodder was variously quoted as LS 3-50 to LS 5-00, occasionally substituted by a tin of marisa albeit, a waste product from beer production, costing LS 0-50 for a day's supply but only

infrequently available. A typical cost of the donkey's subsistence can hence be estimated at LS 4-00 per day.

How the profit margins work out in practice can be seen from case studies of two vendors, one in Dar el Neim, Port Sudan, and the other in Meiyo.

Case study 1: Dar el Neim, Port Sudan

This vendor made 2 trips a day, an average number for Port Sudan. He paid LS 1-00 at the source for each cartload of two 200 litre drums. Roughly half his customers were regular ones (zabuun). These were charged LS 0-75 per jos, while casual customers paid LS 1-00. Each cartload holds 12 jos.

Not including overheads on the cart, his monthly operating expenditure and income worked out roughly as follows, in March 1987.

Income		Unit cost	Total (LS)
Regular customers:	12 jos/day x 30 days	0-75	270
Casual customers:	12 jos/day x 30 days	1-00	360
Total income			630
Expenditure			
Fodder:	30 days	4-00	120
Water:	2 carts/day x 30 days	1-00	60
Less : total expenditure			180
Monthly operating profit:			450

Even after deduction of LS 10/month for depreciation and overheads on the cart, plus a reasonable income of, say LS 200/month for an unskilled worker such as a water vendor, it is clear that a sizeable profit remains. However, two important factors need to be taken into acccount. First, the cost of fodder in Port Sudan is highly seasonal, and it may be that profits are considerably lower at other times of year when fodder prices are

higher. Vendors in Port Sudan state that it can then cost as much to feed one donkey as a family of five. Moreover, profits are held down for part of the year by the seasonal influx of donkey owners from outside Port Sudan.

Second, the depreciation rate on the cart takes no account of interest. Interest rates among low-income groups throughout the developing world are notoriously high. Since the poor have no security to offer to formal lending agencies, they are charged by money lenders in the informal sector who are outside Government control. Since the opportunity cost of capital to the poor is very great, they are willing to pay many times the rates prevailing in the formal money markets.

Case study 2: Meiyo, Khartoum

The second vendor made 4 trips per day. 3 to 5 trips is a common figure in Meiyo, where the queuing time at the borehole and the travel distance are shorter than in Dar el Neim. He paid LS 0-50 at the borehole for each cartload of 12 jos. He had some regular customers, but these received no price discount. All paid the same rate of LS 0-25/jos.

The monthly income and expenditure account was therefore roughly as shown below.

Income	Unit cost	Total (LS)
Water sales: 48 jos/day x 30 days	0-25	360
Expenditure		
Fodder: 30 days	4-00	120
Water: 4 carts/day x 30 days	0-50	60
Less: total expenditure:		180
Monthly operating profit:		180

After deducting LS 10/month for depreciation and overheads on the cart, this leaves only a modest income of LS 180 for the donkey driver,

which compares with a typical monthly wage of LS 150 for an unskilled worker. For a driver who has to share half his profit with the owner of the donkey and cart, it leaves a very bare subsistence (see Section 2.6).

Vendors in Meiyo stated that they made a profit of LS 7 - 10 per day, but this appears to refer to their takings, net only of the cost of water at source, and without deducting the cost of fodder, which is not purchased during the normal day's trading. The vendor in our case study, taking LS 12 each day for 48 jos, and paying LS 2 daily for the water, was making a direct trading profit of this order.

Vendors in Karton Kassala, selling water for LS 1-00 per jos, claimed to make LS 20 - 30 on an average day. After deducting fodder costs and overheads, this leaves a net monthly profit of LS 500 or more. At this level, a vendor can make a living, albeit a very modest one, even after surrendering 75% of his profit to the cart owner, which is the usual percentage demanded under such profit-sharing arrangements in Karton Kassala.

Sources of credit

Thus there are obvious advantages to a vendor in owning his own donkey and cart. However, raising the necessary capital to purchase them is not easy. This is illustrated by the lack of Southerners who have managed to do so, as the money lenders are almost exclusively 'Arab' Sudanese of northern origin. Young Southerners in Karton Kassala quoted this as their chief difficulty. Even among Northerners, it appears that most of those owning their own donkeys are older men.

One way in which capital can be obtained without incurring debt obligations is through a sanduk, or rotating credit association. These are common among low-income communities in Sudan. A number of people, say 10, decide to form a sanduk, each contributing a certain sum of money each month. At the end of the month, one of the 10 chosen by rotation among

them, receives the total sum. For example if the monthly contribution is LS 50, then the total monthly sum in this case would be LS 500 (10 x LS 50). In this way it is possible for people with low incomes to obtain items such as fridges, sewing machines, etc. The advantages are that no interest is paid to moneylenders, and no cash is left in a kitty from which it could be embezzled. However, for those without a secure income, even the modest commitment this involves may be an undertaking they can ill afford.

In Port Sudan, a credit scheme to promote small businesses is run by Acord, a consortium of European non-governmental aid agencies. Only applicants with dependents are considered, but the loan can be repaid over more than a year and is interest-free, although an administration fee of LS 8.00 is charged. Loans are made for a range of purposes, as is shown by the following breakdown of the loans outstanding at the end of 1986.

Type of business	% of total
Water vending	20
Tailoring	22
Coach transport	5
Catering	2
Home improvement loans	24
Others: matters making, soft drinks, vegetable retailing, blacksmiths, electricians, tyre repairers.	27

Water vendors thus account for one in five of the loans. Typically, these will be for LS 1000, repayable at a mutually agreed rate such as LS 50 a month over 20 months. However, no Southerners have applied for water vending loans. Only a few have applied for other purposes, mainly for the smaller investment needed for tyre reparing. It may be that many of the Southerners in Port Sudan do not plan to stay there long before returning to the South; certainly, they are more attracted to casual labour in the docks and other temporary employment. Another reason may be that

many of them are young single men and are therefore not eligible to apply to the scheme.

Still, the scheme has certainly helped many poor households to generate their own income, and if it has increased competition among water vendors and consequently helped to keep prices down, its impact on the urban poor will have extended far beyond the immediate beneficiaries of its loans.

III. CONCLUSIONS

The principal objective of the present study was to measure the elasticity of demand for water among low-income populations purchasing it for domestic use, in the expectation that they were liable to cut back on consumption when its cost was high in relation to their incomes, and with a view to drawing some conclusions regarding policies for cost recovery in the water sector.

In the event, the elasticity of demand proved to be negligible, and in practice undetectable. The same conclusion was reached from three distinct approaches to analysis of the data; by comparing communities paying very different prices, by comparing households paying different prices within a single community, and by examining income elasticity within each of the two communities studied. This is a remarkable and, to many an unexpected result; few would have predicted that households spending more than half their incomes on water would use the same quantities as those paying less than one tenth. Yet it is strengthened by the consistency of the findings between the three methods of analysis.

With hindsight, it is possible to draw an analogy between this result and the findings of studies which have examined the relationship between water consumption and the distance over which it must be carried. The time spent carrying water has its price (see Section 1.5), and distance is a measure of that price. These studies too have found water consumption to be remarkably constant between households whose water source is only a few minutes from the home and those collecting it from a distance of several hundred metres away (Pinnewala and Herath, 1986) or, in Africa, a kilometre (Feachem et al., 1978; Pereira et al., 1981) or even a mile (White et al., 1972). In other words, the elasticity of demand with respect to distance is equally small.

All four of the studies cited above reported a threshold of distance

beyond which water consumption began to fall No such threshold of price was found in the present case, although it is hard to see how it can fail to exist. Clearly, it is impossible for a household to spend more than its income on anything. Nevertheless, some of the households we studied came perilously close to doing so.

It can only be concluded that low-income households in Sudan set an extremely high value on their water consumption, and consider that they have reduced it to the bare minimum beyond which they are not prepared to go, even at the cost of a crippling financial burden. This cost must make itself felt on their food budget, since this constitutes the principal item of expenditure remaining. The percentage of household income spent on water is greatest of all among the poorest households, who can least afford to make sacrifices from the meagre sums available to meet their dietary needs. It follows that the high cost of water in the squatter areas of Khartoum is a major contributor to the malnutrition which is rife there (Section 2.4), and hence that a reduction in this price would be likely to have a significant impact on the nutritional status of the poor.

The large proportion of water used for hygienic purposes (Section 2.9) suggests that the households studied were rational in their use of a resource they valued so highly. If purchased expensively, water was at least used sensibly, for the purposes most conducive to their welfare.

The high value set by the poor on their water consumption can also be seen through the concept of the consumer surplus, explained in Section 1.2. The lower the price elasticity of demand, the greater the consumer surplus. When this elasticity is effectively nil, as in the present case, the consumer surplus is very large indeed. That is to say, the value of water to the low-income residents of Khartoum has been shown here to be far greater than the already large amounts which they pay for it.

It is usually argued by economists that the value of the consumer

surplus should be included when assessing the worth of the outputs from investments for the purposes of economic cost-benefit analysis in project appraisal (Little and Mirrlees 1974) In the case of water supply investments in developing countries, this has not normally been practised, as no objective measurements of the consumer surplus had been made. The results of this study demonstrate that the value to a low income household of its water consumption is little less than its total income. Such a valuation, if used for project appraisal by international funding agencies, would yield cost-benefit ratios or rates of return far more favourable than those obtained hitherto.

The findings of this study have relevance not only for the economic appraisal of water supply developments, but also for their financial sustainability. Since the poor are willing to pay such large amounts for water, there can be no doubt that wealthier households, with private connections to the city's water supply, could pay substantially more than they do at present. There is certainly no justification for offering them the subsidised rates from which they currently benefit.

It is also of interest to consider the effect of the negligible price elasticity found in this study on the dynamics of the water vending market. Firstly, in the conditions of limited supply which currently prevail in Khartoum, in Port Sudan and presumably in many other urban centres, there is no likelihood of a fall in revenue when prices increase. There is thus a considerable incentive for vendors to increase prices. Indeed, it is remarkable that the price of water in communities such as Meiyo is not higher than it already is. The fact that it is not gives further support to the conclusion that no effective control exists by which vendors collectively fix the price of water (see Section 2.10).

On the other hand, it also follows that a small change in the supply of water - that is, the amount available through vendors - could have a

more than proportionate effect on prices. In the circumstances, it is not surprising that water vending and moneylending should largely be in the hands of the same ethnic groups (Section 2.10), since by controlling access to capital they can control supply, and hence exert significant control over prices without need of a price cartel. It is noteworthy that in Hag Youssef, where Oxfam tried to open up access to capital, the same groups quickly stepped in to limit access to the local borehole and thus maintain their hegemony over supply.

Given the high prices paid to vendors for water in urban Sudan, and their catastrophic impact on the budgeting of the poorest households, it may be asked whether offering support to water vendors is a worthwhile intervention to improve access to water by the poor, by comparison with conventional engineering interventions to extend and improve piped water systems.

Certainly, water vending is a relatively inefficient and expensive method of water distribution. It is clear from the case study in Meiyo, for instance (Section 2.10), that no-one makes a fat profit there from water vending. As things stand, the price could not be much lower without prejudice to the livelihoods of the vendors. Further confirmation of this is given by the finding that price discounts are rarely given there to zabuun customers.

However, it is also clear from that example that a vendor's profit is very sensitive to the number of cartloads he can sell each day. With his own subsistence and the donkey's fodder as his principal overheads, accounting for the major part of his total costs, a vendor's time is literally money to him. Much of this time is spent queuing at the water source to fill his cart. If this could be reduced, so also would his costs.

Thus the same conclusion follows, both from the low price elasticity

of demand and from the micro-economics of water vending. The most effective way to make possible a substantial reduction in the price of water would be to increase the supply of water at the public sources from which water vendors fill their carts. By reducing queuing times, this would lower the costs of vending, making price reductions possible in those areas, such as Meiyo, where profits are low. Alternatively, it might create opportunities for more vendors to collect water, particularly in those areas, such as Port Sudan and Karton Kassala, where profits are high. A greater number of vendors would tend to provoke a corresponding increase in queuing times, but the increased competition, and especially the increase on the supply side, could lead to substantial price reductions and help to keep profits within reasonable limits.

Direct evidence of the strong impact of changes in supply on the prevailing prices is provided by the dramatic increase in the price of water in Karton Kassala which has occurred over recent years (Section 2.4). Here, the price increases resulted from government intervention to restrict the availability of water sources. There is no reason to believe that a return to the previous supply position would not produce a corresponding fall in price to its former level, or somewhere near it.

Greater availability of public water points would offer a further benefit by providing an opportunity for households to exercise their only sanction and dispense with the services of water vendors entirely. This would exert a strong downward influence on prices; the threat of it probably helps to keep down profits in Meiyo. Moreover, it would afford an escape for the poorest households which at present suffer most from the necessity of paying for all the water they consume.

The beneficial impact on prices of an improvement in the supply of water to squatter areas is thus potentially great. It is not a necessary result, however, as markets are subject to political as well as economic

forces. Water vendors, moneylenders and water point concessionaires are an important political force with a considerable financial interest in maintaining the status quo. Improved supply makes price reductions possible, but not inevitable. That might require a measure of government intervention.

There are ample precedents for such interventions. Water is one of the necessities of life, and governments frequently intervene to control the prices of such necessities, particularly foodstuffs, though such a measure would be neither prudent nor feasible in the context of an informal market such as water vending.

However, the existing regulations on licences for water vendors and on concessions for the operation of public water points could be used to restrict the more extreme cases of exploitation. A first step would be to make more effective the control of prices charged by water point concessionaires, subject to the sanction of withdrawal of the concession.

The other possible intervention for the Government would be to facilitate credit for those wishing to purchase their own donkeys and carts. The success of the Acord scheme in Port Sudan demonstrates that there is a demand for such credit, and shows that loans can be recovered under such circumstances. It might not be necessary to subsidise this credit. Even if it were decided to charge commercial interest rates, administration costs, and a reasonable additional percentage to make provision for irrecoverable loans, the rates would probably be much more favourable than those currently charged by the moneylenders of the informal sector.

An estimate of the sums involved can be made by the following calculation. A typical vendor selling 4 cartloads of 400 litres each day can serve over 50 people, if their average consumption is between 25 and 30 l.c.d. Of Khartoum's population of 1.8 million, it has been estimated that

24% are in urban poverty groups, and that 70% of these, a total of 300,000 people, depend on water vendors (Section 2.3). These can be served by 6,000 vendors. In order to finance a new donkey and cart for each of them every five years (or alternatively, to increase the number of vendors by 20% each year) would require an annual investment of LS 1,700 x 1,200 = LS 2.04 million, or roughly £340,000. Since this sum could be recovered within 2 years, a total of £500,000 would be sufficient to set up a long-term revolving fund for the purpose.

This sum is small by comparison with the amounts invested in conventional civil engineering works for water supply improvements in any large city. It is also small by comparison with the millions regularly lent by the commerical banks of the formal sector in Khartoum, and with the sum of £20 million spent each year by the British Government in development aid to Sudan. It would have the advantage of providing benefits targeted on the poor, particularly on the poorest of the poor, and of creating employment by promoting the use of labour-intensive technology.

The decision to undertake such a credit scheme could by taken by commerical banks (possibly underwritten by the Government) or by the Sudanese Government itself. It could be stimulated by a proposal from an aid donor such as the UK Overseas Development Administration, or by a pilot scheme in a single squatter area run by any of the non-govermental aid agencies active in Sudan. Whether operated as a pilot scheme or on a full city-wide scale, credit arrangements for water vending would benefit greatly from the support of the local authorities to ensure that they were not restricted to a single ethnic group, but also accessible to the minorities, particularly Southern Sudanese, who make up a substantial proportion of the poorest in Khartoum.

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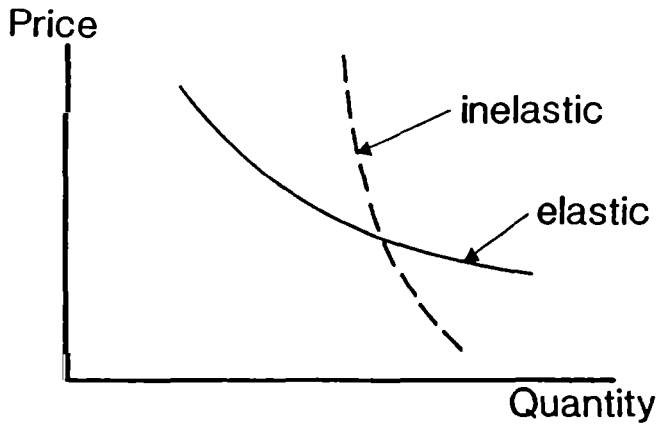


Figure 1. Demand curves for an elastic and an inelastic market.

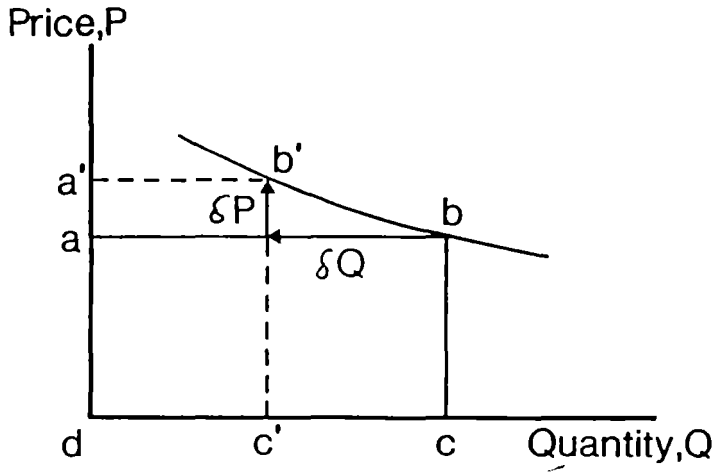


Figure 2. Effect on demand of a small change in price.

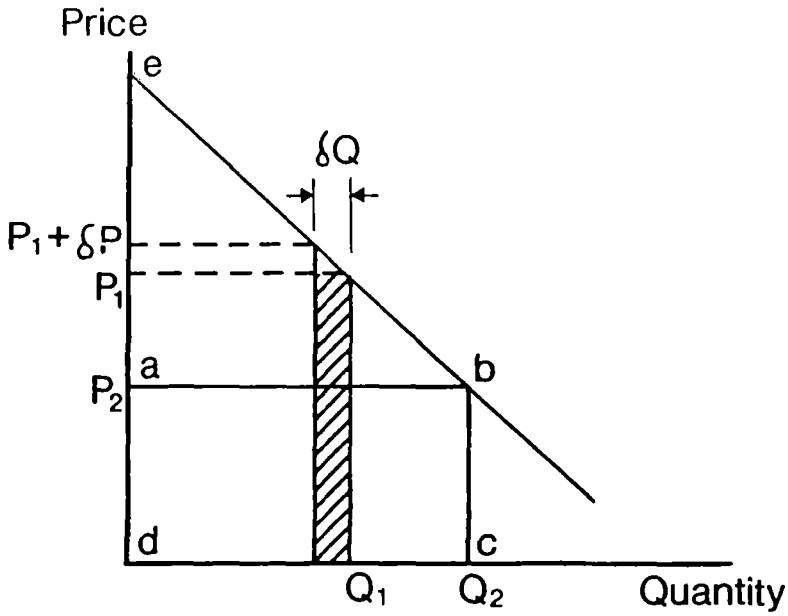


Figure 3. Graphical representation of the consumer surplus.

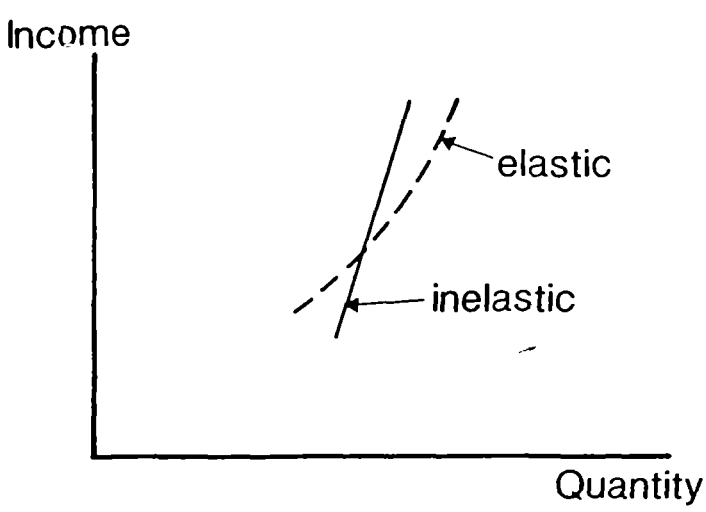


Figure 4. Income elasticity of demand.

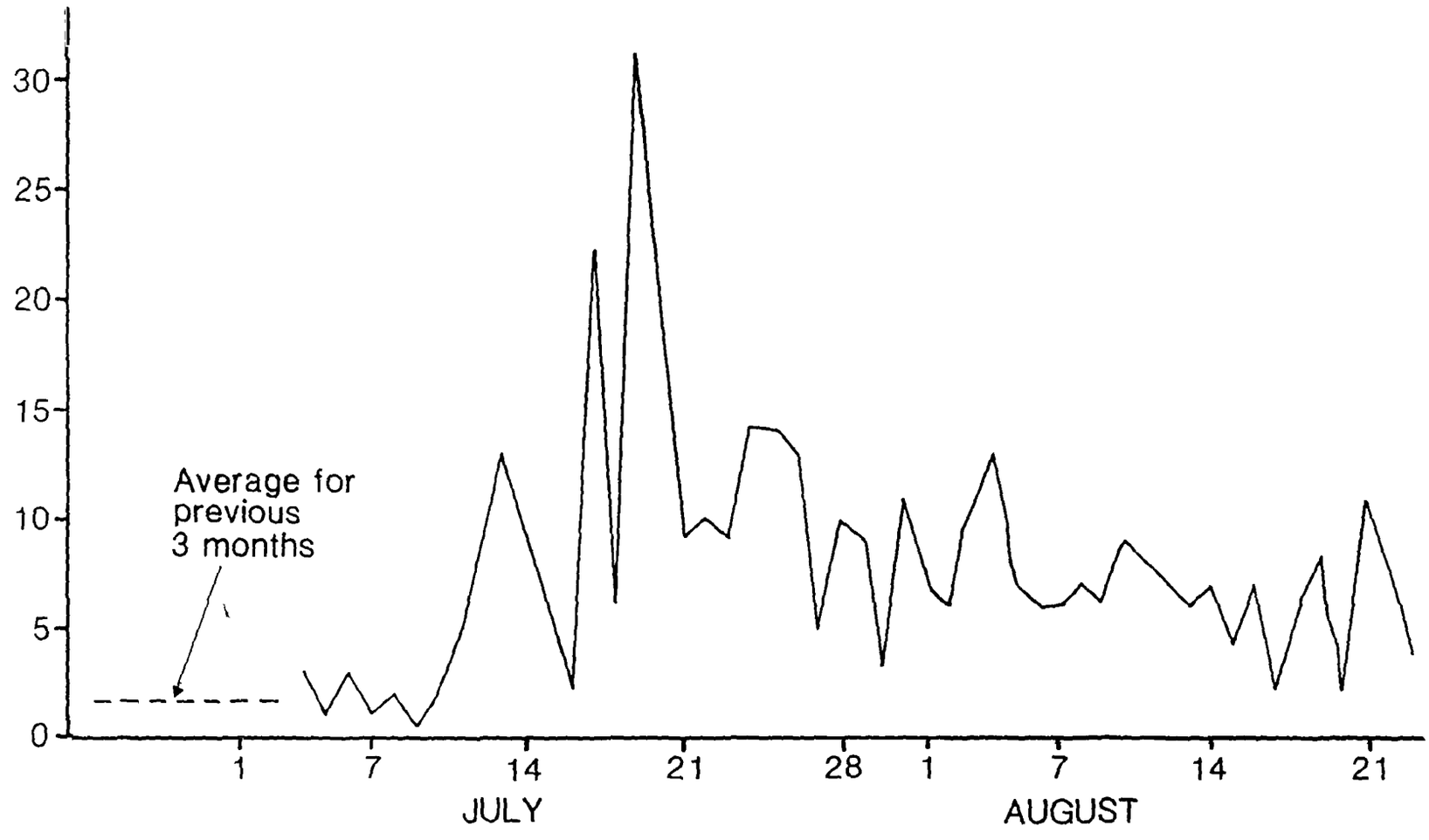


Figure 5. Daily reporting of typhoid cases in Kosti, Sudan (pop. 65,400) before, during and after a water-borne epidemic in July 1976.
(Source: Elzubier, 1977.)

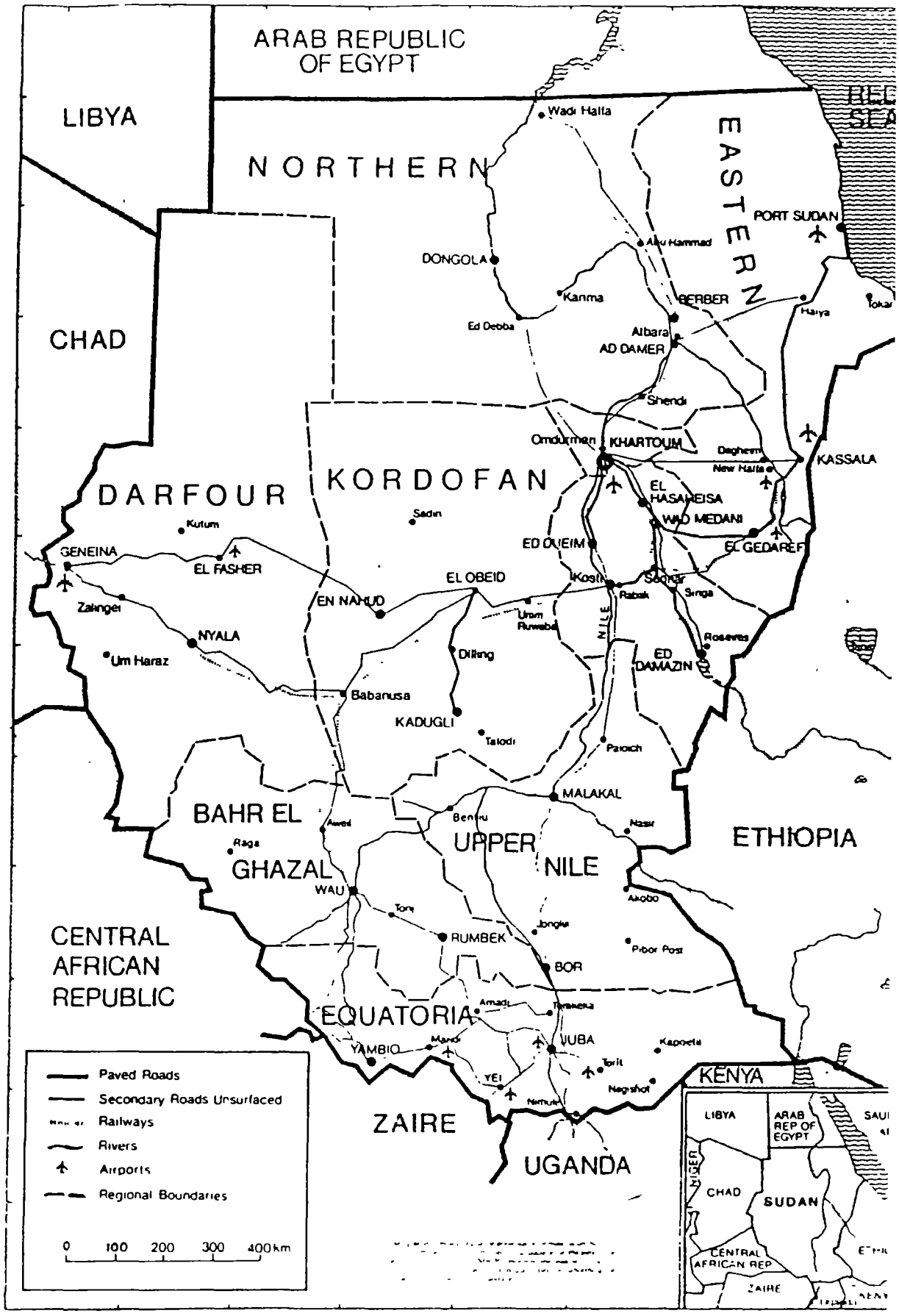


Figure 6. Map of Sudan.

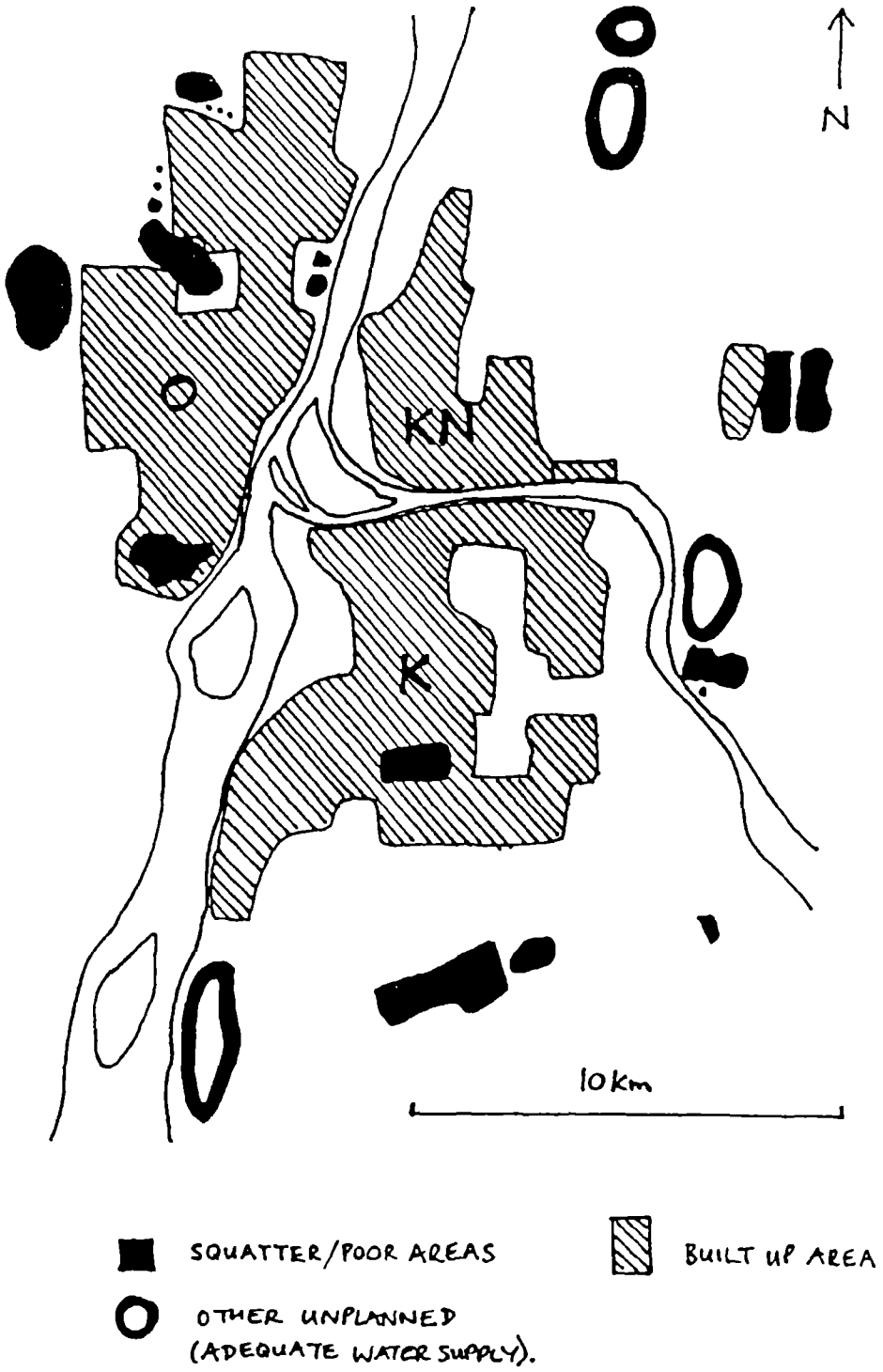


Figure 7. Map of the three towns making up Greater Khartoum, showing principal squatter areas.

O = Omdurman, K = Khartoum, KN = Khartoum North.

(From Antoniou, 1980.)

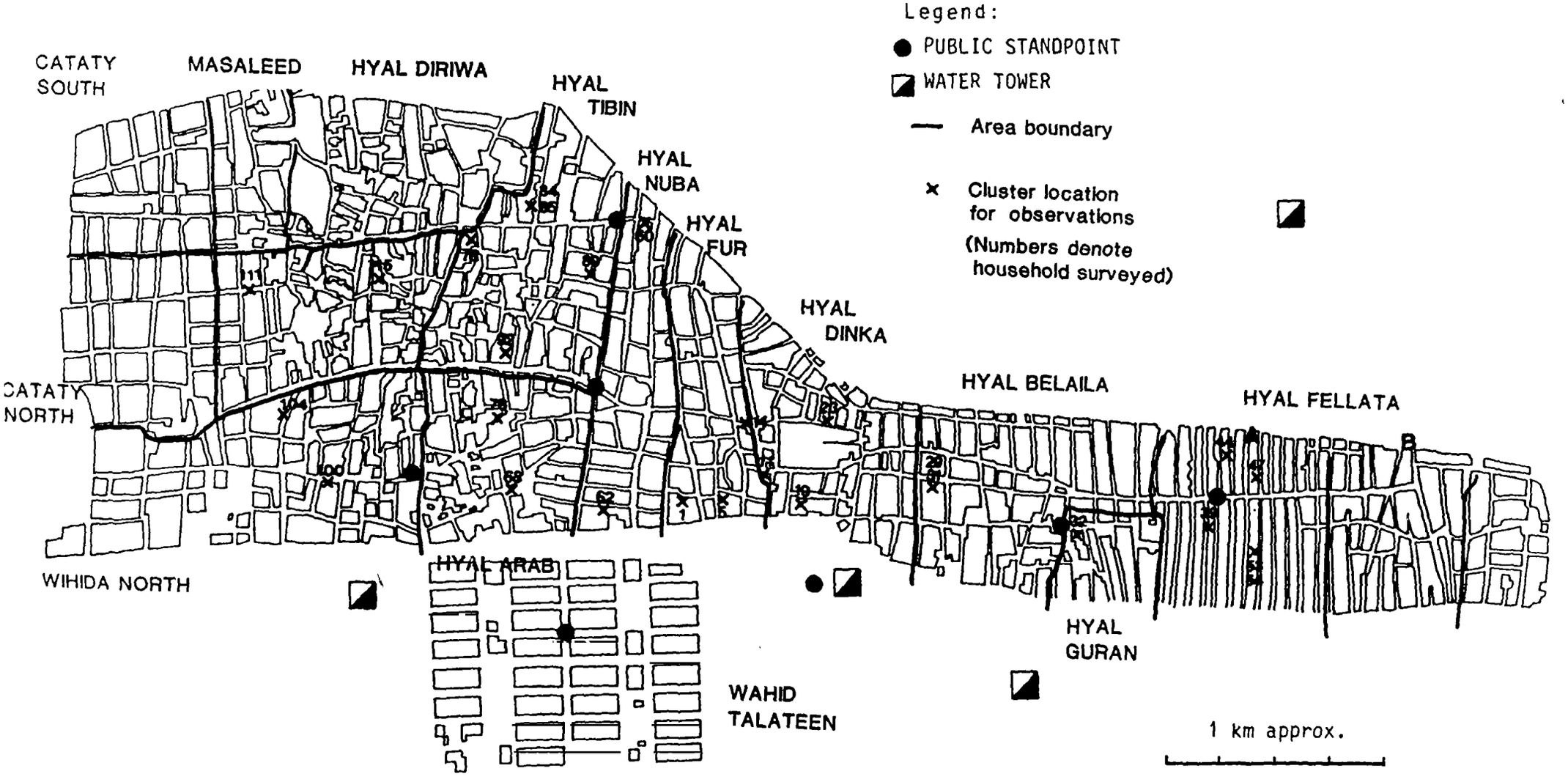


Figure 8. Map of Meiyo, showing locations of water towers and public standposts. The tower adjoining the Comboni Church borehole is closest to the centre of the area. The overlay shows the division into neighbourhoods and the approximate locations of the clusters of survey households.

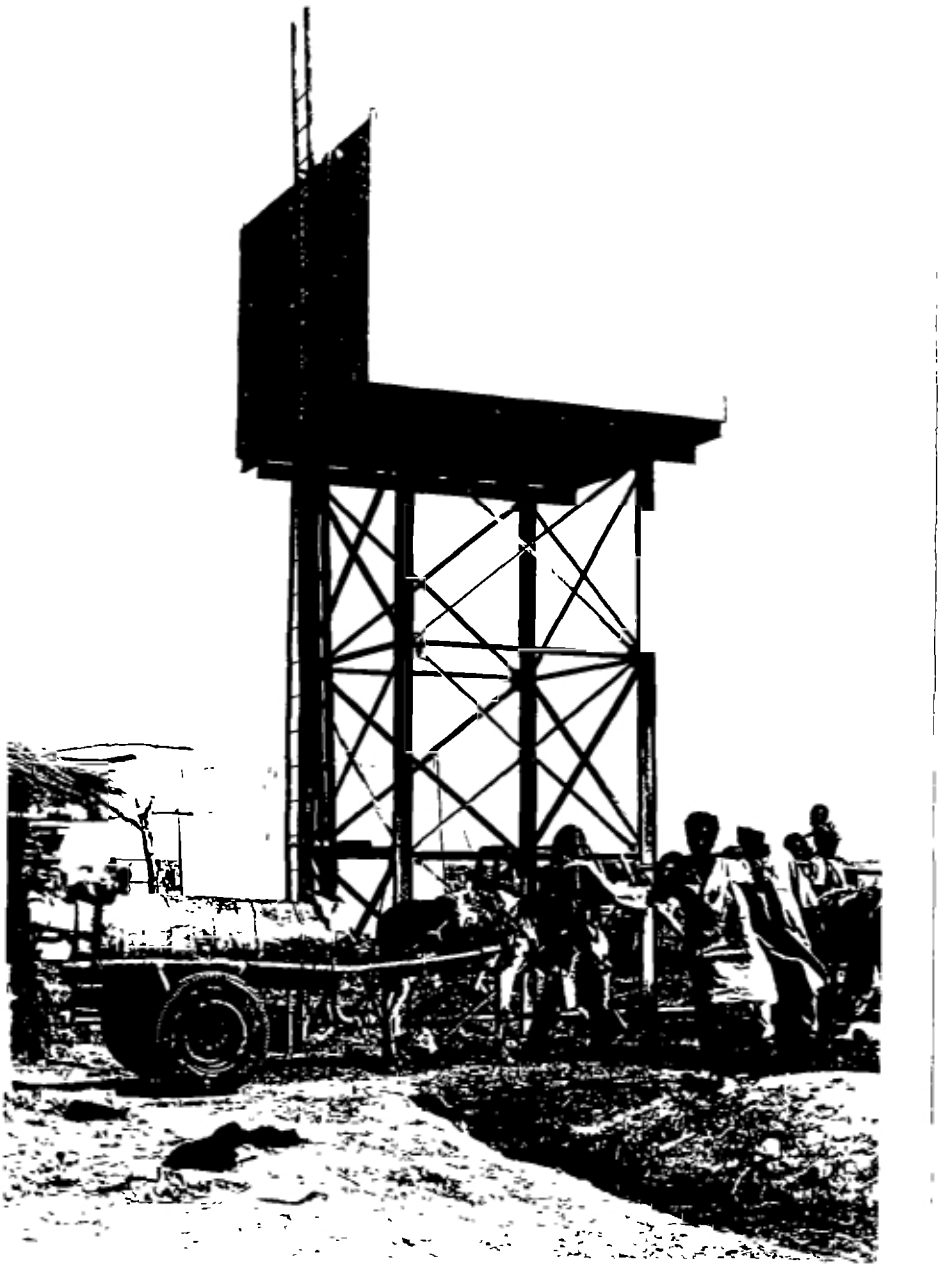


Figure 9. The water tower at the borehole run by the Comboni Church.

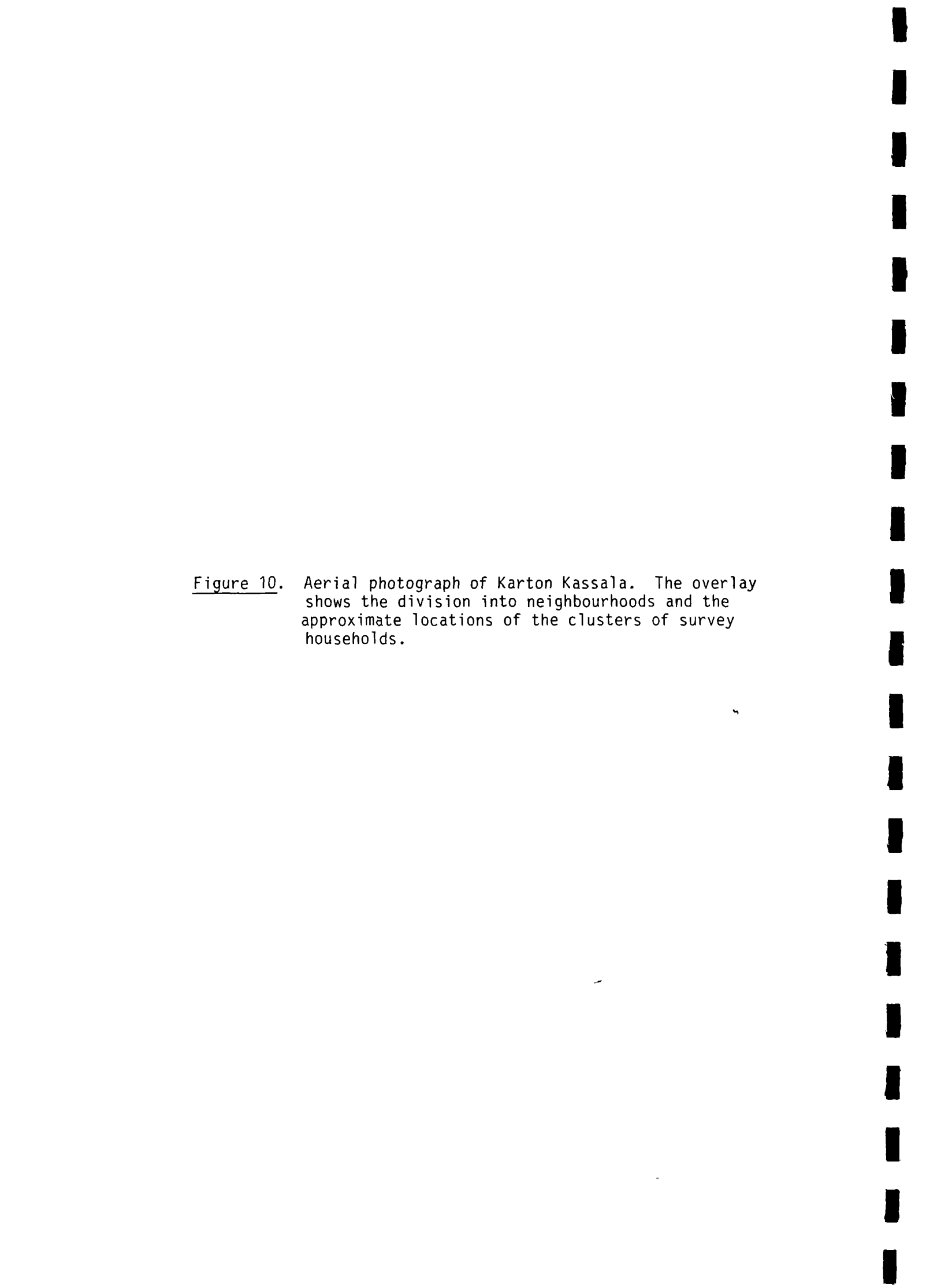
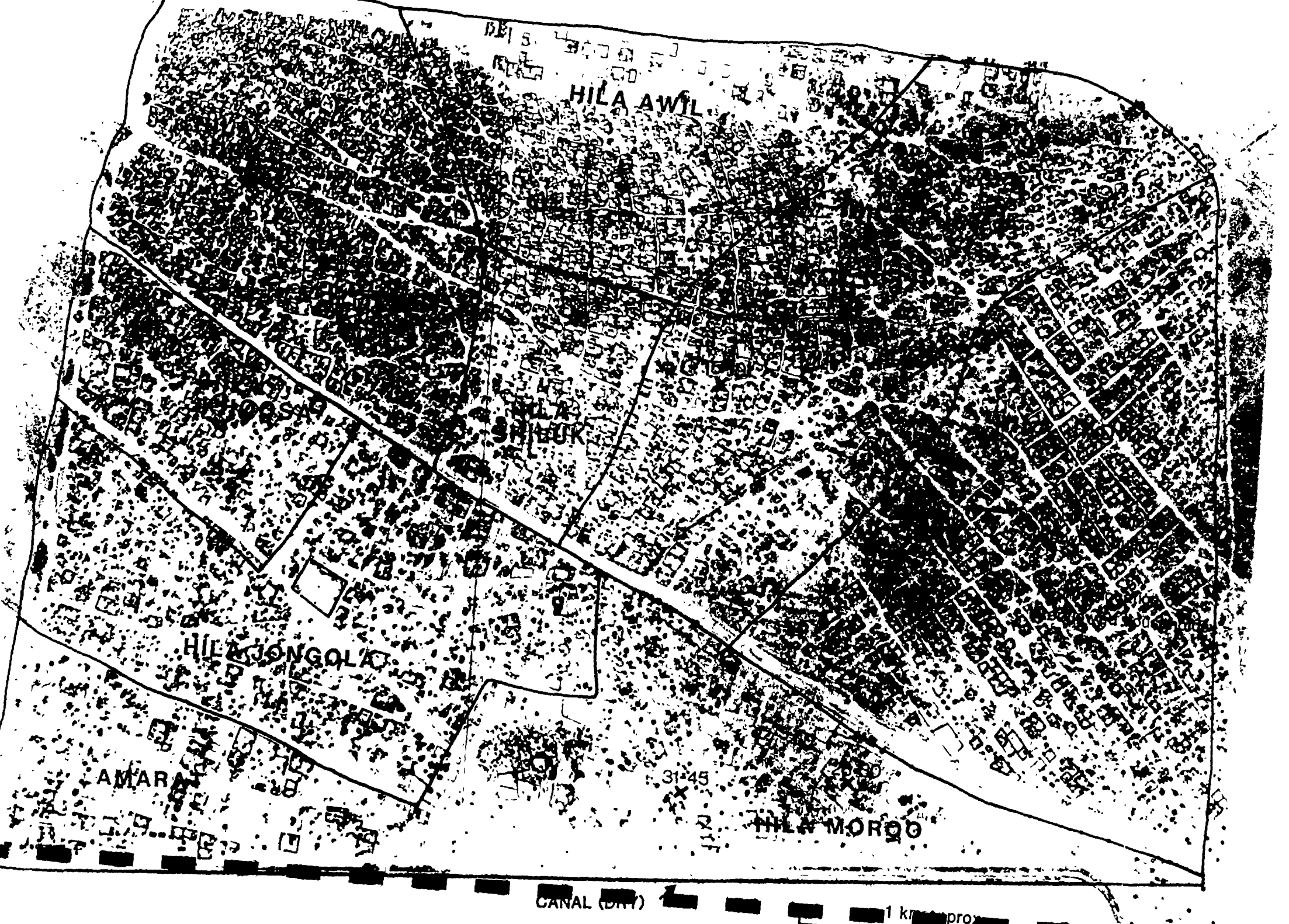


Figure 10. Aerial photograph of Karton Kassala. The overlay shows the division into neighbourhoods and the approximate locations of the clusters of survey households.


HILA AWIL
HILA SHEUK
HILA JONGOLA
AMARA
31-45
HILA MORGO
CANAL (DRY)
1 km approx

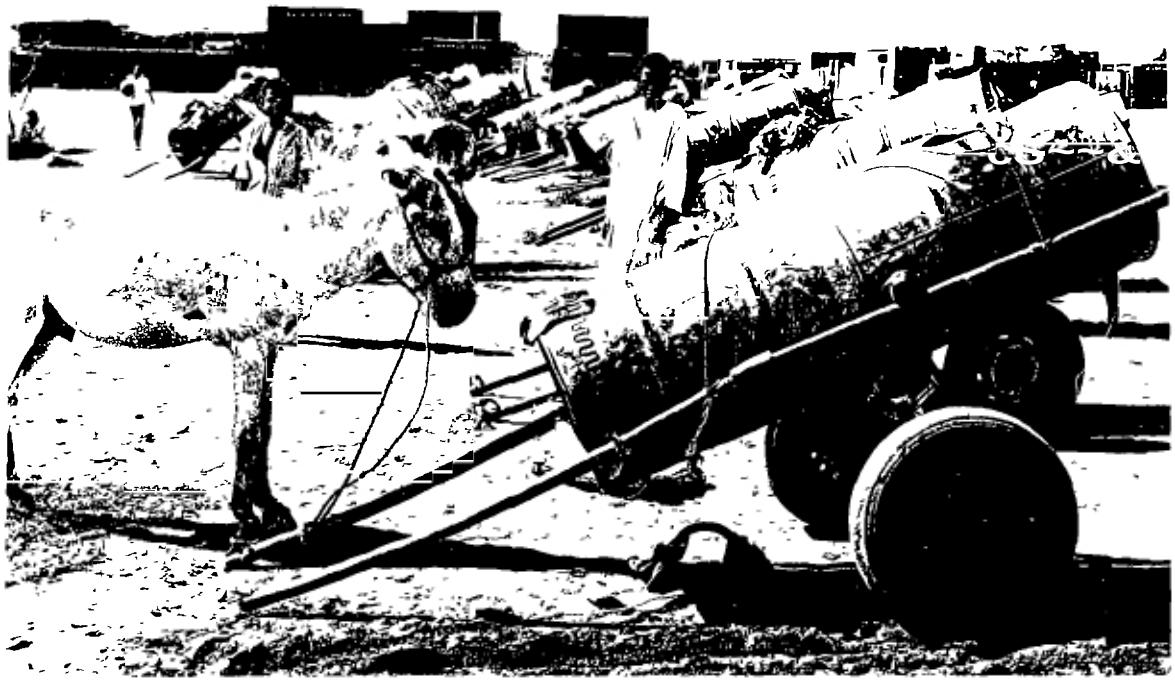
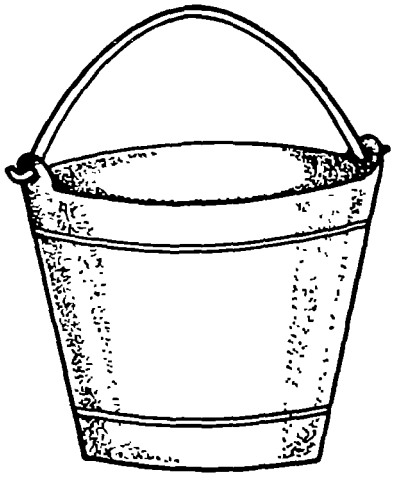
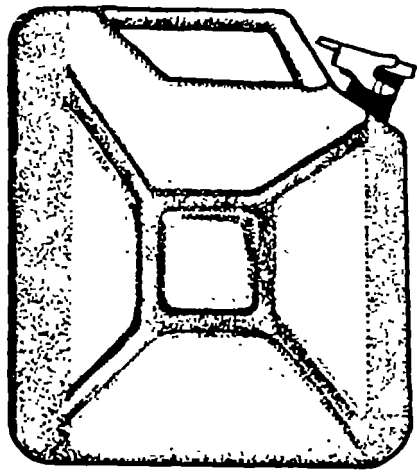


Figure 11. A water vendor's donkey and cart, queuing at a borehole North of Karton Kassala.

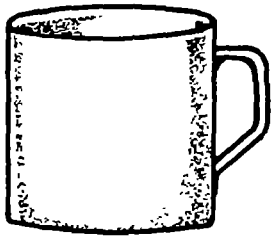
Figure 12. Filling up. Note the queue of carts in the background.



"Girder" bucket - 18 l



Jerry can - 18 l
(1 jos = 2 jerry cans)

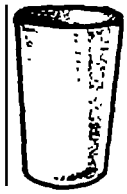


"Cos Kabir"

Large tin mug - 1200 ml
Small tin mug 600 ml

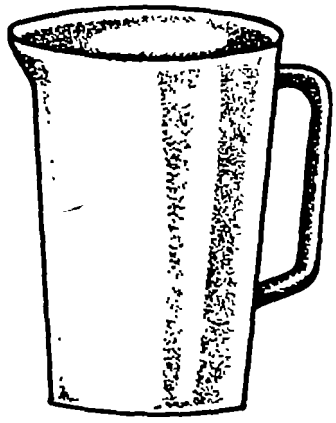
"Cora"

Enamel bowl (small) - 900 ml



"Cubbaya"

Tea cup - 150 ml



Jug - 2.4 l

Figure 13. Vessels commonly used for water (not to scale)

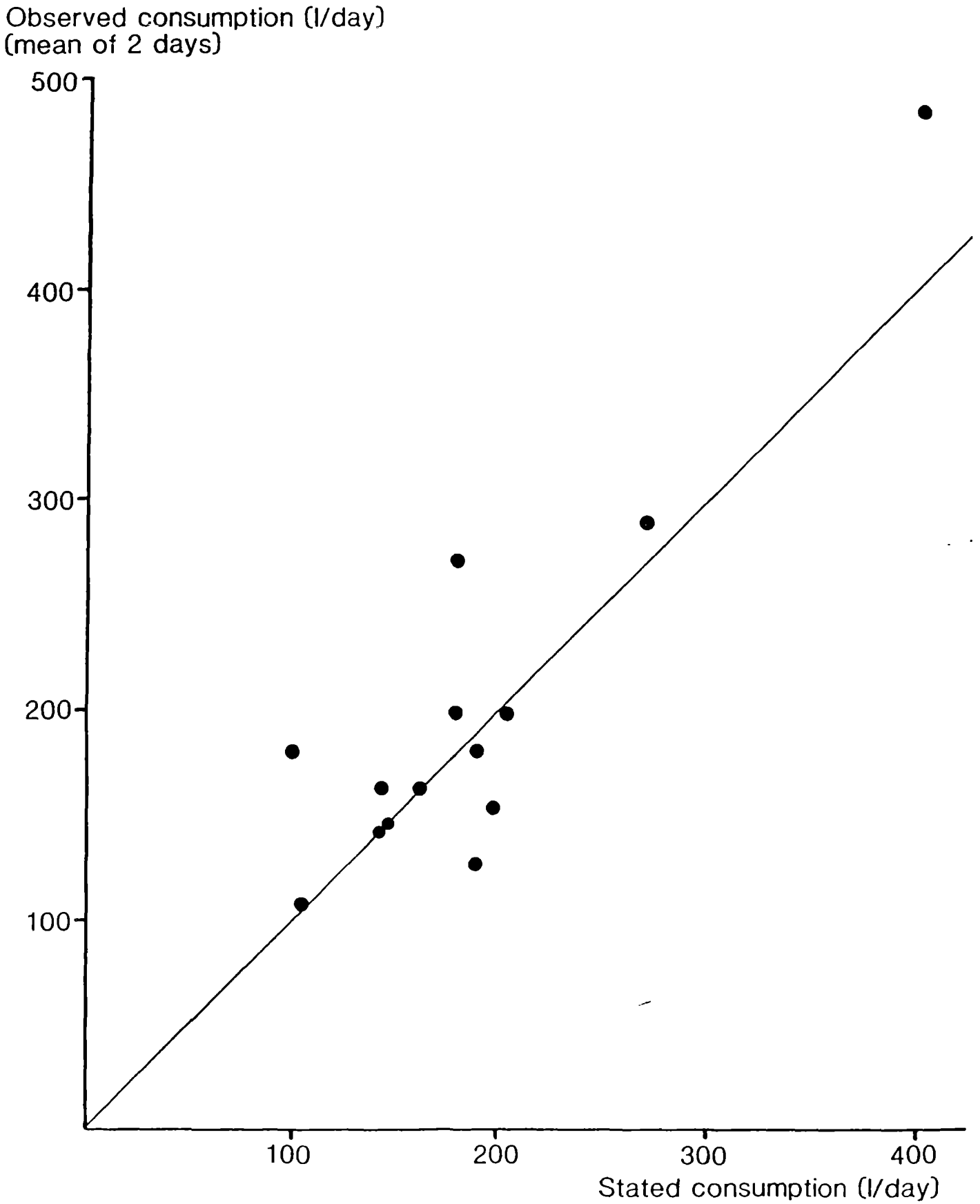


Figure 14. Comparison between stated and observed household consumption. All subsequent figures refer to stated consumption.

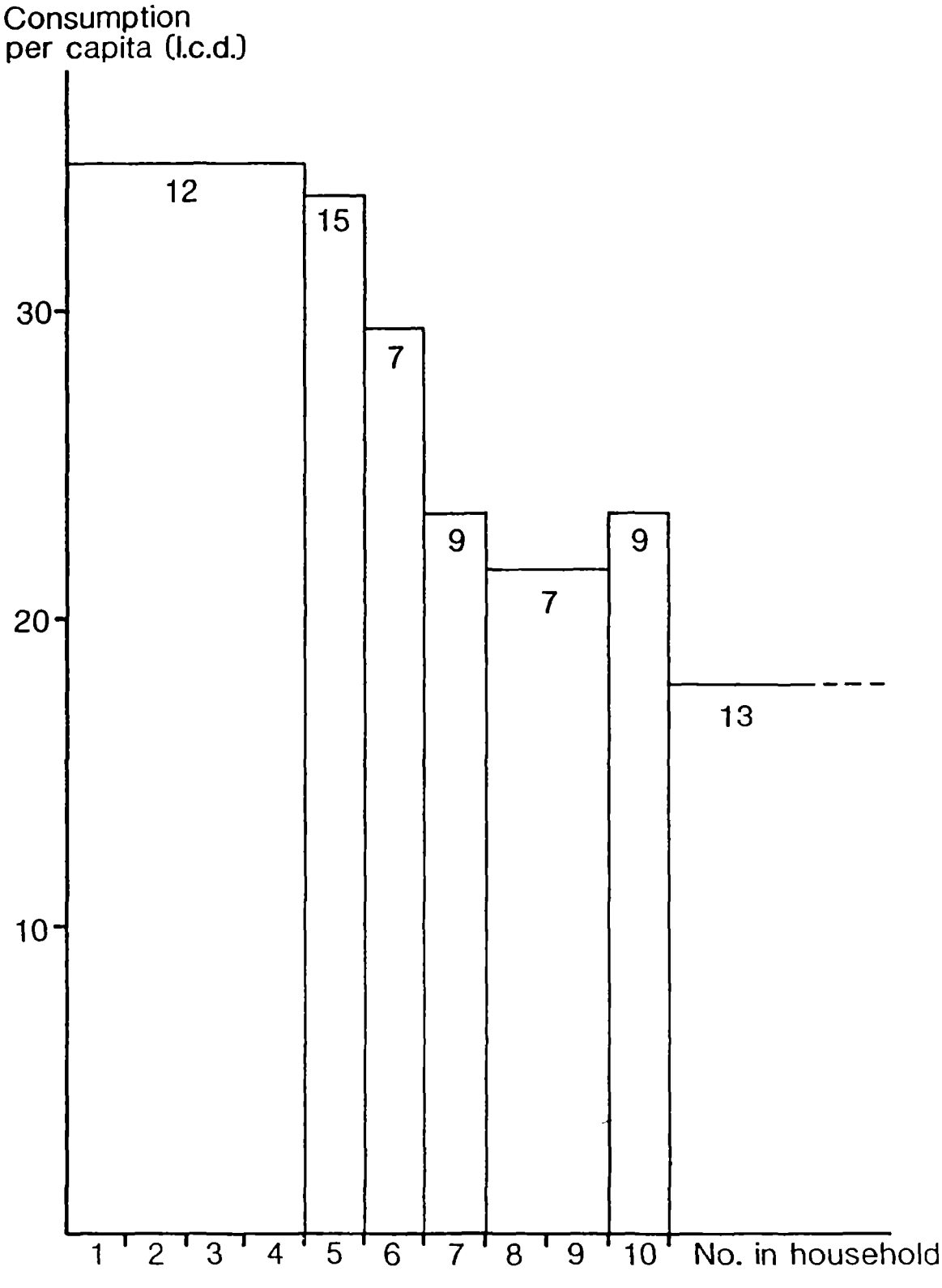


Figure 15. Relationship between per capita water consumption and household size. The numbers on the graph indicate the number of households in each range.

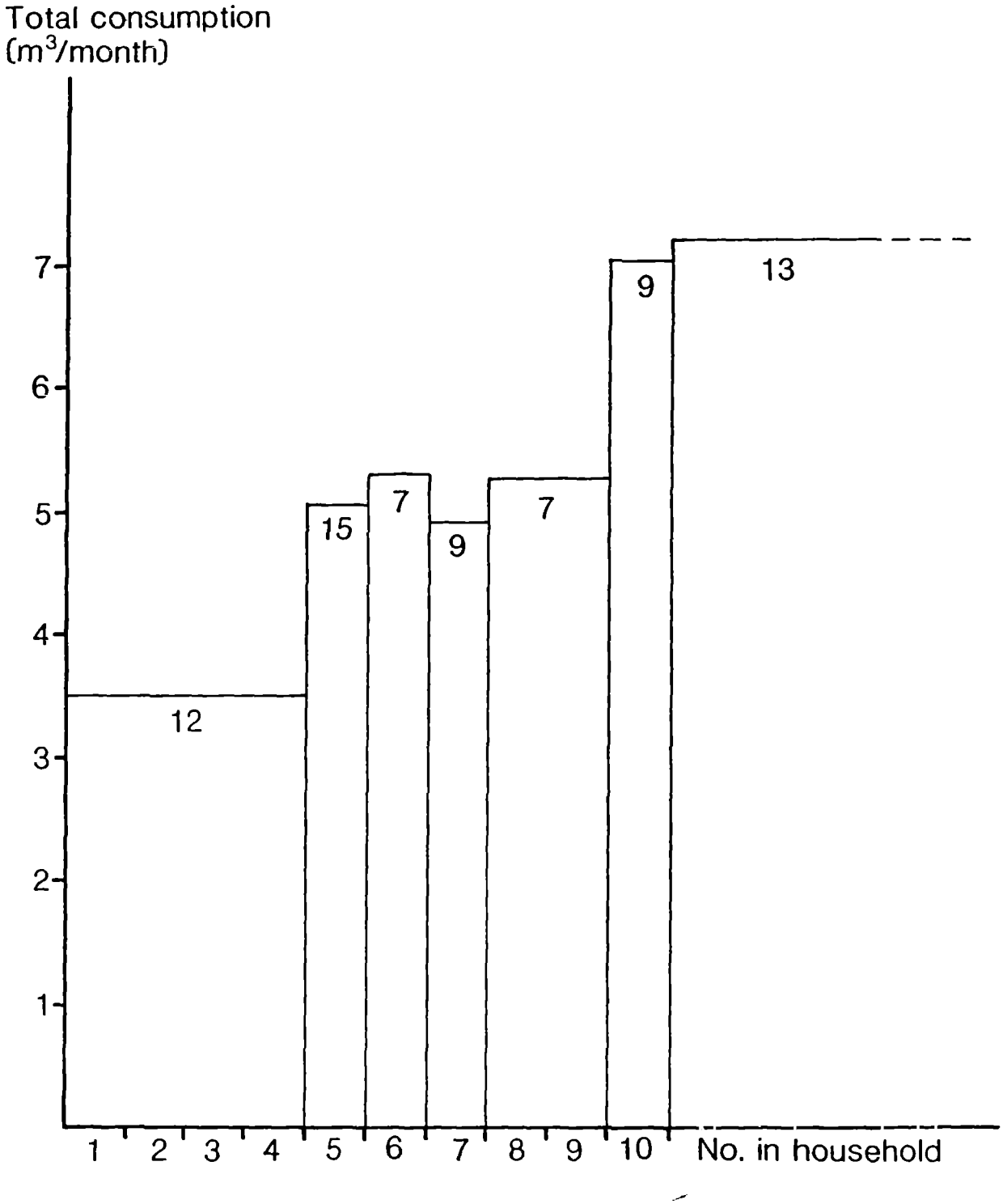


Figure 16. Total household consumption, plotted against household size. The numbers on the graph indicate the number of households in each range.

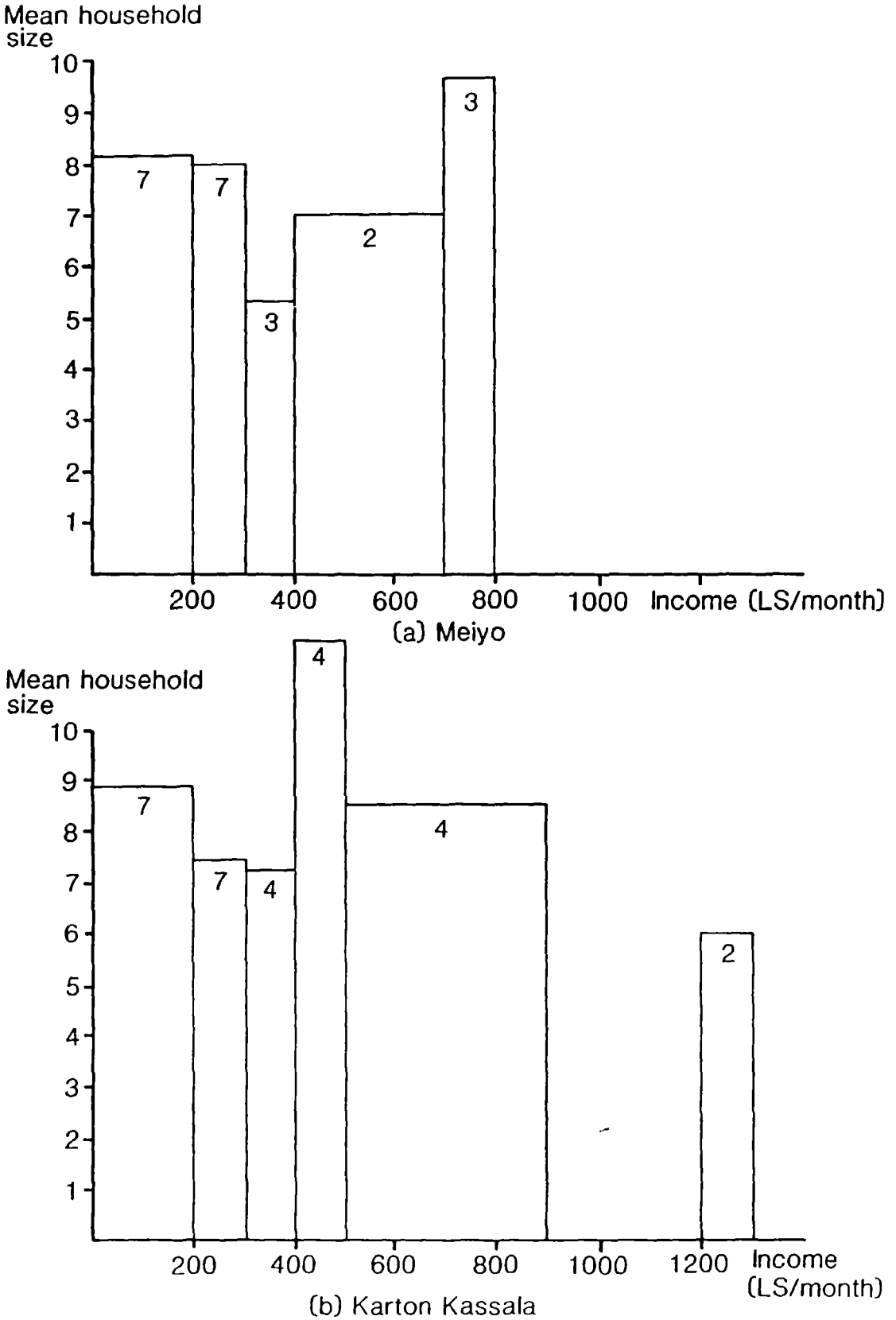
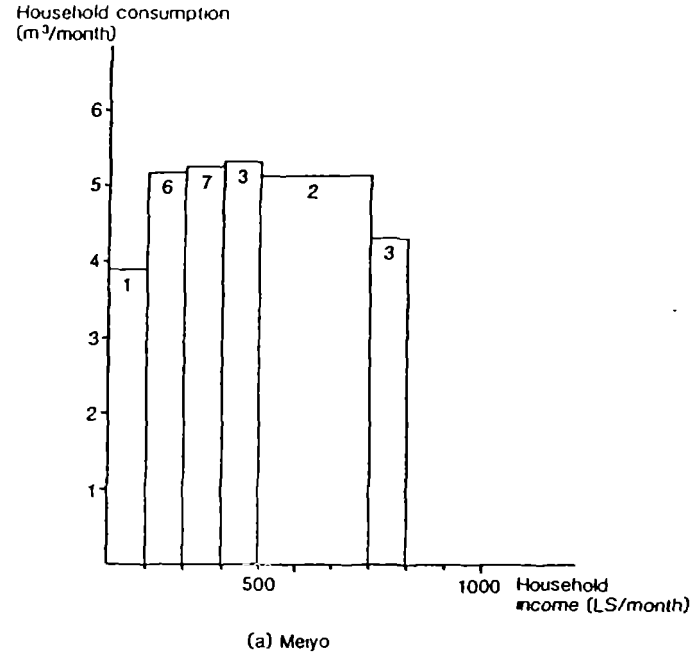
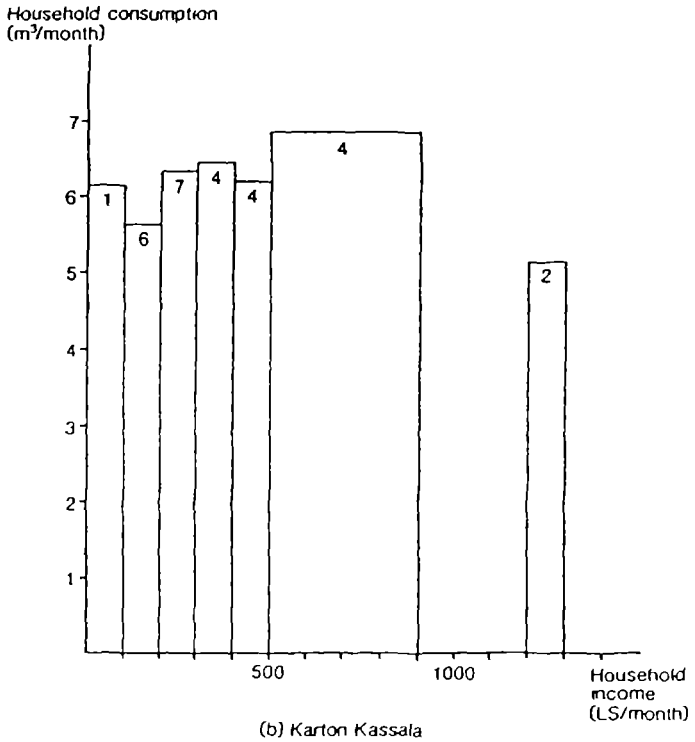


Figure 17. Household size plotted against income, for (a) Meiyo and (b) Karton Kassala. The numbers on each graph show the number of households in each income range.



(a) Meiyo



(b) Karton Kassala

Figure 18. Household water consumption plotted against income, for (a) Meiyo and (b) Karton Kassala.

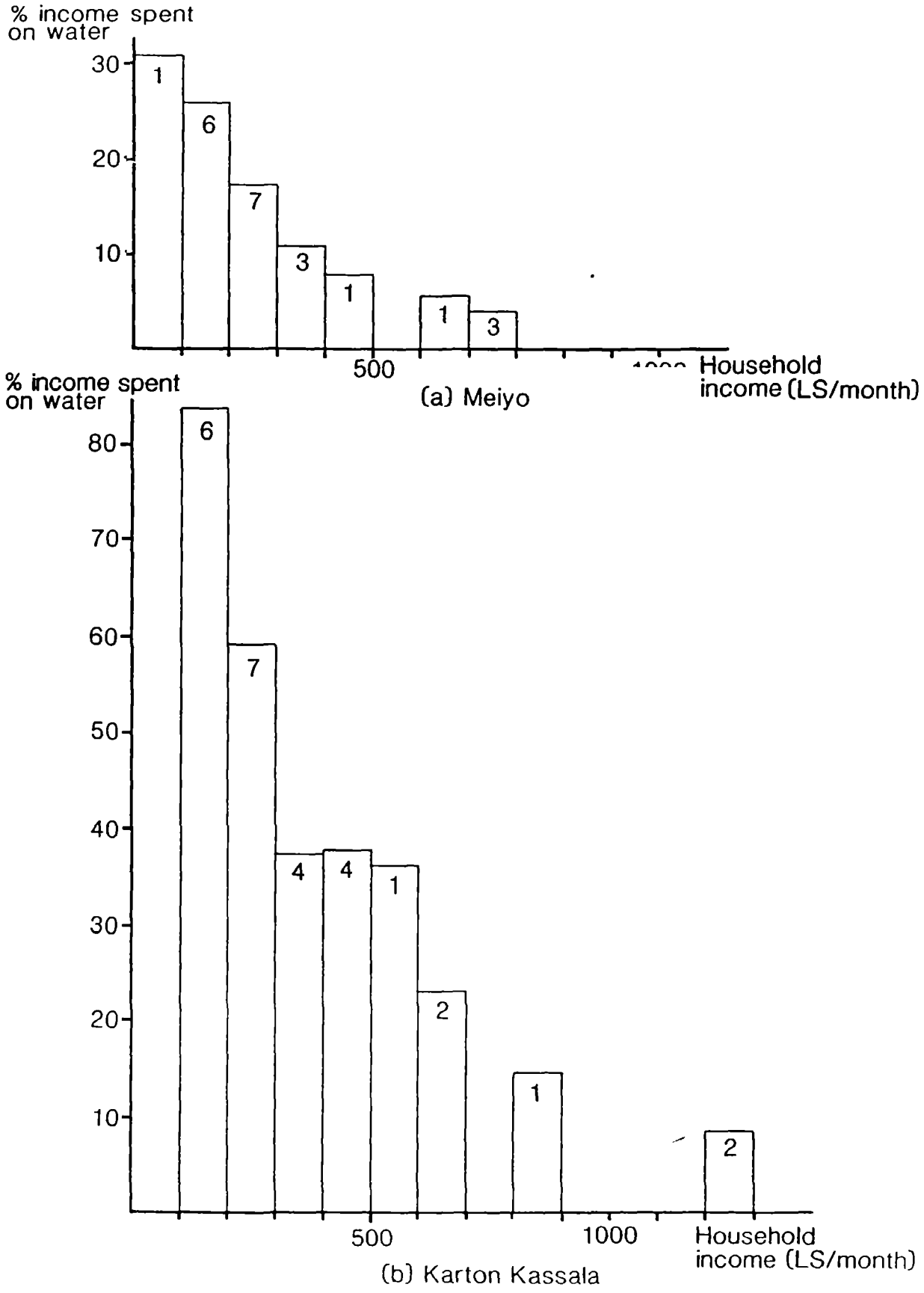


Figure 19. The proportion of household income spent on water, plotted against household income, in (a) Meiyo and (b) Karton Kassala.

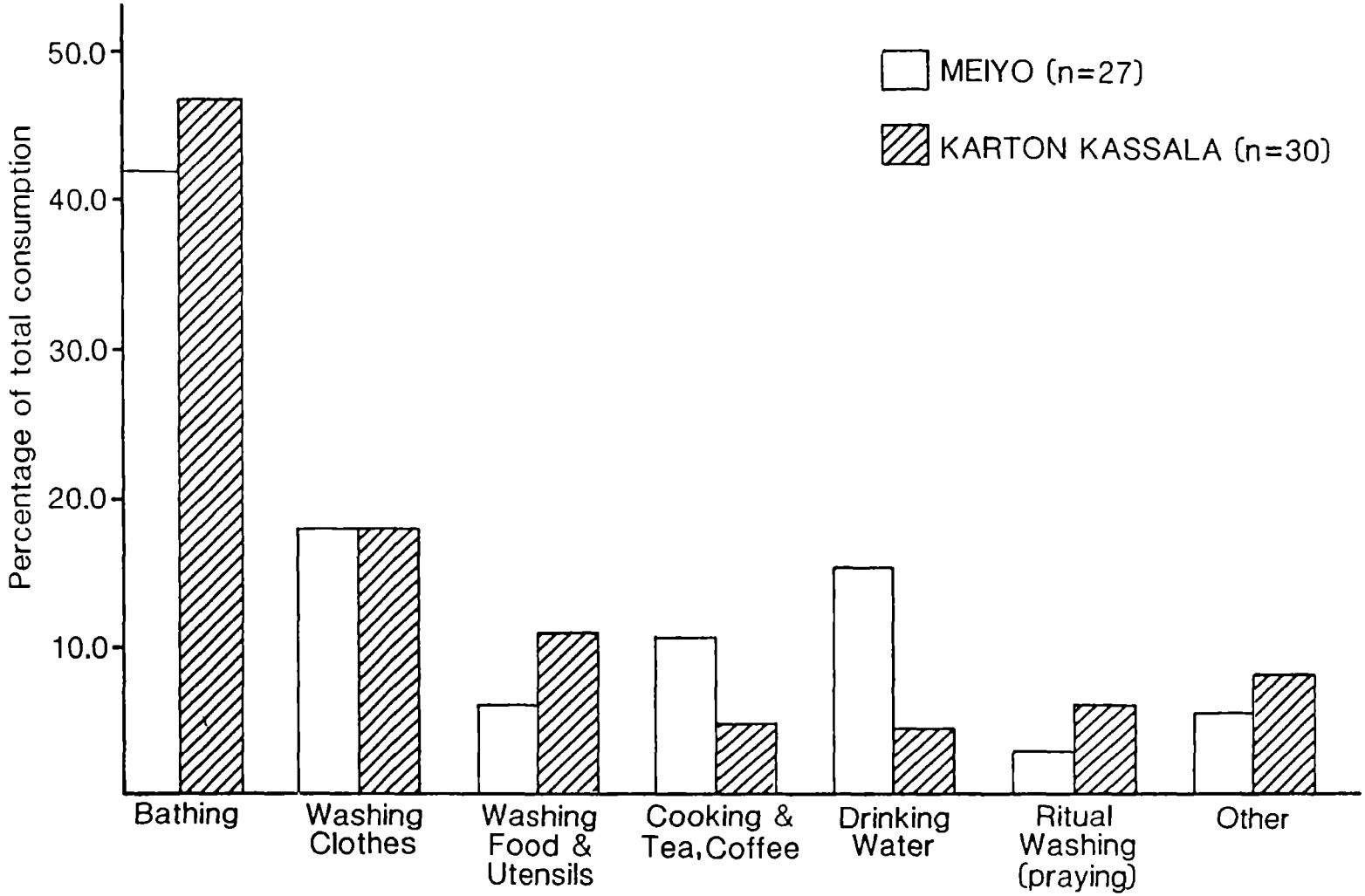


Figure 20. The proportion of water used for each purpose in Meiyo and Karton Kassala.

APPENDIX A

QUESTIONNAIRE USED IN

MEIYO AND KARTON KASSALA

Community : Quarter : H/HOLD NO :

Observer : Date : Time :

1. Where do you get your water from ? (caro, water collected from public tap, etc.)

Source	Distance	Cost per unit
1.		
2.		
3.		
⋮		

2. If you collect water, can you tell me :

containers used	size	description	collector

3. Do you use the same source winter and summer ?

If yes, go to 5

If no, fill in table4

4.

Time of year الفصل	main source المصدر الرئيسي	variation in price اختلافات السعر	variation in quantity used.
winter الشتاء			
summer الصيف			

5. Storage for water in the home

container	size	use of water from this container

6. Where are your water storage containers? (near latrine?)

7. Does anyone in your household make aragi or marisa?

If yes go to 8

8. How often do you make aragi/marisa? How much water do you use each time?

type of alcohol	quantity of water used	unit cost of water	frequency of brewing (per week)

9.

Drinking (unboiled)				
Cooking + tea, coffee				
Personal washing < 5				
5 - 14				
14 +				
Washing food + utensils *				
Washing clothes *				
Garden watering				
Livestock				
Brewing and industry				
Other				

* Note here if done at source ie. public tap.

10. Overall, are you satisfied with your existing water-supply?

Problems with existing water supply

	Yes / NO
danger to health	
looks dirty	
smells bad	
tastes bad	
inconvenient	
expensive	
cannot get enough	
other	

(List the worst three by number)

11. What do you think should be done to improve the water supply? (probe)

12. Do you do anything to make your water better to drink? (coagulant, boiling, filtering, leaving to stand, etc)

13 Do you go to the health clinic at Wahid Talateen for medical treatment?

If yes, for which diseases do you go there?

If no, why not?

14. What is the household's main source of income? (money from wage? money from other source? - marisa, aragi could be important sources of income)

15. Does any income come from selling food, vegetables etc. or rearing and selling of livestock?

If no, go to 16
If yes, fill in table below.

good	number	market value	sub-total
			Total

16. Is there anyone in this house who works for a wage?

16A. If yes, go to 17
If no, go to 18

17.

Type of job	Income /year

18. Do you send money to anyone who doesn't live with you?

19 Is there anyone who goes away to work and sends back money to contribute to the total household income? ie. does not live at home

If no, go to 20
If yes, explain below.

20 Of the total income, how much is available to you for household expenditure?

21. Type of Habitation

	Building	no. of rooms	walls	roof	floor	Windows	door
2							
3							

Size of compound

22. Does this house belong to you?

If yes, go to 23

If no, go to 24

23. How much is it worth?

24 Do you have any of these in your possession?

car ☐ bicycle ☐ donkey ☐

radio/cassette ☐ electricity ☐ latrine ☐

fridge ☐

Family name: Religion:

Tribe (ethnic origin): Nationality:

Informant:

Names of people in household	Relation to head of household	level of education	M F	age

APPENDIX B

SUMMARY OF HOUSEHOLD DATA-

TOTAL WATER USE

Total Water Use in Meiyo

House-hold no	Area of origin	House-hold size	Income/ month (LS)	Average daily use (litres)	(l c d)
1	Darfur	7	790	144	20 6
5	Darfur	5	150	105	21 0
11	Juba	4	150	177	44 0
14	Darfur	5	-	144	28 8
20	Wau	5	380	144	28 8
23	Juba	18	150	403	22 4
29	S Sudan E. Sudan	3	200	152	50 0
31	Chad	5	100	87	17 5
32	Burnu (Chad)	7	100	72	10 3
39	Nigeria	10	750	100	10.0
44	Nigeria	5	360	198	39 6
47	Nigeria	12	750	205	17.1
53	Nigeria	2	-	36	18 0
54	Nigeria	8	-	172	21 5
60	Nuba	6	200	180	30.0
62	Nuba	6	-	144	24 0
68	Arab	11	200	198	18.0
76	Arab	6	200	100	16 7
78	Tibin	11	250	150	13 6
84	Tibin	11	90	130	11 8
85	Tibin	5	480	180	36 0
89	Tibin	9	600	162	18 0
92	Tibin	7	150	190	27 1
100	Wihida N	12	200	270	22 5
104	Wihida N	6	300	190	31.7
111	Wihida N.	7	250	180	25 7
115	Wihida N	3	-	88	29 3

Total Water Use in Karton Kassala (cont)

House-hold no	Area of origin	House-hold size	Income/ month (LS)	Average daily use (litres)	Average daily use (l.c d)	Average price paid (LS/drum)	% canal water
28	Moroo	5	300	108	21 6	3-00	100
29	Moroo	6	180	216	36 0	3-16	92
30	Moroo	11	200	320	29 1	3-00	100
31	Moroo	5	-	126	25 2	3-86	57
32	Moroo	10	-	216	21 6	3-00	100
33	Moroo	7	-	130	18.6	5-00	0
34	Moroo	16	-	180	11 2	4-20	40
35	Moroo	7	-	108	15 4	3-00	100
36	Moroo	5	-	216	43 2	4-00	50
37	Moroo	6	-	180	30 0	4-20	40
38	Moroo	4	-	42	10 5	4-50	25
39	Moroo	5	-	216	43.2	3-00	100
40	Moroo	8	-	216	27 0	3-00	100
41	Moroo	6	-	226	37.7	4-92	4
42	Moroo	10	-	360	36 0	3-80	60
43	Moroo	5	-	216	43 2	3-00	100
44	Moroo	3	-	216	72.0	5-00	0
45	Moroo	4	-	155	38.7	3-80	60

Total Water Use in Karton Kassala

House-hold no	Area of origin	House-hold size	Income/ month (LS)	Average daily use (litres)	Average daily use (l c d)	Average price paid (LS/drum)	% canal water
1	Nuba	7	540	280	40 0	5-00	0
2	Nuba	5	1200	162	32 4	4-00	0
3	Nuba	10	650	244	24 4	5-00	0
4	Nuba	7	1280	180	25 7	5-00	0
5	Nuba	8	120	144	18 0	4-33	33
6	Nuba	8	60	204	25 5	5-00	0
7	Nuba	4	320	156	39.0	5-00	0
8	Nuba	4	450	117	29.2	5-00	0
9	Nuba	10	360	314	31 4	5-00	0
10	Nuba	5	600	100	20.0	5-00	0
11	Khoosa	8	400	117	14 6	5-00	0
12	Khoosa	14	400	294	21.0	6-00	0
13	Khoosa	2	250	48	24 0	3-00	100
14	Khoosa	21	400	294	14 0	5-00	0
15	Khoosa	5	280	312	62 4	5-00	0
16	Fur	10	390	279	27 9	4-00	50
17	Fur	7	120	192	27 4	5-00	0
18	Fur	10	150	244	24 4	5-00	0
19	Fur	3	-	108	36 0	5-00	0
20	Shiluk	10	200	180	18 0	5-00	0
21	Shiluk	19	150	217	11 4	4-00	50
22	Shiluk	11	200	180	16.4	5-00	0
23	Shiluk	10	-	180	18 0	4-60	20
24	Shiluk	4	150	108	27 0	4-50	24
25	Shiluk	8	240	216	27 0	5-00	0
26	Moroo	12	827	288	24 0	3-00	100
27	Moroo	5	200	216	43 2	5-00	0

APPENDIX C

SUMMARY OF HOUSEHOLD DATA:

DIVISION OF WATER USE

Division of water use in Meiyo

House-hold no.	No. of people				litres/household/day							Ave daily consump-tion per household (litres)
	5	5-14	14+	Total	Drinking (unboiled)	Cooking + tea, coffee	Washing food + utensils	Washing clothes	Bath-ing	Pray-ing	Live-stock	Other	
1	1	1	5	7	2 85	13 45	18 6	22.0	63 0	5 4	18 0	-	14-
5	2	2	1	5	4 5	6 1	18 0	27 0	37 0	3 0	-	9 -	10[illegible]
11	1	1	2	4	9 45	9 7	18 0	36 0	76 5	-	-	27 35	17[illegible]
14	0	0	5	5	16 1	3 0	23 0	31 7	63 0	6 0	-	0 9	14[illegible]
20	1	1	3	5	26 7	28 2	22 6	30 0	32 3	-	-	4 2	14[illegible]
23	3	2	13	18	26 0	27 3	33.3	36 0	279 0	-	-	-	403
29	1	0	2	3	1 35	4 0	18 5	15 0	81 0	12 0	-	20.6	152
31	2	1	2	5	1 8	4 8	7.2	12.0	54.0	6 0	-	-	87
32	3	2	2	7	1.2	2 9	10 0	18 0	24 5	12 0	4 5	-	72
39	3	3	4	10	2 85	10 1	2.4	9 0	63 0	12.0	-	0.3	100
44	0	1	4	5	1 9	22.7	17.0	10.0	47.5	12.0	54 0	33.0	198
47	1	5	6	12	8.85	8 7	10 65	12.0	143.5	18.0	-	-	205
53	0	0	2	2	1 05	2 4	5.4	10.0	9.0	6 0	-	-	36
54	0	2	6	8	8 5	6 15	20 85	36.0	90 0	9 0	-	-	172
60	1	0	5	6	3 6	11 75	10 5	36 0	109.0	12 0	2 4	6 5	180
62	0	2	4	6	8 1	5 5	22 5	30 0	42 75	-	-	35 15	144
68	1	3	7	11	15 05	9 55	16.95	28.0	102.6	25 0	0 6	-	198
76	2	2	2	6	7 5	1 9	20 4	18 0	35 0	9.0	-	8 0	100
78	1	4	6	11	7 5	14 05	20 3	24 0	76.5	9 0	-	-	150
84	1	3	7	11	10 2	5 7	14 7	35 0	54 5	-	-	10 0	130
85	2	1	2	5	11 1	7.7	18 35	41 2	58 5	3 0	36 0	-	180
89	0	3	6	9	2 4	8 2	5 0	15 0	117.0	12.0	0.6	-	162
92	1	2	4	7	6 3	4.05	10 65	18 0	114.0	18 0	-	18 0	190
100	2	4	6	12	18 0	4 2	20 1	54 0	112 5	13 5	2 4	45 3	270
104	0	2	4	6	6 6	4 35	11 0	18 0	122.0.	24 0	-	0 3	190
111	2	0	5	7	1.2	1 6	18.3	30 0	112 5	12.0	-	-	180
115	1	0	2	3	1 5	4 35	18.75	40.0	22 5	-	-	-	88

Division of water use in Karton Kassala

House-hold no.	No of people				litres/household/day								Ave daily consump-tion per household (litres)
	5	5-14	14+	Total	Drinking (unboiled)	Cooking + tea, coffee	Washing food + utensils	Washing clothes	Bath-ing	Pray-ing	Live-stock	Other	
1	3	0	4	7	54 0	54 0	18 0	54 0	90 0	6.0	-	-	280
2	1	0	4	5	10 2	18 0	9 0	72 0	40 5	12 0	-	-	162
3	3	5	2	10	11 6	35 0	10 4	18 0	108.0	24 0	36 0	-	244
4	1	4	2	7	21 0	18 0	14.3	54 0	40 5	12 0	18 0	-	180
5	0	3	5	8	15 7	17.3	9.0	36 0	63.0	-	0.6	3 4	144
6	2	2	4	8	9 2	18 0	8 3	28 6	108 0	12 0	18 0	1 9	204
7	1	0	3	4	5 7	9 8	9 0	36 0	55 2	12 0	18 0	9 0	156
8	2	0	2	4	23.5	10 1	9 0	19 7	18 0	9 0	18 0	9 0	117
9	2	4	4	10	48 0	27 0	9 0	54 0	126.0	24 0	18 0	8 0	314
10	1	0	4	5	16 0	8.3	9 0	27 0	36 6	-	-	2 5	100
11	1	1	6	8	8 7	11.1	7.3	18 0	63 0	9.0	-	-	117
12	1	4	9	14	24 0	18 0	9 0	36 0	207 0	-	-	-	294
13	0	0	2	2	12.0	9 0	2 4	2.5	18 0	-	-	5.0	48
14	5	5	11	21	19 7	36 0	18 0	40.0	162.0	-	18 0	-	294
15	2	2	1	5	90 0	36.0	18 0	36 0	90 0	24.0	18 0	-	312
16	3	3	4	10	36 0	36.0	18 0	54 0	126 0	-	4.5	4 5	279
17	1	3	3	7	36.0	19 5	7 3	27 0	72 0	12 0	18 0	-	192
18	2	6	2	10	33 5	14.0	9 0	16 8	108 0	24 0	36 0	-	244
19	1	0	2	3	24 0	8 0	9 0	6 5	45 0	-	15 0	-	108
20	1	5	4	10	36 0	9 0	9.0	36 0	90 0	-	-	-	180
21	3	3	13	19	54 0	10.0	9.0	36.0	108.0	-	-	-	217
22	7	0	4	11	36.0	18.0	9.0	44.0	72 0	-	-	-	180
23	2	2	6	10	24 0	18 0	9.0	36 0	90.0	-	-	-	180
24	1	0	3	4	17 0	18 0	4.0	26 0	36 0	-	4 6	2 5	108
25	1	2	5	8	36 0	18 0	9.0	33 0	117 0	-	-	3 0	216
26	1	5	6	12	54 0	36.0	18.0	24 0	155 0	-	-	-	288

Division of water use in Karton Kassala (cont)

House-hold no	No of people				litres/household/day								Ave daily consump-tion per household (litres)
	5	5-14	14+	Total	Drinking (unboiled)	Cooking + tea, coffee	Washing food + utensils	Washing clothes	Bath-ing	Pray-ing	Live-stock	Other	
27	0	2	3	5	54 0	22.4	36 0	31 0	72 0	-	-	-	216
28	1	1	3	5	20.0	10 5	8 0	36 0	33 5	-	-	-	108
29	1	0	5	6	18 0	36.0	18 0	48 0	94 5	-	-	-	216
30	2	4	5	11	72 0	36.0	18 0	21 0	171 0	-	-	-	320
31	1	1	3	5					72 0				126
32	3	4	3	10					90 0				216
33	2	1	4	7					99 0				130
34	1	2	13	16					130 5				180
35	2	2	3	7					72 0				108
36	0	2	3	5					72 0				216
37	1	2	3	6					72 0				180
38	0	1	3	4					36 0				42
39	1	0	4	5					81 0				216
40	1	0	7	8					108 0				216
41	3	1	2	6					72 0				226
42	4	4	2	10					90 0				360
43	2	1	2	5					63 0				216
44	0	1	2	3					54 0				216
45	1	0	3	4					63 0				155

[redacted]