Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

Informal Irrigation in peri-urban areas

A summary of findings and recommendations

G A Cornish
P Lawrence

KAR project R7132

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HR Wallingford

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Contract - Research

This report summarises the findings of the Knowledge and Research Contract R7132, Improved Irrigation in Peri-Urban Areas, carried out by the Water Management Department of HR Wallingford for the British Government's Department for International Development (DFID). The research objective was to improve understanding and knowledge of the productivity and hazards of peri-urban irrigated agriculture, with the aim of identifying measures to improve output whilst minimising risks to health and the environment. Fieldwork was conducted in and around Kumasi, Ghana, and Nairobi, Kenya.

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Executive Summary

Informal irrigation in peri-urban areas
A summary of findings and recommendations.

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Report OD 144

Although many agencies engaged in Urban and Peri-urban Agriculture (UPA) stress the importance of water as a production input, there is little detailed information available describing the use and management of this resource. To address this knowledge gap the British Government's Department for International Development (DFID) funded this research project to obtain quantitative and qualitative information on the productivity and constraints of *irrigated*, peri-urban agriculture.

Research was carried out over three years within a 40km radius from the centre of Kumasi, Ghana and within a 20 km radius from the centre of Nairobi, Kenya. Within these zones, pressures for land use change and the associated problems of insecurity of tenure and rising land values are confined to areas close to the city, but other urban influences – markets, services, input supply and resource pollution – are present throughout the zone.

The studies included the following activities:

- Rapid scoping and wide-scale farmer questionnaire surveys
- Detailed farm budget studies and wealth ranking surveys
- Water quality studies
- Workshops involving researchers, farmers and other stakeholders

This report draws together the key findings from the research and sets out recommendations derived from the study. More detailed information is contained in the reports listed in table 4 of the main report.

The studies have led to the following key conclusions:

- Informal Urban and Peri-urban Irrigated Agriculture (IUPIA) is widely practised, providing an important source of cash income to thousands of poor households in the urban and peri-urban zones of Nairobi and Kumasi.
- Despite this finding, and the level of interest in urban and peri-urban agriculture amongst donors and researchers, aspects relating specifically to irrigated cropping are widely overlooked by government ministries because:
  - Irrigation infrastructure is minimal and individual plots are small so it falls outside the remit of government irrigation departments.
  - Proximity to urban centres, combined with the focus on non-traditional crops, result in the sector being overlooked by over-stretched agricultural extension services that focus on traditional food and cash-cropping systems.

- City administrations are ill-equipped to address the needs of the sector and may ignore it or act against it when bylaws relating to land use are infringed, infrastructure is damaged, or concerns over consumer health are raised.

- Agronomic practices, including land preparation, crop husbandry and water management are often poor and farmers have little access to good information or demonstrations of good practice.
- Water sources used for irrigation are often highly polluted, posing a threat to the health of producers and consumers.
- Water scarcity or the lack of appropriate means to convey water from source to crop is often a critical factor that limits farmers' production.

The information from the individual studies, which is presented in this report, is summarised here.

The extent of informal urban and peri-urban irrigation and income generation

The extent and importance of informal, irrigated, peri-urban agriculture appears to be generally under-estimated in government statistics. Data from both cities show that informal irrigation is widely practised by individuals generally acting without support from government or NGO's, and is the primary source of cash income for over 80% of households involved. In the 40km radius around Kumasi there are estimated to be 12,700 households irrigating at least 11,900 ha. In the smaller study area around Nairobi (only ¼ that of Kumasi) at least 3,700 households irrigate 2,200 ha. To put this in perspective the total, formally irrigated, area reported by the Government of Ghana is just 6,400 ha. (Kenya reports approximately ten times this area with 66,600 ha, (FAO, 1995)).

Unlike other forms of urban and peri-urban agriculture, which are often valued for their direct contribution to family food security, access to irrigation facilitates production on a more commercial basis, generating a cash income. However, as yields are often low and the areas cultivated are small, returns remain low. Average family income generated from informal irrigated agriculture in Kumasi, where irrigation occurs over approximately 5 months (December – April) was $US 153, with the best performers achieving almost $US 360. In Nairobi, where irrigated production continues through the whole year, average annual income generated from informal irrigated agriculture was $US 279.

Farmer characteristics

Gender

In Kumasi, 86% of those managing an irrigated plot are men – by tradition women are engaged in production of household food crops, with men controlling cash crops. By contrast, the majority of irrigators in Nairobi (66%) are women.

Age and time irrigating

The average age of farmers in Kumasi is 37, and most are ethnic Asantes. These data tend to refute the suggestion made in earlier studies that intensive vegetable farming around Kumasi is a specialised activity carried out by young male *migrants*, farming on a "hit and run basis", moving to new areas when soil fertility reduces. Most farmers engaged in IUPIA are neither young nor migrants, and there is little evidence that migrant farmers are quicker to move on than indigenous farmers. Expansion of the area under informal irrigation has only occurred recently. Over 60% of villages report that the number of farmers practising dry season irrigation has increased significantly over the last 10 years.

In Nairobi, the average age of peri-urban farmers is 36, and 49% have been irrigating for 4 years or less.

Other occupations
90 % of those practising irrigated cropping describe it as their "main" occupation and in approximately 60% of cases irrigators report no second occupation. In both areas, 84 % of farmers listed irrigated vegetable production as the primary source of household income. Rainfed farming ranked second in importance as an income source in Kumasi but was insignificant as a source of income for households involved in IUPIA in Nairobi.

Wealth
In both Nairobi and Kumasi, irrigators tend to be classed, by their own communities, as having "average" or "above average" wealth, but it would be wrong to conclude a causal relationship between practising irrigated production and improving wealth status. It is more likely that because of the financial resources needed to engage in irrigated vegetable cropping, the opportunity is only open to such families.

Although judged by their communities' own standards to be of "average wealth", urban and peri-urban irrigators are still poor when judged by international standards. Income per head amongst Kumasi irrigators' households may be as low as 14 US cents per day, if it is (conservatively) assumed that irrigated cropping provides only half the total household income. This figure is well below the international poverty indicator of $US 1/head/day.

Land holdings and tenancy
A striking finding in Kumasi is that just over half those questioned are paying cash to rent land. As cash rental is not a feature of traditional Ghanaian farming systems these results indicate that customary land tenure arrangements are being transformed. The average rental cost is $US 15/ha/month although there is large variation around this mean. Cash rental is much less common in Nairobi – only 15% of the farmers surveyed rent land and the average monthly charge is $US 6/ha/month. Illegal squatting is widespread in Nairobi (39% of respondents) but there is little evidence that squatters are being regularly harassed or moved on.

The greater availability of land and water in the villages around Kumasi leads to larger average holdings of 0.9 ha. In the more urban context of Nairobi, where pressure on land is greater and water more scarce, holdings average just 0.6 ha. The same factors lead to greater mobility between plots in Kumasi than is seen in Nairobi.

Irrigation water management
Shallow groundwater drawn from dugouts is the most common water source in Kumasi but this is seldom available around Nairobi where the main sources are

rivers and abstraction from sewers – a water source used by 36% of farmers included in the surveys.

There are important differences in the conveyance methods used in the two study areas. In Kumasi "conventional" surface irrigation methods are not used, all irrigation is by overhead means, with water normally carried from the source in buckets and applied with watering cans. In Nairobi, use of open earth channels is commonplace. The use of motorised pumps is evident in both cities although in Kumasi only 5% of farmers own a pump, compared with 33% in Nairobi. However, occasional rental of pumps is more widespread in Kumasi.

Seasonal irrigation applications in Kumasi were found to be low. Farmers who make occasional use of pumps to supplement manual carrying applied an average of 1.1 mm/day over the dry season. Those irrigating only manually applied as little as 0.25 mm/day or less. It is likely that crops were exploiting water already held in the soil either from the previous rainy season or from permanent, shallow groundwater. The little irrigation that was applied assisted in early crop establishment and slowed the rate of depletion from the soil profile. In Nairobi, where the annual rainfall is much lower, irrigation applications were much higher, averaging about 3.5 mm/day, though depths of application varied between sites and according to the method of water conveyance. The hours of labour devoted to irrigation in the two cities reflect this pattern. In both locations irrigation was the greatest consumer of labour but in Nairobi this amounted to 1,530 hrs/ha (191 person-days/ha assuming 8 hrs continuous irrigation); whilst in Kumasi labour spent in irrigation was just half this at 860 hrs/ha or 107 person-days/ha.

Cropping practices and yields

In Kumasi, the quality of land preparation varies greatly between sites. In the majority of cases the natural vegetation is cleared away leaving a broken and uneven surface with a coarse tilth into which seedlings are transplanted. In a few cases, well-formed, flat-topped, raised beds are prepared with space between beds giving access for weeding and watering. Plot preparation and crop management generally appeared to be of a higher standard in Nairobi.

The most widely grown irrigated crops in Kumasi are, in descending order, tomato, garden egg, okra, hot pepper and cabbage. In Nairobi the most common are kale, tomato, spinach, maize and cabbage. Yield data obtained for tomato, garden egg and okra in Kumasi indicate that yields are low. Data collected in Nairobi suggest that while yields there are below the "expected range with good management" they are better than those seen in Kumasi. Direct comparison is only possible for tomato. In Kumasi the average yield was just 2.4 t/ha while in Nairobi it was 11.6 t/ha.

The picture emerges of households investing heavily in human and financial resources to grow irrigated vegetables but due to poor cropping practices and frequently limited water supply, yields are poor, although a cash profit is still possible. There appears to be a clear need for improved extension advice to growers alongside actions to improve water supply and management.

Farm budgets
The detailed farm budget studies showed the average cost of production in Kumasi to be $US 215/ha, with labour costs making up 57% of this total. The average profit, after costs were deducted from revenue, was $US 337 /ha. (The actual profit figure was $US 153 as the average plot size in this detailed study of 21 farmers was 0.46 ha). Access to a perennial water source and regular hire of a motorised pump does not lead to improved profitability – slightly improved revenues are more than outweighed by much higher production costs.

Farmers making profits substantially above these average values generally achieved average or above average yields for their dominant crop, but the greatest factor influencing their profit was the ability to sell consistently at above average prices. Better than average agronomic skills are not sufficient to ensure higher profitability – they must be matched by good marketing skills.

In Nairobi, detailed farm budget studies were carried out on just six farms and there was great variation in both costs and incomes across those six such that simple, average values would be misleading. The farm with the greatest profit of $US 1,380 also had the greatest costs, totalling $US 418. (This is equivalent to a profit/ha of $US 9,678 and expenditure of $US 2,923). This farm lies in the west of Nairobi where the water is relatively clean and it was the largest of the plots studied in Nairobi. However, location and access to water is no indication of actual profitability. The two farmers at Thiboro, in western Nairobi, with cleaner water, larger and better laid out plots returned the highest and lowest profits/ha of the sample. The two farmers at Maili Saba, using highly polluted water on small hillside plots to the east of Nairobi secured the second and fourth highest levels of profit/ha in the sample.

Paid labour was only used on the two larger plots to the west of Nairobi.

Marketing
In both cities individuals market produce – neither formal nor informal marketing groups have met with much success. Kumasi farmers are more inclined to transport some of their produce to market than is the case in Nairobi. In both locations individual consumers and traders buy produce from the field, though field sales to consumers are much more widespread in Nairobi than Kumasi. The Nairobi farmers do not rank marketing as a serious constraint to their enterprises – in constraints ranking it was last. By contrast, the producers around Kumasi ranked marketing as a major constraint, coming second only to credit provision. This is a consequence of the complex marketing arrangements involving “market queens”, travelling traders and central market traders who, between them, control prices paid to farmers. The farmers see themselves as being exploited by this well-entrenched system but have been unable to act against it, either individually or collectively.

Credit
In Nairobi, credit of any kind is seldom used and its absence is not regarded as a constraint. However, for growers around Kumasi, credit provision and marketing are strongly linked as the traders and market queens are widely used as a source of informal credit. Although this credit attracts no interest and requires no formal

collateral it ties the grower into an exclusive agreement with the trader to sell all produce through them.

Water quality
Targeted water sampling programmes were carried out in both cities to obtain basic data on the quality of water being used by irrigators. This information was compared with microbiological water quality guidelines set by the World Health Organisation (WHO), to provide an indication of the scale of risk to irrigators and consumers.

There appears to be little risk to irrigated crop production from the concentrations of heavy metals observed in Kumasi. In Nairobi, the concentrations of manganese and some other heavy metals could be toxic to plants and may pose an indirect threat to human health, although guidelines are lacking.

The data from Nairobi show generally very high levels of microbiological pollution. Numbers of faecal coliform in the Nairobi River to the east of the city centre are similar to effluent drawn directly from sewage mains at Maili Saba, and 19,000 times greater than the WHO recommended limit for unrestricted irrigation. Only the shallow well at Thiboro, upstream of Nairobi City, yielded water that lies close to the WHO guidelines, and even this exceeded the threshold on two sampling dates. In Kumasi, levels of pollution are generally lower with two sites upstream of the city centre lying on or about the WHO threshold value and even the worst site, downstream of Kumasi, exceeded the guideline by only 90 fold.

Risks to the health of irrigators who come into regular contact with these waters are beyond dispute. Where fresh salad and other vegetables likely to be eaten raw are irrigated there is also a clear danger to consumers. Even where produce is cooked before consumption, there remains a risk of disease transmission from the handling of dirty crops. Quantitative data on consumers' use of vegetables – cooked or eaten raw – and the distribution of crop types relative to water quality, remains to be obtained.

It is not easy to identify simple interventions that are likely to be acceptable to growers, consumers and municipal agencies. Many growers depend on the use of polluted water to sustain their livelihoods and any action to ban or restrict their production is unlikely to be effective. Possible policy and technical interventions are reviewed in section 11.

Farmers' perception of constraints
In Kumasi, the shortage or unavailability of credit is the outstanding constraint identified by all farmers, irrespective of their irrigation method, followed by marketing and access to water. Concerns over the unavailability of labour or land are of least concern for all farm types. For the majority of farmers reliant on manual carrying of water for irrigation, access to water is the second greatest constraint after credit. 80 to 85 % of the farmers questioned believe they are constrained by their water supply – they cannot apply as much as they would like, their yield is affected by water shortage or water supply limits the area they cultivate.

In Nairobi, obtaining an adequate supply of water is the primary constraint. Obtaining other inputs, such as seed and agro-chemicals, is also a serious constraint. As the farms included in this study are close to the urban centre, theft of crops and equipment and damage to crops are also significant issues. In contrast to Kumasi, neither credit nor marketing is ranked as a significant constraint.

Options for improvement

Water quality

Programmes aimed at reducing the health risks associated with irrigated urban and peri-urban agriculture must be broad-based, with technical interventions and institutional change working in parallel. They must provide an incentive for producers and consumers to change current practices and make change possible, without those groups incurring high additional costs. The technical and institutional resources needed to eliminate the use of polluted water for crop irrigation by informal irrigators should not be underestimated.

Raising the awareness of producers and consumers of the health risks associated with the use of polluted water for vegetable irrigation can provide an incentive for change amongst consumers, traders and growers. Traders may be encouraged to maintain improved levels of hygiene in the storage, washing and presentation of produce – avoiding the use of dirty water to freshen produce. To achieve this market traders must have easy access to clean water supplies. The traders may also pass on the demand of consumers to growers, seeking only to buy produce from farmers using clean water.

Where farmers are pressed by traders to supply “clean” produce or where premium prices are paid for “safe” produce they have an incentive to use clean water sources. However, alternative, cleaner water sources must be available to them and if premium prices are to be paid, consumers need some form of assurance, through a system of certification, that produce has been grown using clean water.

The provision of clean water sources is a major challenge. Water drawn from shallow wells or dugouts might be expected to be less polluted than that in rivers draining urban centres, but the studies in both cities showed the mean faecal coliform count in all monitored wells to exceed the WHO guideline for unrestricted irrigation. There is a need for field research to determine if simple protection measures, combined with awareness raising amongst farmers, can raise the water quality from these wells to a level that consistently lies within the WHO guideline.

In the short term, to provide existing irrigators with a water source of improved quality, some form of simple and low cost treatment must be available at the point of use, i.e. after water is abstracted from the watercourse and before application to the crop.

Actions such as short term retention of water in pools and the current practice of holding water in field side drums before applying it to the crop merit further evaluation to determine their effects on levels of pathogen die-off. Approaches such as these merit research and field evaluation with farmers, but actions must be low cost, or, where this is not possible, the farmer must be able to receive a premium for the financial and labour investments made in cleaning the water supply. This can probably only be brought about through awareness raising campaigns and effective crop certification programmes.

Improved water availability

In Kumasi, 70% of irrigators stated that the physical effort or the cost of paying labour limited the amount of water applied to crops. In Nairobi, only 12 % of respondents said that the effort of irrigation limited their cultivated area, whilst 24% referred to the water source drying up. Thus, in Kumasi, the effort of irrigation severely constrains production while in Nairobi water scarcity is a greater constraint.

There appears to be considerable potential in Kumasi for demonstrating and evaluating the acceptability to farmers of low-cost water lifting devices such as treadle pumps. These pumps can reduce the drudgery and effort required of those carrying water, and considerably improve the productivity of irrigation labour. Unlike motorised pumps, they can be used in combination with shallow dugouts – one of the most common sources of water.

There was no evidence in either city of small dams being used by communities or farmer groups to retain water for dry season irrigation. Construction of such dams requires adequate technical supervision in site selection, dam design and construction, but these skills exist within the public and private sectors. It should not prove too difficult to use these agencies to implement such an intervention to improve the availability of water for urban and peri-urban irrigation. However, attention would need to be given to determining if irrigators would welcome such intervention, which would have to be managed on a communal basis. The number of technically appropriate sites may be limited in some localities but small dams are certainly an intervention worthy of further evaluation by both government departments and NGOs.

Improved agronomic practices

Knowledge of good agronomic practices, from the preparation and care of nursery beds, planting densities, weed and disease control, and water management through to the maintenance or improvement of soil fertility by use of manures, compost and inorganic fertilisers, is generally poor amongst urban and peri-urban irrigators. Developing and promoting good extension materials and establishing farmer groups to receive and evaluate extension advice is probably one of the most effective short-term interventions, with the objective of increasing productivity and improving farmer income from informal irrigation, that is available.

Credit

This was only an issue in Kumasi, where existing, formal micro-credit provision through the Poverty Alleviation Fund is widely discredited as being too politicised. While communities shared a common opinion that the vegetable farmers should co-operate to strengthen their bargaining powers in obtaining formal financial assistance, there are only a few cases where this approach had been successfully adopted, and formation of groups was not received very enthusiastically by farmers at the project workshop.

Improved access to credit could be provided through formal and semi-formal micro-credit arrangements purposely tuned for IUPIA and channelled through the banks or well-established NGOs. Impartial monitoring and control would be essential to ensure that the facility achieves its purpose.

Marketing

Again, marketing is only seen as a constraint in Kumasi. There is potential for farmers to work together to plan production schedules to coincide with periods of price peaks but more particularly to regularly obtain and compare price information from several market centres. Where farmers can avoid being "locked in" to selling into a single market, access to such market information, provided it can be coupled with access to traders from the alternative markets, could enable farmer groups to exploit regional variations in supply and demand of fresh produce.

Formation of farmer co-operatives capable of negotiating better prices with the traders and market queens is an obvious option but has proved difficult to achieve in practice, and this suggestion was not received very enthusiastically by farmers attending the Kumasi workshops.

Exchange rates and Acronyms

Exchange rates used in this report

Nairobi detailed study 2000 US$1 = KSh78.8
Kumasi detailed study 2000 US$1 = Cedi 4380

Acronyms

IUPIA	Informal urban and peri-urban irrigated agriculture
MPN	Most probable number
NRI	Natural Resources Institute, Chatham
WHO	World Health Organisation
UNEP	United Nations Environment Programme

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1. INTRODUCTION

1.1 Background

There is growing recognition of the importance of informal agriculture practised in the urban and peri-urban zones of cities in the developing world. Although many agencies engaged in Urban and Peri-urban Agriculture (UPA) stress the importance of water as an input to urban and peri-urban agricultural production, there is little published or on-going research that focuses on the informal irrigated sector. Although water is often acknowledged as an essential input, it is usually only considered in detail with regard to water quality and health. To address this knowledge gap, the British Government's Department for International Development (DFID) funded a three-year research project to obtain quantitative and qualitative information on the productivity and constraints of *irrigated* peri-urban agriculture.

The outputs anticipated in the project logical framework were:

1. Quantitative data on productive output per unit of water and land of peri-urban irrigation identified. Socio-economic and environmental constraints identified.

2. Practical measures to sustain and enhance productivity of peri-urban irrigation identified and reported.

3. Results disseminated to NGOs, governments and funding agencies.

1.2 Informal Urban and Peri-Urban Irrigated Agriculture (IUPIA)

The project focussed on Informal Urban and Peri-urban Irrigated Agriculture (IUPIA), an identifiable component of the larger urban and peri-urban agricultural sector, (UPA). A distinction is made between formal and informal irrigation, whereby informal irrigators have little or no assistance or support from government or other agencies and are generally not dependent on any purpose-built, fixed structure for water conveyance. A further distinction is made between irrigated and non-irrigated agriculture. Irrigated agriculture has been taken to include agriculture where the supply of water, in addition to direct rainfall and residual moisture, is a major component of farm activities.

1.3 Extent of the peri-urban zone

Different workers have used different definitions of the peri-urban zone. The NRI Peri-Urban Baseline Study of Kumasi used the following definition:

> "The peri-urban interface is defined by strong urban influences, easy access to markets, services and other inputs, ready supplies of labour, but relative shortages of land and risks from pollution and urban growth". (Holland *et al.* 1996)

The size and shape of the "peri-urban footprint" surrounding a city depends to a large extent on the indicators that are selected to carry out the characterisation. For example, the zone affected by waterborne urban pollution will lie downstream from a city, while a peri-urban zone defined on the basis of access to markets may be so large as to extend across national boundaries. The delineation of the peri-urban area is further complicated by the shifting nature of land zones within and around cities and towns as they expand.

Urban agriculture is mostly characterised by small-scale, non-commercial production providing food primarily for the household, and is carried out on vacant lots, gardens or roadside verges. Peri-urban agriculture is found in the urban hinterland – a zone influenced by the presence of the urban centre, but often rural or semi-rural in appearance. Production is carried out on a larger scale, with most produce being sold to generate a cash income. Exceptions to these general rules can be readily identified. For example, the urban plots located on main roads that grow and sell ornamental plants for sale that are widespread in Nairobi, or vegetables produced for sale on vacant housing lots in affluent residential areas in both Kumasi and Nairobi, are urban and commercial.

We have adopted a pragmatic approach in defining the boundaries of the study areas. This was based, in part, on a characterisation of irrigated agricultural production systems, but also influenced by the finite resources available to the project for farmer surveys and other studies, which inevitably placed a limit on the size of the area that could be covered.

For the Kumasi study, following Blake *et al,* (1997), we studied informal irrigation practices occurring within a 40 km radius of Kumasi centre. Within this area, pressure on land use and the associated problems of insecurity of tenure and rising land values are generally only seen in the villages close to Kumasi, but other influences – markets, services, provision of inputs and resource pollution – are significant throughout the area. For Nairobi, where significant irrigation activities occur close to the city centre, a geographical limit of a 20 km radius from the centre of Nairobi was taken which broadly coincides with the limits of Nairobi City.

1.4 Summary project description

The project consisted of four components, mostly carried out in both study areas, which are summarised in Tables 1 and 2.

Table 1 Summary of project components

Component	Activities
Literature reviews, scoping and farmer questionnaire surveys	Quantification of the extent of informal irrigated agriculture in the study zones.
	Collection and analysis of socio-economic data from farmers involved in informal irrigated vegetable production, detailing irrigation and water management practices and farmers' perceptions of constraints.
Detailed farm budget and wealth ranking surveys	Collection and analysis of specific information on agricultural practices, use of family and external labour and other inputs, farm budgets, and incomes derived from irrigated vegetable production in the informal sector.
	Wealth ranking in communities involved in IUPIA.
	Preliminary study of credit and marketing issues (in Kumasi).
Water quality studies	Literature review on wastewater re-use, particularly as it relates to uncontrolled use of polluted water for informal irrigation in peri-urban areas.
	Targeted water sampling and analysis programmes providing an indication of the physical, chemical and microbiological quality of waters used for irrigation.
Workshops	Interim Kumasi workshop – feedback and discussion of initial results by researchers and farmers, verification with farmers of initial Kumasi findings.
	Final workshop – feedback and discussion of results to a wider group, including project collaborators, participants representing researchers, government departments, NGOs, international organisations, (FAO and IWMI) plus some of the farmers involved in the Kumasi study.

Table 2 Scale and timing of field studies

	Initial questionnaire survey	Detailed studies	Water quality sampling
Nairobi	June – August 1999. 152 farmers from 34 production areas.	June – September 2000. 6 farmers at 3 locations.	August – September 2000. 5 sampling sites sampled on 10 dates.
Kumasi	November 1998 – January 1999. 410 farmers from 64 villages and 6 city centre sites.	November 1999 – June 2000. 21 farmers from 3 villages.	February – March 1999. 9 sampling sites sampled on 5 dates.

1.5 Study areas

Selected basic characteristics of the two study areas are summarised in Table 3.

Table 3 Selected physical characteristics of the two study cities

	Kumasi	Nairobi
Average annual rainfall (mm)	1345	680
Dry season	November – March	June - October
Elevation (m)	280	1640
Population	0.7 million	2 million
Principal irrigated crops	Tomato, garden egg, okra, chilli pepper	Kale, tomato, cabbage, spinach
Piped sewage for large parts of city	No	Yes

1.5.1 Kumasi

Kumasi is the second largest city in Ghana with a population of about 700,000 (including the city, suburbs and settled commuter areas). It is located in the tropical forest eco-zone about 300 km north west of Accra, at an altitude of 280 m. The average rainfall of 1,345 mm is weakly bi-modal with a principal wet season between March and June, and a subsidiary wet period between September and November. The city lies across a drainage divide. Much of the drainage from the metropolitan area flows to the south into the Sisa-Oda system. A small portion of the northwest of the city, including the environmentally important Suame Magazine vehicle breaking area, drains to the northwest into the catchment of the Owabi dam and thence into the Ofin River. The terrain is generally moderately dissected with slopes of 5 % to 15 % and has a local amplitude of relief of up to 30 m. There are large numbers of small second and third order streams, some of which dry up during the dry season. The larger streams are perennial.

A wide range of irrigated crops, the most popular being tomato, garden egg, okra and hot pepper, are grown between mid-December to mid-March. However, crops established under irrigation are still being marketed in May and June.

1.5.2 Nairobi

Nairobi is located at an elevation of 1,670 m, has a population of two million people, and covers an area of around 700 square kilometres. It extends from the foothills of the Aberdares in the north, to the Ngong Hills in the south, and from the Embakasi plains in the east, up to the slopes of the Great Rift Valley wall in the west. The average annual rainfall of 680 mm follows a seasonal pattern, with the "long" rains falling between March and May, and "short" rains between October and December. Most irrigation activity occurs during the driest months between June and September, although for more than 90% of farmers irrigation is a year round activity. Over 50 different crops are grown, ranging from local subsistence crops such as maize and kales, through to exotic vegetables such as celery and Chinese cabbage. The most widely grown crops are kales, tomatoes, cabbage and spinach.

Four main rivers flow from west to east through the centre of Nairobi. The Mathare River lies furthest to the north, and enters the Nairobi River just downstream of the city centre. The Montoine River lies to the south of Nairobi River, and becomes the Ngong River downstream of Nairobi dam. The Ngong River flows into the Nairobi River east of the city. Several smaller tributaries drain into the four rivers along their course. Urbanisation is occurring at a rapid rate. Large quantities of raw sewage and household waste drain directly into the city's rivers from housing estates and slums located along their banks and untreated industrial effluents are discharged into the rivers. There is concern that their waters are unsuitable for irrigation. A significant number of farmers irrigate with raw sewage diverted from the city's sewage mains.

1.6 This report

The first sections of this report (chapters 2 to 10) present a summary of the key results from studies carried out in Kumasi and Nairobi. More information on the methodologies adopted and detailed results are available in a series of technical reports listed below. These can also be downloaded from the HR Wallingford web site:
http://www.hrwallingford.co.uk/dissemination/reports/catchments.html#DFIDreports.

Table 4 Project reports available from HR Wallingford

Report No	Referenced as	Title
OD/TN 95 Sept 1999	Cornish *et al*, (1999)	Water quality and peri-urban irrigation: An assessment of surface water quality used for irrigation and its implications for human health in the peri-urban zone of Kumasi
OD/TN 97 March 2000	Cornish and Aidoo, (2000)	Informal irrigation in the peri-urban zone of Kumasi: Findings from an initial questionnaire survey
OD/TN 98 March 2000	Hide and Kimani (2000)	Informal irrigation in the peri-urban zone of Nairobi, Kenya: Findings from an initial questionnaire survey
OD/TN 103 February 2001	Cornish *et al*, (2001)	Informal irrigation in the peri-urban zone of Kumasi: An analysis of farmer activity and productivity
OD/TN 104 April 2001	Hide, Kimani and Kimani, (2001).	Informal irrigation in the peri-urban zone of Nairobi, Kenya: An analysis of farmer activity and productivity
OD/TN 105 April 2001	Hide, Hide and Kimani, (2001)	Informal irrigation in the peri-urban zone of Nairobi, Kenya: An assessment of surface water quality used for irrigation
April 2001	HR Wallingford, (2001)	Informal peri-urban irrigated agriculture: Opportunities and Constraints. Proceedings of a workshop held at KNUST, Ghana, 7 – 9 March 2001

The last section of the report, chapter 11, develops recommendations based on the study findings for practical measures to sustain and enhance the productivity of peri-urban irrigation. Issues requiring further investigation are identified in this section.

2. EXTENT OF IUPIA IN KUMASI AND NAIROBI

Estimates of the areal extent and contribution to incomes of farming families involved in IUPIA are presented in this section.

2.1 Areas of irrigated production

The areal extent and number of households reliant on IUPIA within the study areas can be estimated from the data collected in the initial studies and reported in Cornish and Aidoo (2000) and Hide and Kimani (2000). Summary data are given in Table 5, while the location of significant IUPIA activities identified in the study areas are shown in Figures 1 and 2.

As the number of households involved in IUPIA within the study area are known to be underestimated, (Cornish and Aidoo, 2000; Hide and Kimani, 2000), the figures for both irrigated areas and numbers of farmers should be regarded as a lower bound to the actual areas and numbers in the study zones.

Table 5 Extent of informal irrigation in the study areas

City	Gross study area, including built up areas. (km^2)	Mean irrigated plot area[1] (ha)	Median range of irrigated plot area (ha)	Minimum number of households involved in IUPIA	Estimated minimum area of IUPIA (ha)
Kumasi	5,027	0.94	0.25<0.49	12,700	11,900
Nairobi	1,257	0.60	0.1 <0.24	3,700	2,220

Note: 1. Estimates are based on sampling of 410 farmers in Kumasi and 158 farmers in Nairobi. Estimates of the mean farm area used to estimate the areal extent of IUPIA have an uncertainty at the 95 % confidence level of around +- 10 % for Kumasi and +- 25 % for Nairobi.

2.1.1 Extent and expansion of IUPIA in Kumasi

The large area of informal irrigation within a 40km radius of Kumasi contrasts with the 6,400 ha under formal irrigation reported in FAO's statistics for the whole of Ghana (FAO, 1995). Kumasi alone supports an area of informal irrigation almost twice that of all formal irrigation in the country and further substantial areas of informal irrigation exist around Accra and Takoradi.

Traditionally, a small amount of irrigation has always been carried out in the dry season, usually by women, to grow chillies and tomatoes for household consumption. It is only more recently that small-scale, more commercial production has developed, carried out mostly by men. In 40% of the villages visited, some irrigation has been practised for at least the last 30 years, but 60% of the communities report that the number of farmers involved in irrigation has increased significantly since 1990. This reported recent expansion of IUPIA is illustrated in Figure 3.

2.1.2 Extent of IUPIA in Nairobi

The smaller area of informal irrigation identified around Nairobi was recorded over a much smaller study area. When this is taken into account the extent of IUPIA is only slightly less than that seen around Kumasi. (In Kumasi, the irrigated area is estimated to be 2.4% of the study area; in Nairobi it is 1.8%.) Figures on irrigated areas in Kenya for 1998 reported by the Ministry of Agriculture and Rural Development (Cited by Muchangi in HR Wallingford, 2001) identify only 1,500 ha of Urban and Peri-urban irrigation for the whole country. This study identified more than 2,200 ha of informal irrigated agriculture within 20 km of the centre of Nairobi. As in Ghana, it seems that the extent and importance of IUPIA is under-reported in government statistics.

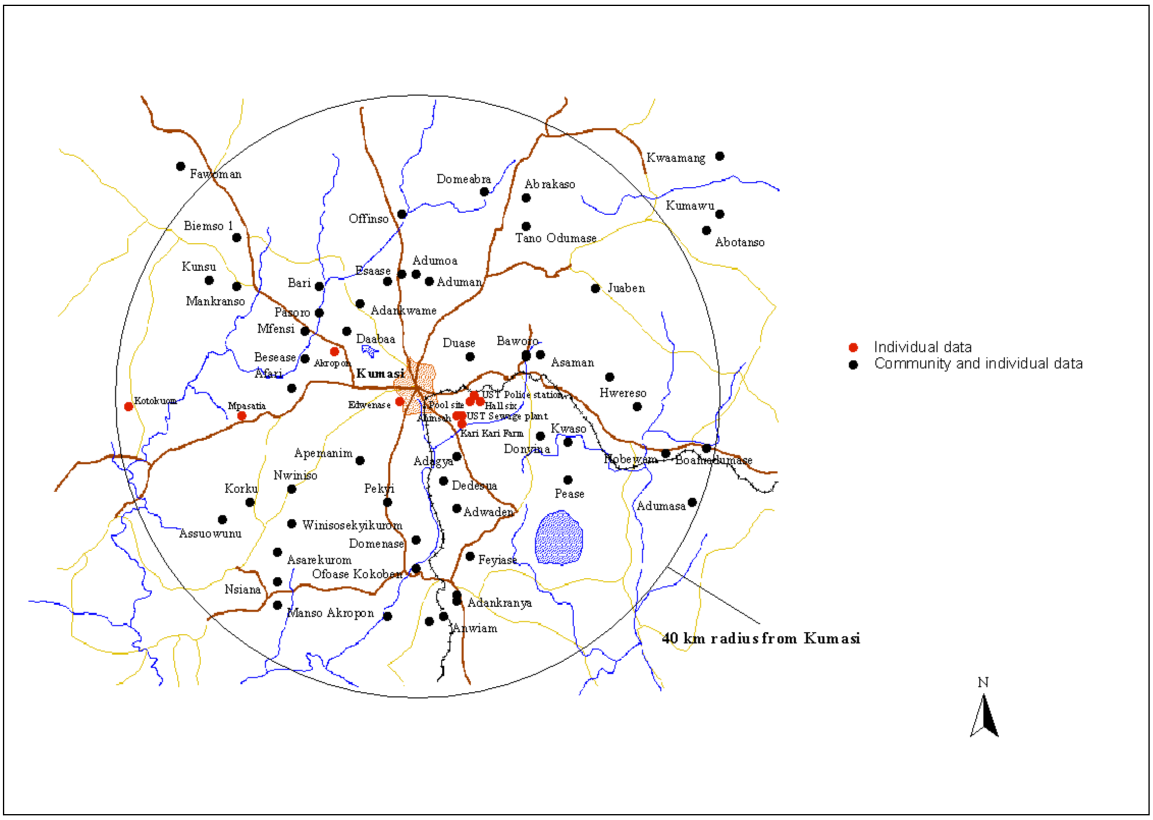


Figure 1 Locations of IUPIA activities, Kumasi

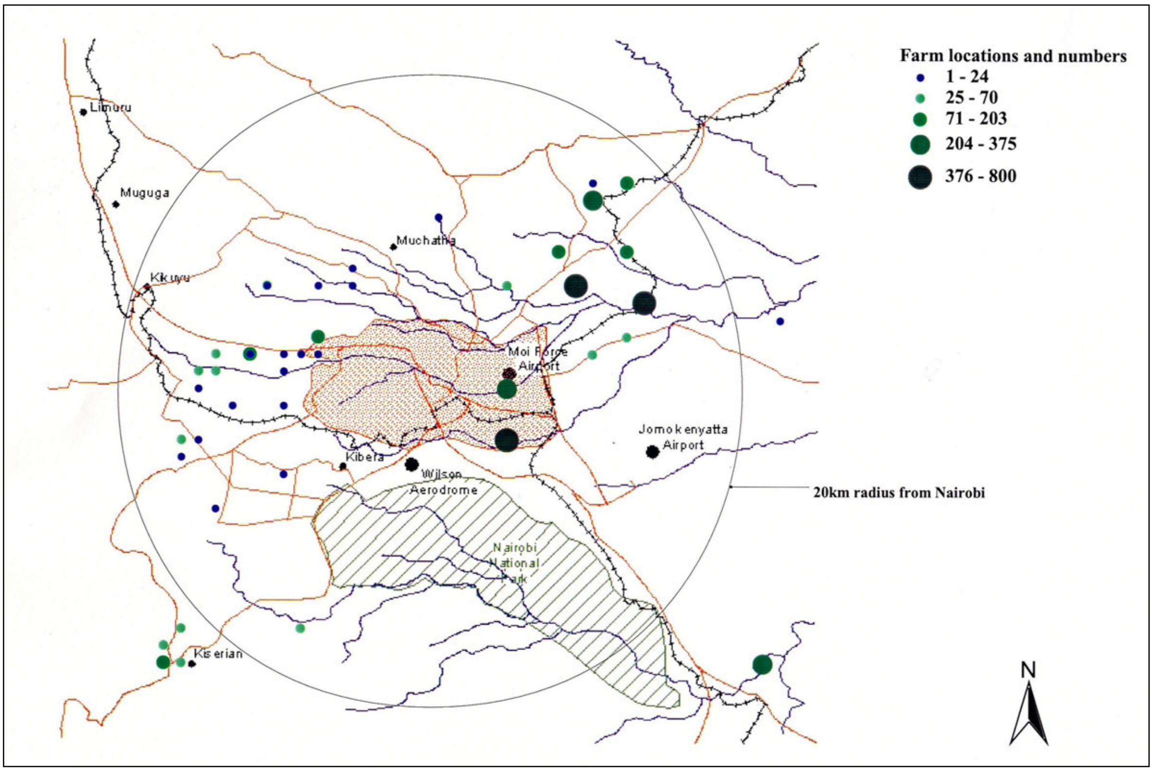


Figure 2 Locations of IUPIA activities, Nairobi

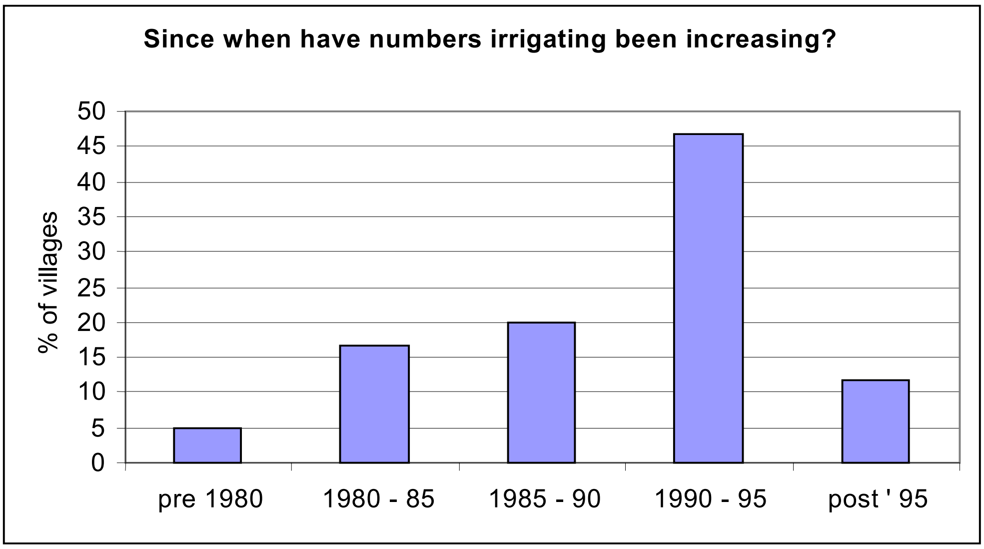


Figure 3 Increase in number of farmers irrigating vegetables, Kumasi.

2.2 Revenue and profits from IUPIA

In Kumasi, 84% of farmers interviewed in the initial survey, all of whom practised irrigation, reported that the sale of irrigated vegetables provides the largest source of cash income to the household. The proportion of produce consumed by the household is a small fraction of the total production, although the beneficial contribution of fresh vegetables to the household diet should not be overlooked.

The detailed studies of 21 farmers, reported by Cornish *et al.* (2001) indicate that the average revenue from irrigated cropping in 2000 was $US 559/ha. Average profit (revenue minus cash costs of production) was $US 340/ha. If the irrigated area within the 40km radius is 11,900 ha, then the value of production will be about $US 6.7 million, and the profits from IUPIA over the study area will have been at least US$ 4 million.

In Nairobi, the same percentage of farmers (84%) reported that profits from the sale of irrigated vegetables provided their main source of income. The average revenue per farm derived from the initial questionnaire was $US 1,696/ha, while the annual revenue for IUPIA derived from more detailed questioning of nineteen farmers during the wealth ranking study, reported in Hide, Kimani and Kimani, (2001), was $US 3,040 /ha. These figures are substantially larger than the revenues generated in Kumasi. However, it should be noted that while irrigated vegetable production is a year round activity in Nairobi, it is only carried out during the relatively short dry season in Kumasi.

Detailed farm budget studies in Nairobi involved only six farmers –too small a sample to derive a valid indication of the profits generated by IUPIA over the Nairobi study zone. However, the detailed budgets indicate a mean ratio of profit to revenue of 0.61, the same as in Kumasi. Using this ratio, with the information on revenues derived from the wealth ranking study reported in Hide and Kimani (2000), profits generated by IUPIA in the Nairobi study zone could be in excess of $US 4 million.

3. CHARACTERISATION OF FARMERS INVOLVED IN IUPIA

Some key results derived from surveys of 410 farmers in the Kumasi study area and 158 farmers in the Nairobi study areas are listed in Table 1 of Annex 1 where mean data are tabulated. (See Cornish and Aidoo, 2000 and Hide and Kimani, 2000 for more detailed information.)

3.1 Gender

Farmers producing irrigated vegetables in the Kumasi study area are mostly men (86%), although approximately a third of those interviewed indicated that they work jointly with their spouse. This contrasts with traditional bush fallow cultivation systems in Ghana that provide food for the household, which is seen as women's activity. Men usually grow cash crops, although women and children provide a substantial proportion of labour required. More information on the division of men's and women's labour in IUPIA activities is given in section 5.4.

In contrast to Kumasi, nearly two-thirds of the farmers interviewed in the Nairobi study area were women. Similar proportions of men and women farmers were recorded in a wider study of the smallholder irrigated sector in Kenya. (Chancellor and Hide, 1997).

3.2 Age and ethnicity

The average age of farmers in Kumasi is 37. Women farmers, who may be divorced or widowed, tend to be older, (44). Most Kumasi farmers (89%) are ethnic Asantes, who report their region of origin as the Asante region (88%). These data tend to refute the suggestion (made in Brook and Davila*,* 2000 and earlier NRI reports) that intensive vegetable farming around Kumasi is a specialised activity carried out by young male *migrants*, farming on a "hit and run basis", moving to new areas when soil fertility reduces. Most farmers engaged in IUPIA are neither young nor migrants, and there is little evidence that migrant farmers are quicker to move on than indigenous farmers. 43 % of indigenous farmers have farmed their present plot for 3 years or less, compared with 48 % of migrants.

Farmers in Nairobi tend to be younger than Kumasi, – 34% are aged between 20 and 29 whilst the average age is 36. On average, women farmers are younger than men farmers. 71% are Kikuyu, reflecting the fact that Nairobi is situated in the Kikuyu lands. Only 4% of farmers were born in Nairobi itself. The vast majority of farmers practising irrigated farming in and around the city have moved towards the city from more rural locations. The average length of time farmers have lived in Nairobi is 18 years.

3.3 Main occupations and sources of income

In both areas, about 90% of farmers listed farming as their main occupation, with a high proportion of farmers in Nairobi (67%) having no other occupation. In Kumasi, farmers had a wide range of secondary occupations, the most frequently cited being trading. In both areas, 84 % of farmers listed irrigated vegetable production as the primary source of household income. Rainfed farming ranked second in importance as an income source in Kumasi, but was insignificant as a source of income for households involved in IUPIA in Nairobi.

3.4 Wealth ranking

Using communities' own assessments of wealth and poverty, just over two thirds (68%) of households in the Kumasi study area fall into the "average wealth" category. (From a survey of 1,400 households located in five villages, reported in Cornish *et al.* (2001)) Average wealth is the category that the communities regard as providing generally adequate housing, and access to sufficient cash and other resources to engage in farming, put their children through school and provide adequate clothing. Of the remaining households, 3% are classed by their peers as being of above-average wealth and 29% are of below-average wealth. The last group is characterised by very poor housing, little access to land, being regularly in debt and seldom able to pay school fees or communal levies.

Irrigators tend to be slightly wealthier than the community as a whole, with a lower percentage of irrigators in the "below-average" group and a larger percentage in the "average" and "above-average" groups, as Figure 4 illustrates.

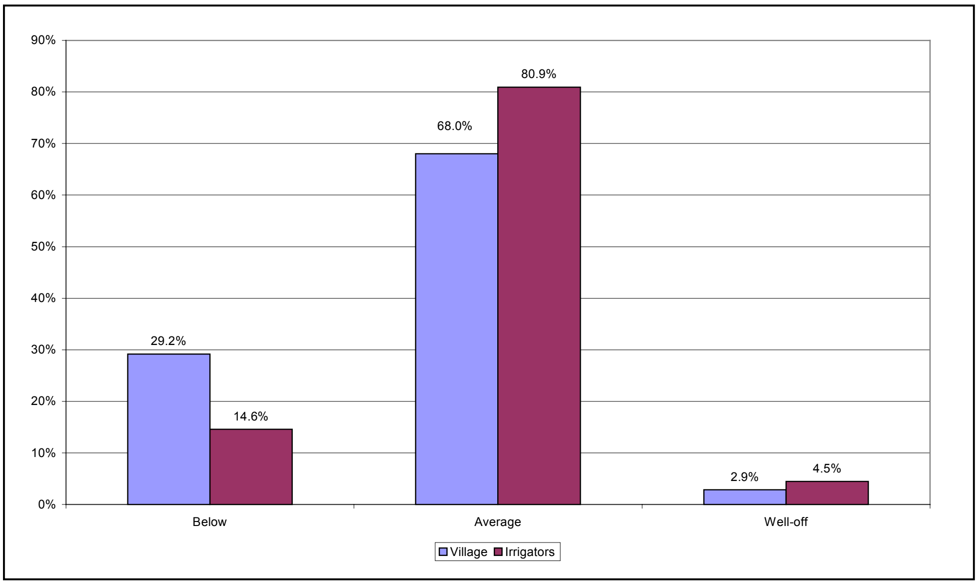


Figure 4 Relative wealth of irrigators and non-irrigators – Kumasi

To put these results in perspective, the average profit of the farmers involved in the farm budget studies described later was $US 152. The average household size in the sample consisted of six members. Based on the conservative estimate that profits from IUPIA represent only 50% of the total annual household cash income, the annual income *per head* of average households would be $US 51. This represents an income well below the international poverty indicator of $US 1/head/day. Data on household income distribution for Kumasi indicates that household income in the lowest quintile, in 1993, was $US 405, (Brook and Davila, 2000), i.e. substantially greater than a conservative estimate for the average income for households engaged in UIPIA in 2000.

A smaller wealth ranking exercise carried out in Nairobi, with a sample of thirty farmers from three locations, provided similar results. Farmers producing irrigated vegetables tend to be comparatively better off in terms of wealth status than non-farmers. Irrigators occupied the top half of positions in the wealth ranking whilst non-farmers occupied the bottom eight positions. This pattern was true at each of the three sites.

These data do not necessarily indicate that irrigated vegetable farming leads to improved wealth. It is more likely that a certain level of wealth is needed in order to become an irrigator.

4. LAND HOLDINGS AND TENANCY

A summary of key data derived from the initial questionnaires and reported in Cornish and Aidoo, 2000 and Hide and Kimani, 2000, is listed in Table 2 of Annex 1. There are many similarities between the two locations, but also some striking differences, particularly in land tenure arrangements as Figure 5 shows.

While the proportion of land owned by farmers, or farmed under share-cropping arrangements are similar, (30%), more than half of Kumasi farmers pay cash to rent land. As cash renting is not a common feature of traditional Ghanaian farming systems, these results indicate that customary land tenure arrangements are being transformed. For irrigated vegetable cultivation cash tenure is short, the most common period being only 3 months. The cost of land rental varied considerably, with a few farmers reporting rents greater than $US 70/ha/month, but 60% of respondents pay less than $US 10/ha/month. The average was $US 15 /ha/month.

In Nairobi, 39% of the respondents reported that they were squatters. This proportion corresponds approximately with the proportion of farmers stating that the land they cultivate is owned by government or the Nairobi City Council. Tenancy arrangements for 11% of the Nairobi sample could not be clarified, possibly reflecting the reluctance of some farmers to admit that they are squatting on government land. Cash tenants represent only 15% of farmers, and where land is rented on a cash basis annual rents per ha vary from less than US$25 to over $300. The average rent paid is $75 per ha per year. This is equivalent to a monthly rent of $US 6.25, and indicates that land rental costs are lower in Nairobi than Kumasi.

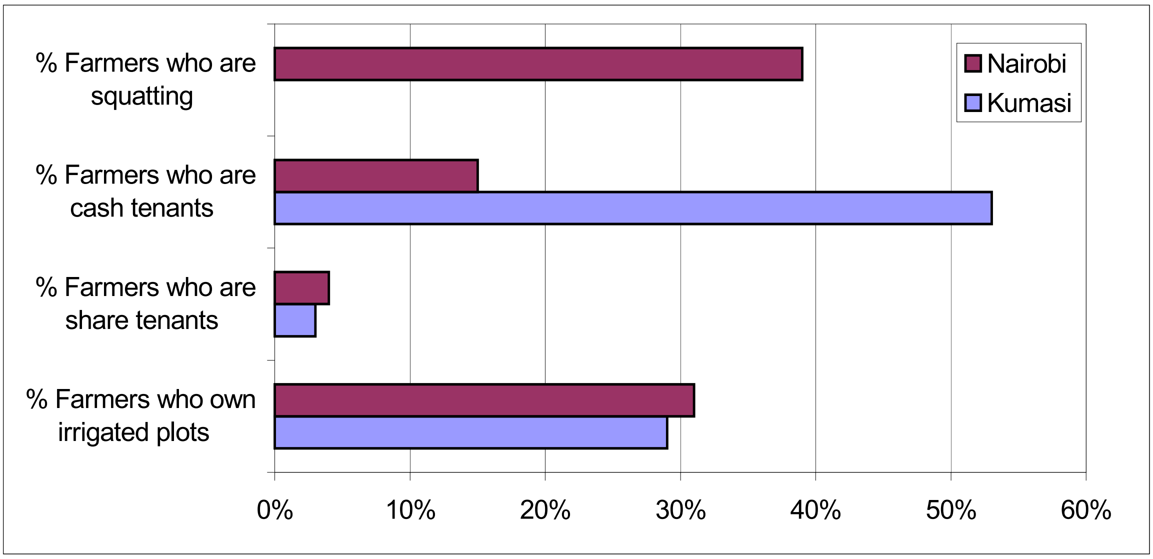


Figure 5 Percentage of farmers with different tenurial status

In Kumasi, 20% of IUPIA practitioners farm only irrigated plots, having broken completely with the traditional rainfed cropping practices of the region. The other 80% hold both irrigated and rainfed land. In Nairobi, a far larger proportion of farmers (55%) are engaged solely in IUPIA, reflecting, in part, the lower rainfall in Nairobi and thus a greater reliance on irrigated production.

Irrigated plot sizes tend to be larger in Kumasi (0.9 ha), where there appears to be no shortage of land to rent, than in Nairobi (0.6 ha).

Farmers in Kumasi had been irrigating on average for 10½ years, but only about half this time on their current plot(s) (5.8 years). The length of time that any single plot has been cultivated under irrigation varies considerably. In both centres, 30% of the plots had been cultivated by the farmer questioned for two years or less. Kumasi farmers indicated that many of them would move to a new plot once yields started to diminish, and the widespread use of short-term, cash tenancies facilitates this.

There appears to be much less mobility in Nairobi, as evidenced by similarity in the number of years irrigating and the number of years irrigating the same plot, and the longer average period that irrigated plots had been farmed. There is little evidence in the Nairobi data to support an assumption that squatters have lower security of tenure, and thus move more frequently than land owners. The average period that land owners had been farming at a single location (8.2 years), is only slightly longer than for squatters, (7.2 years).

5. IRRIGATION AND AGRONOMIC PRACTICES

5.1 Water management

Irrigation water is obtained from a range of sources, conveyed to the fields and applied to the crops using a number of different methods, as described in Cornish and Aidoo, (2000) and Hide and Kimani, (2000) and summarised in Tables 3, 4 and 5 of Annex 1.

5.1.1 Water sources

In Kumasi, rivers and shallow groundwater provide water for 91% of farmers engaged in IUPIA. About 55% of farmers rely on dugout wells (1 or 2 m deep hand dug wells located adjacent to a water course or in a natural depression), at some time during the season, making this by far the most common water source. Many of the farmers use streams or pools early in the season, but rely on dugouts as the streams dry up. Pump operators draw water mainly from the perennial rivers (68%) or from stream pools (21%).

About half the Nairobi farmers obtain water from streams with only a small percentage (5%) using pools or dugouts. The striking feature of the Nairobi findings is the high proportion of farmers (36%) who irrigate with raw or partially treated sewage. This is obtained either directly from settlement ponds, or from the sewers carrying sewage to the main Nairobi sewage works located to the east of the city. These are blocked and the vents broken, allowing sewage to flow along contour canals that have been constructed along the upper edge of the irrigated area (See Figure 6).

Figure 6 Sewage diverted for irrigation from a vent, Nairobi

5.1.2 Conveyance methods

In Kumasi, more than 80 % of farmers carry water manually from the source to the field. The distance that water is carried varies between individuals, with about 50% of farmers moving water less than 50m. However, the average distance that water is carried is about 200m.

The physical work and effort involved in lifting and carrying water long distances over uneven and rough ground is one of the striking features of these studies. It is not surprising that almost 70% of the farmers said that the effort required to carry water limits the area they cultivate. More than 80 % reported that access to water constrained the area that could be cultivated, or limited the quantity of water that could be supplied and thus reduced yields.

Only 5% of Kumasi farmers own their own pumps, but a further 18 % report that they have hired pumps. (The data in Table 4 of Annex 1 for pump use may not have captured some farmers who rely mostly on manual carrying but are occasional pump hirers.) None of the farmers using motorised pumps draw water from dugouts, as these shallow wells do not give sufficient yield for pumps to be used.

In Nairobi, the most common method of conveying water to the fields is by gravity channel, this method being used on 42% of farms. Almost all farmers using sewage water use this method, which has clear advantages when contact with polluted water has to be minimised. Pumps are used by 38% of farmers (33% own their own pumps and only 5 % hire), whilst just over a quarter (26%) carry water to their fields manually. Distances from water source to plot are generally much less than for Kumasi, with 91% of farmers conveying water less than 50 m.

There are therefore important differences in the conveyance methods used in the two study areas. In Kumasi, there is no use of “conventional” surface irrigation methods where water is channelled over the ground; all irrigation is by overhead means. The use of motorised pumps is also more restricted in Kumasi, with only 5% of farmers owning their own, compared with 33% in Nairobi. However the rental of pumps is more widespread in Kumasi.

5.1.3 Water application

The majority of farmers apply water to the crops with watering cans, or with buckets and perforated tins in Kumasi . These are filled directly at the water source, or with water carried from the source and stored in an oil drum located on the plot. Pump irrigators normally use 50mm uPVC pipes to convey the water from the pump to the field, and connect a short length of 50mm lay-flat hose at the uPVC pipe outlet. The irrigator then stands and sprays water from the hose-end, trying to spread the water uniformly, and prevent crop and soil damage from the impact of the jet. The same practice is seen amongst most pump operators in Nairobi.

The use of overhead irrigation, when water is manually lifted and carried from the local source, is appropriate when farmers are renting land for short periods, as it avoids the labour involved in levelling or grading of beds. Irrigators can adjust the volume applied to different crops at varying stages of growth, and water use efficiency is likely to be high. By contrast, the wild spraying of water from a 50mm lay-flat hose adopted by most pump users is a very inefficient way of applying water. Observations in the field show that the application uniformity is very low, resulting in very uneven crop stands. The initial unevenness of application is compounded when water runs off the field surface and ponds in depressions on the usually unlevelled plots. When plants are small, the risk of damaging seedlings with the water jet is high. To try and minimise this risk operators cut back the operating speed of the pump, which results in the pumps running very inefficiently.

In Nairobi, methods of water application reflect the wider use of water conveyance in open channels from the source. Thus, the 39% of Nairobi farmers who apply water in furrows or basins convey water to the field in open channels, and are mostly sewage irrigators. Watering cans and buckets are used solely or in combination with other methods by 31% of farmers.

5.1.4 Irrigation applications

The amounts of water applied by irrigators was investigated during in the detailed farm studies reported in Cornish *et al.* (2001) and Hide, Kimani and Kimani (2001).

Rainfall recorded at Kumasi airport over the period is shown in Figure 7.

Apart from a storm event of about 60 mm in January, very little rain fell between December and the middle of March. The "dry season" thus lasted about three months. The volumes of water applied by farmers participating in the detailed farm studies, reported in Cornish *et al*, (2001), are listed, along with other data in Table 6 of Annex 1. As several assumptions are required to calculate the quantities of water supplied, these figures will not be very precise, but they do provide some unexpected insights on the irrigation practices adopted.

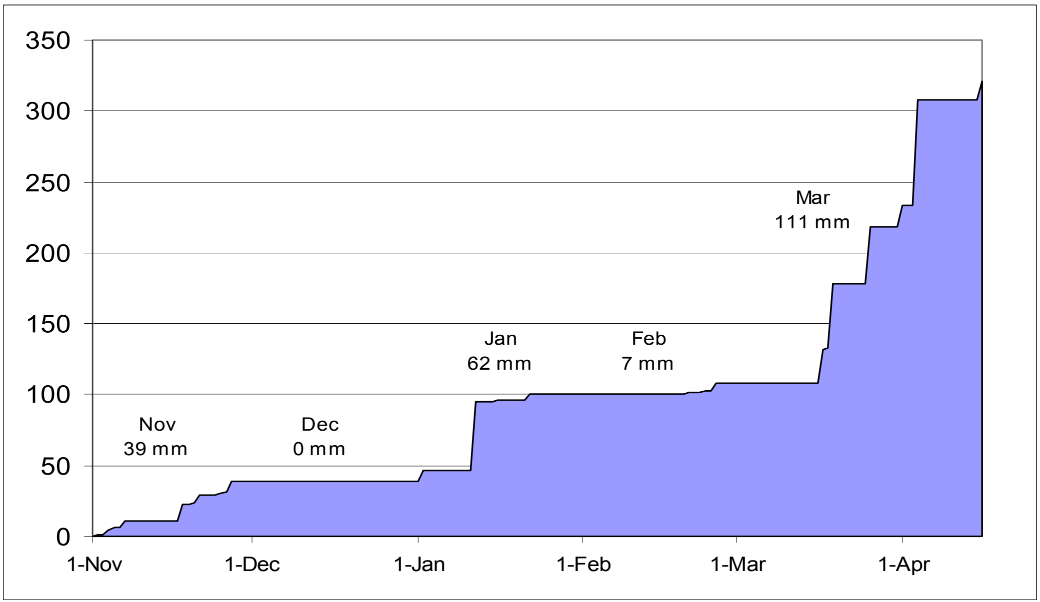


Figure 7 Cumulative rainfall at Kumasi Airport 1st November 1999 – 15th April 2000

Averaged data derived from Table 6 of Annex 1 are shown in Table 6 below.

Table 6 Calculated daily water applications applied by Kumasi irrigators

	Pump Irrigators	Manual Irrigators
Water depth applied by irrigation (mm/day)	1.1 (6)[1]	0.14 (15)
	-	0.25 (6)[2]
Proportion of irrigation water pumped	0.67 (6)	-
Total water depth applied (irrigation + rainfall, mm/day)	2.37 (6)	1.58 (15)
	-	2.12 (6)[2]

Notes: 1.The number of farms used in the calculation of average water applications is given in brackets in the table.
2. As more than half the manual irrigators applied very small amounts of water, less than 10 mm over the irrigation period, the table also includes averaged data for the six manual irrigators who applied the most water.

The general conclusions are:

- Irrigators with access to hired pumps still relied on manual water carrying to supply about one third of the water applied.
- Many manual irrigators supplied very small amounts of water, the six farmers supplying the most water averaging an application of only 0.25 mm/day.
- As the crop water requirement for the period is around 3.5 mm/day even the pump farmers (on average) did not provide enough water to meet the theoretical crop water requirement.

The surprising feature of the results is the number of farmers who applied an insignificant depth of water through irrigation, in many cases less than 10mm over the season, yet achieved average or above average yields. It seems unlikely that errors in recording the water volumes applied or the cropped areas could be large enough to account for this apparent discrepancy. Many crops, particularly egg plant, are clearly utilising the shallow groundwater found along valley bottoms, where most IUPIA activities are concentrated, to supply most of their water requirement.

This is not to suggest that the irrigation efforts of the farmers are unnecessary. Farmers are very unlikely to invest the levels of human effort and cash that they do in irrigation if it were not needed. Irrigation is certainly essential when crops are in their early development, when roots are not deep enough to exploit groundwater. Farmers seem to have continued to apply small volumes of water through the "dry" season, when the crops had attained their maximum rooting depths.

Irrigation depths applied by the Nairobi farmers participating in the detailed studies are shown in Table 7.

Table 7 Calculated daily water applications applied by Nairobi irrigators

Site	**Thiboro**		**Mau Mau Bridge**		**Maili Saba**	
Method	Watering can	Watering can	Watering can/treadle pump	Watering can	Gravity + some bucket	Gravity + some bucket
Depth applied (mm/day)	0.5	3.4	2.6	2.2	8.3	3.7

The greatest depths of water are applied on farms at Maili Saba, with values of 8.3 and 3.7 mm/day, respectively. This is not surprising, since only a very small proportion of the water supplied at this location is lifted manually. Of the other farms, where all water is applied manually, one farmer at Thiboro applied an average depth of 3.4 mm/day. This was achieved by filling, carrying and emptying over 300 watering cans per day, and explains why irrigation is listed as the most labour intensive farm activity. One farmer occasionally used a treadle pump to apply water. On those days when the treadle pump was used an average of 6.9mm was applied, compared to 3.2mm when using watering cans.

The average daily crop water requirement during the study period, Nairobi's winter, is approximately 3 to 4 mm/day. A substantial portion of the crops' water requirement was thus met by the irrigation applications supplied by the farmers. Except for one farm at Maili Saba, where crops are intermingled seemingly haphazardly, differing water depths are applied to different crops. It is probable that the farmers concentrated their irrigation efforts on the more productive crops.

5.2 Plot preparation

5.2.1 Plot preparation in Kumasi

In Kumasi, preparation of the plot uses more hired labour than any other cropping activity, but the amount of land preparation and final appearance of the plot varies widely between farmers. In the majority of cases preparation consists only of clearing away the natural vegetation, leaving a broken and uneven surface with a very coarse tilth into which seedlings are transplanted. A typical plot is shown in Figure 8.

Figure 8 Typical IUPIA plot - Kumasi

In a few cases, particularly where the total plot size is small, a number of flat-topped, raised beds are prepared. Here there is more working of the soil to produce a fine tilth and the crops can be reached more easily for weeding, watering and harvesting from the walkways left between the beds. Figure 9 shows such a plot. These plots have the appearance of being better prepared and managed but we do not have production data that would enable direct comparisons on the effects of plot preparation on yields.

Figure 9 Well-prepared IUPIA plot - Kumasi

Where the plot lies in a valley bottom, raised beds may be used to provide soil that is not waterlogged. Under these conditions irrigation may only be required when plants are first transplanted or where the groundwater level drops quickly as the dry season advances.

Because farmers rely either on direct application of water to the base of each plant or overhead irrigation from a watering can, there is no land forming for surface irrigation. Surface irrigation is not used even where motorised pumps are used to deliver water to the plot.

5.2.2 Plot preparation in Nairobi

Plots are generally much better prepared in Nairobi, possibly reflecting the impact of agricultural extension services of the Ministry of Agriculture that operate in the more rural locations to the west of the city. Of the 55 IUPIA clusters located in the scoping survey, three were selected for detailed farm studies. All three lie along the Nairobi River. At Thiboro, about 10 km west of the city centre, farm plots are situated on land sloping down to the Nairobi River near its source. Small hand-dug wells have been constructed, and water is drawn from here and spread over the crops using buckets and watering cans. A typical plot size is 60m by 20m. The farms are well organised with terracing and separation of crops, as Figure 10 shows.

Figure 10 IUPIA plot Thiboro - Nairobi

Nearer the city centre, at Mau Mau Bridge, small dams and weirs have been constructed by the farmers along the river to raise the water level. This enables water to be diverted to hand-dug canals which irrigate the lower areas of the farm plots. Water is drawn from ponds dug at the end of the canals to irrigate crops at higher elevations using buckets and watering cans. Again the plots are well organised with terracing and crop separation. See Figure 11.

Figure 11 IUPIA plots at Mau Mau Bridge- Nairobi

To the east of the city centre at Maili Saba, farmers have removed manhole covers and blocked the city's main sewer, causing raw sewage to rise up the manholes and flow out over the land (Figure 6). Hand-dug canal systems have been constructed to irrigate an estimated 100 farm plots. Farmers operate the canal system on a weekly basis, allowing flow to each farmer's plot on two specified days of the week. Some farmers have invested considerable time and effort in terracing the land despite the fact that they are squatting.

5.3 Cropping and Yields

5.3.1 Kumasi

In Kumasi, many farmers aim to harvest two irrigated crops between October and April. First planting is often carried out in October, taking advantage of the short rains in this month to help germinate and establish the crop. Where possible, harvesting is then timed to coincide with peak demand over the Christmas and New Year period. Farmers with a reliable water supply will then plant again in January, with a view to harvesting around the Easter period. The full list of irrigated crops grown, derived from the initial farmer surveys, is shown in Table 7 of Annex 1. The five most widely grown ranked by crop area are listed here in Table 8.

Table 8 Five most widely grown irrigated crops in Kumasi

Crop	No of Farmers growing crop	Area (ha)
Tomato	193	99.3
Garden egg	177	84.1
Okra	153	77.7
Hot pepper	114	55.6
Cabbage	53	18.5

Tomato, garden egg, okra and hot pepper account for 84% of the total recorded crop area. Tomato is the most widely grown crop, grown by 47% of 410 respondents.

Figure 12 shows the spatial distribution of the four most popular crops grown in each village.

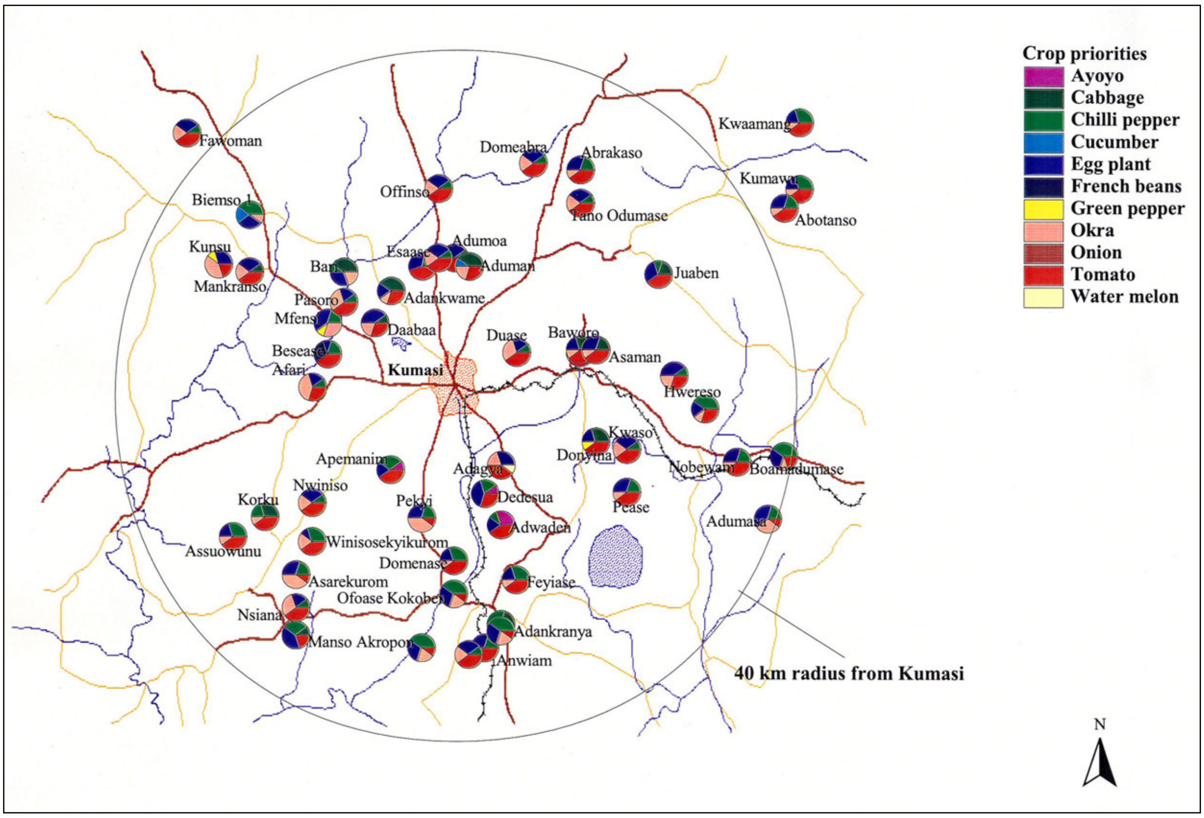


Figure 12 Spatial distribution of four most popular crops grown in each village – Kumasi

The widespread distribution and popularity of the fruit vegetables – tomatoes, garden egg, okra and hot pepper – is apparent. There is no obvious correlation between choice of crops and location relative to the urban centre of Kumasi, except for lettuce. Lettuce cannot easily be stored or transported over large distances, and is mostly grown close to Kumasi or near the major roads serving the city.

Precise determination of crop yields from data recorded by the Kumasi farmers proved to be difficult, as standard weights and measures are not used when buying and selling crops. Baskets, rubbers, pans, "large and small" sacks and "large and small" boxes are all traded. Also, it proved difficult to define accurately the area of crop being grown, as inter-planting of crops within a single plot is common.

Despite these constraints, estimates of crop yield were made for three widely grown crops, garden egg, tomato and okra, using both data on reported harvests and cropped areas collected in the initial farmer surveys, and from the detailed data recorded by twenty-one farmers in the detailed farm studies. These are shown in Table 9. (The number of farms from which average yields were computed are shown in brackets).

Table 9 Approximate average yield data - Kumasi

Crop	Farmer surveys Average yield (t/ha)	Detailed farm studies Average yield (t/ha)
Garden egg	4.7 (148)	3.7 (17)
Tomato	2.4 (176)	2.2 (6)
Okra	1.2 (130)	0.49 (4)

Average yield results from the two sources are reasonably consistent. Clearly, yields derived from the detailed data, which is based on daily records from farm diaries, are more "precise " while yields from the farm survey data, based on farmer recall, will be more representative as they cover a larger number of locations, farm types and farmers. However, there may be a greater element of wishful thinking on the part of farmers included in the yields reported in the survey data.

In both cases, averaged data mask very wide variations between farms. For example, there was an 11-fold difference in yield in the case of garden eggs, and between 3- and 4-fold yield differences for other crops in the data from the detailed farm studies.

Meaningful correlation could not be established between crop yields and any of the following variables:

- Labour hours on individual tasks or total labour
- Expenditure on fertiliser
- Expenditure on all inputs – seed, fertiliser, pesticide and herbicide

For two crops, garden egg and tomato, a relationship was established between the depth of water applied and yield, but as in some cases irrigation supplied only a small proportion of the estimated crop water requirement these correlations may not be very meaningful.

5.3.2 Nairobi

A much wider range of crops is grown in Nairobi, where irrigation is a year-round activity. The long and short rains occur in March to May and November to December, respectively, and during these periods irrigation is used to supplement rainfall. A number of crops are grown continuously, for example, kales, spinach and tomatoes, whilst others are grown at specific times of the year. Table 8 of Annex 1 lists the crops identified by the farmer surveys, ranked by the number of farmers growing them and area cultivated.

The five most popular crops are listed in Table 10 below.

Table 10 Five most widely grown irrigated crops in Nairobi

Crop	No of Farmers growing crop	Area (ha)
Kales	81	30.1
Tomatoes	45	23.1
Spinach	38	12.5
Maize	28	12.1
Cabbage	21	11.6

It is seen that the most widely grown crops are kales, tomatoes, spinach, maize and cabbage, grown on 89 ha, with an average cropping intensity of 150%. In reality the cropping intensity will be higher, perhaps as high as 200%, since information was only collected for the three or four most important crops grown by each farmer. The average number of crops grown by each farmer is 4, with a maximum of eight crops grown.

The geographical distribution of crops was investigated after dividing crop types into three categories:

- Subsistence crops, e.g. arrow roots, maize, kales, cassava;
- Local market vegetables, e.g. beans, tomatoes, egg plant, cabbage;
- Exotic vegetables, e.g. celery, Chinese cabbage, cucumber, lettuce.

Figure 13 shows the geographical distribution of these crop types. The highest proportion of local vegetables and subsistence crops are grown in Mavoko district. It is notable that significant exotic vegetable production occurs in Makadara where farmers have smaller plots with no land rights, use sewage water and are located in one of the poorer areas of Nairobi. Proximity to markets may encourage production of these exotic crops in these areas but a point of concern is that many of these exotic crops are eaten raw, unlike the subsistence and local market crops that are generally cooked.

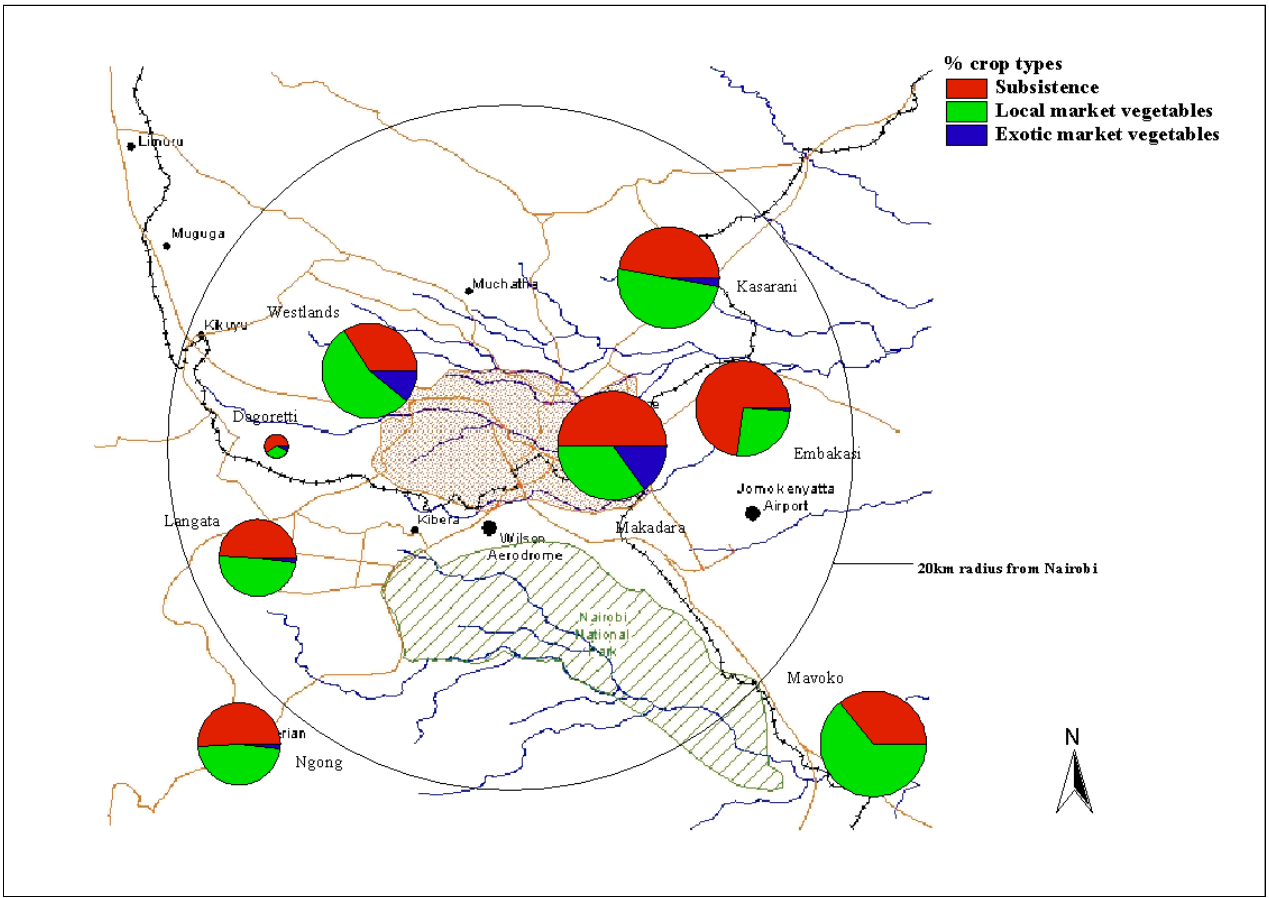


Figure 13   Crop type by District - Nairobi

As twenty-two different crops were grown by the six farmers participating in the detailed farm studies, averaging to produce a list of the most popular crops would be meaningless. However, kales were grown by five of the six farmers, and covered the largest area.

Yield estimates for the Nairobi study zone were derived from the reported harvest and area grown collected in the farmer surveys. Initial calculations indicated yields for some farms that were unrealistically high, possibly due to intensive cultivation on very small plot areas. To provide realistic averages, extreme yields were discounted from the analysis. Yield data were also collected during the detailed farm studies. As only six farms were studied, and some crops are only grown on one or two farms, these data cannot be used to provide more precise estimates for yields over the study area. Yield data derived from both sources are shown in Table 11.

Table 11 Approximate average yield data - Nairobi

Crop	Farmer surveys (t / ha)	Detailed farm studies (t / ha)	Expected range with good management[1] (t / ha)
Kales	7.2	6.3	3 – 15
Tomatoes	11.6	9.4	10 – 30
Cabbage	4.5	6.3	10 – 30
Spinach	7.4		4 – 20
Maize	2.7		5 – 10
French beans	3.9		2 – 5
Cowpeas	3.2		3 – 5
Beans	0.9		1 – 2
Lettuce	5.3		5 – 10
Courgettes	10.7		n / a

Note: 1. Expected yields for irrigated crops in the smallholder sector in Kenya (Kimani, personal communication 2000*)*.

As in Kumasi, yields derived from the detailed farm study support the yield estimates derived from the farmer surveys which are based on farmer recall. Average yields tend to be at the lower end of the range expected in more formal smallholder irrigation schemes.

5.4 Use of labour

In Kumasi, labour inputs devoted to a range of tasks were obtained from farmer recall during the initial farmer surveys, and later in more detail from daily diaries maintained by farmers. This section is based on the detailed data obtained from studies at twenty-one farms, and reported in Cornish *et al.* (2001).

Table 12 shows average total labour hours per hectare by task, and the average percentage of these hours that are provided by paid labour. All labour hours have been treated equally, i.e. labour equivalents have not been used to adjust for differences in the amount of work done by a man, a woman or a child.

Irrigation used most labour (38% of total hours), followed by weeding (23%). However, although irrigation uses the greatest amount of labour, only 9% of that labour is paid. By contrast, the land preparation tasks of clearing, burning and bed formation use on average only about 11% of the total labour hours, but rely heavily on hired labour, with more than half the labour input (61%) being paid labour.

Table 12 Paid and unpaid labour hours per hectare spent on different tasks - Kumasi

Task	Average hours/ha	% of total hours/ha devoted to task	% of labour input to task provided by paid labour
Clearing, burning, forming beds	245	11	61
Planting, weeding Spraying, applying fertiliser	826	37	16
Irrigation	859	38	9
Harvest	135	6	5
Maintenance and other tasks	191	8	30
Total	**2,256**	**100**	**-**

Data collected on labour inputs in Nairobi are summarised in Table 13.

Table 13 Average labour inputs/ha - Nairobi

Task	Average hours/ha	% of total hours/ha devoted to task
Planting	130	5
Manuring	57	2
Spraying	87	4
Weeding	566	24
Irrigation	1,530	65
Total	**2,370**	**100**

Note: Labour inputs for land preparation and harvest were not recorded

Given that labour requirements for land preparation and harvest were not captured in the study, it appears that the overall levels of labour input are greater in Nairobi than Kumasi. In particular the effort devoted to irrigation in Nairobi is almost twice that in Kumasi. In both cities, irrigation uses the greatest part of the total labour input, followed by weeding.

Communities' perceptions of the division of labour between men and women in the Kumasi study area were investigated through discussions with key informants, and also in the initial farmer questionnaire, see Cornish and Aidoo, (2000) and Cornish *et al.* (2001). Men's and women's roles are summarised in Table 14.

Key informants reported that land clearing, burning and the raising of beds are arduous tasks, classified as male activities. A male farmer can carry out these activities himself or rely on paid labour, but the independent female farmer has to rely on paid male labour. Nursery management requires knowledge in detecting early pest/disease attack and careful study of seedling growth, and has become a male task, occasionally assisted by women and children for watering. The other tasks such as re-dressing of beds, fertiliser application, chemical spraying and motorised irrigation of crops are all deemed to be either too arduous or requiring special skill and are therefore also considered as men's tasks.

Weeding and water carrying require no specialist knowledge, and are traditionally activities for women and children, even though repeated lifting and carrying sufficient water for irrigation is extremely strenuous work. Key informants also suggested that women and children carry out much of the weeding not only because it is a task traditionally assigned to them, but also because they are regarded as being better qualified to handle the closely planted and delicate vegetable plants.

Table 14 Task division between men and women - Kumasi

Task	Usually carried out by men	Usually carried out by women and children
Clearing bush and Raising beds	X (94%)	(6%)
Nursery, Planting/transplanting, Fertilising, Spraying	X (60%)	(40%)
Watering	X (42%)	(58%)
Weeding	(58%)	X (42%)
Watering carrying	(42%)	X (58%)

Note: Classifications of roles, indicated by an 'X' in the table, are derived from key informant interviews, the percentages are derived from the initial survey of 410 farmers.

The data collected in the initial questionnaire survey does not always support the perceptions of key informants. Thus while survey data confirms initial land preparation as an activity carried out predominately by men, more men than women carry out weeding even though this was classified by key informants as a women's activity. As no distinction was made in the questionnaire between water carrying and water application, the figures from the survey in the table are for both activities, and thus do not differentiate the gender roles assigned to these tasks as reported by key informants.

There seems to be much less gender differentiation of tasks in the Nairobi study area. The proportion of men and women carrying out the tasks listed below is similar to the proportions of men (37%) and women (63%) farmers recorded in the initial survey, with relatively small differences in gender roles between tasks as Table 15 illustrates.

Table 15 Task division between men and women – Nairobi

Activity	**Proportion carried out by women (%)**
Land preparation	61
Planting/transplanting	61
Weeding	60
Applying manure	77
Applying agro-chemicals	65
Watering	60
Harvesting	61

6. FARM BUDGETS

Detailed data on costs and revenues from IUPIA were obtained for twenty-one farms located in three villages in the Kumasi study zone, and for six farms at three locations in Nairobi. Data for individual farmers are summarised in Tables 9 and 10 of Annex 1. More detailed information for individual farms is presented in Cornish *et al.* (2001) and Hide, Kimani and Kimani (2001).

6.1 Farm budgets - Kumasi

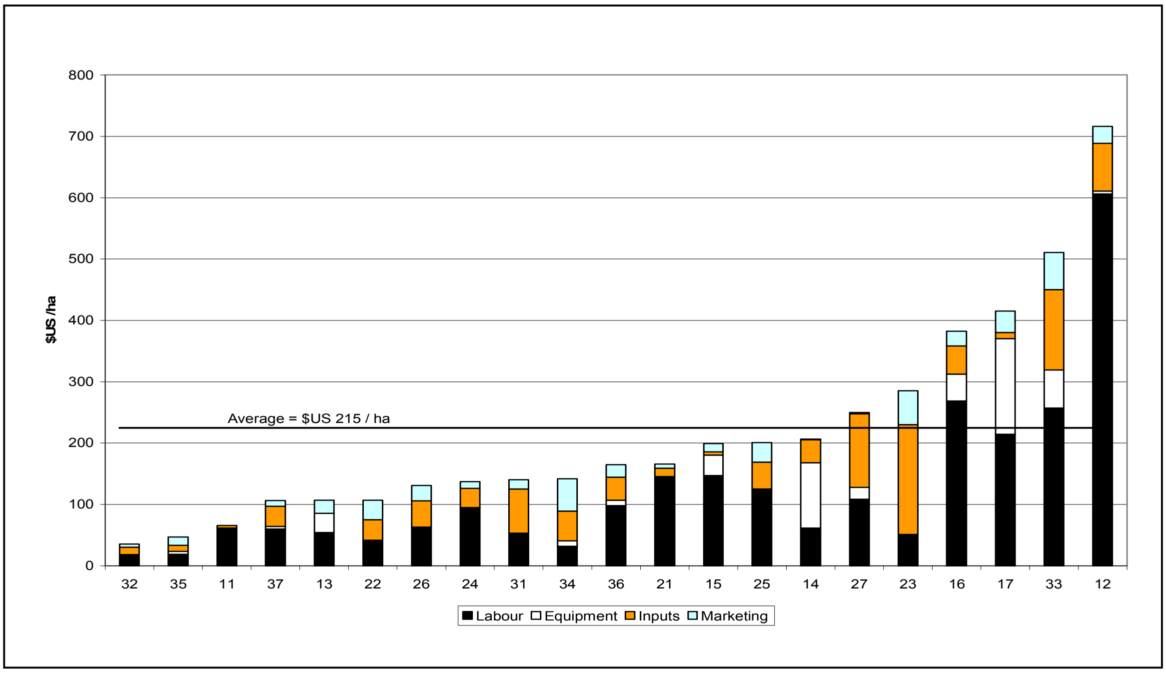
Farmer expenditure on a range of production and marketing costs was recorded. This included labour, the costs of hiring and operating equipment such as a knapsack sprayer or pump, agronomic inputs including seed, fertiliser, and pesticide, and costs of transporting produce to market.

Mean data, derived from Table 9 of Annex 1, are given in Table 16. The breakdown and range of expenditure on inputs by different farmers is shown in Figure 14.

On average, labour costs are the largest component of input costs, at 57%. However, there are significant differences between pump and manual irrigators. Input costs for pump irrigators are about double those of manual irrigators. Similar amounts per ha are spent on marketing, but pump irrigators spend about three times more on labour and, less surprisingly, about nine times more on equipment. (All the pump users hired pumps.) Pump irrigators in this sample seemed to spend significantly less on agronomic inputs than the manual irrigators.

Table 16 Labour, input and marketing costs - Kumasi

		Labour ($US/ha)	Equipment costs ($US/ha)	Agronomic inputs ($US/ha)	Transport to market ($US/ha)	Total ($US/ha)
Pump irrigators	Cost	225	63	29	21	338
	% of total	67%	19%	9%	6%	
Manual irrigators	Cost	82	7	54	23	166
	% of total	49%	4%	33%	14%	
All Irrigators	Cost	123	23	47	22	215
	% of total	57%	11%	22%	10%	-



Note: Costs were converted to $US / ha to allow comparisons to be made between locations, but as all the farmers irrigate less than 1 ha (on average 0.46 ha), the actual costs incurred were considerably lower than those tabulated. Opportunity costs of family labour are not included.

Figure 14 Farmers' costs - Kumasi

Table 10 of Annex 1 sets out the cost, revenue and profit data for each of the farmers. The average profit level was similar for each of the three villages included in the survey, even though there are large differences in irrigation methods, level of inputs and the crops grown. Farmers securing profits greater than $US 200 are found in all three villages.

Average costs, revenues and profit according to irrigation type are shown in Table 17.

Table 17 Average costs, revenues and profits, Kumasi

Irrigation type	Input costs ($US/ha)	Land rent ($US/ha)	Revenue ($US/ha)	Profit ($US/ha)	Actual profit (US$)
"Pump" farmers	338	0	613	275	124
Manual farmers	163	10	538	366	164
All farmers	215	7	559	337	153

The range of profits achieved by farmers (revenue minus input costs, excluding the opportunity cost of family labour) are shown in Figure 15.

These data indicate that access to a perennial water source (the Oda River) and a motorised pump, did not provide higher than average profits for pump irrigators. Their average costs of production are far higher than for manual irrigators, but revenues are not commensurately larger. Pump farmers, in fact, occupied four of the last six places when the profits achieved by the twenty-one farmers profits are ranked. (In Figure 15, pump farmers are numbers 12 to 17).

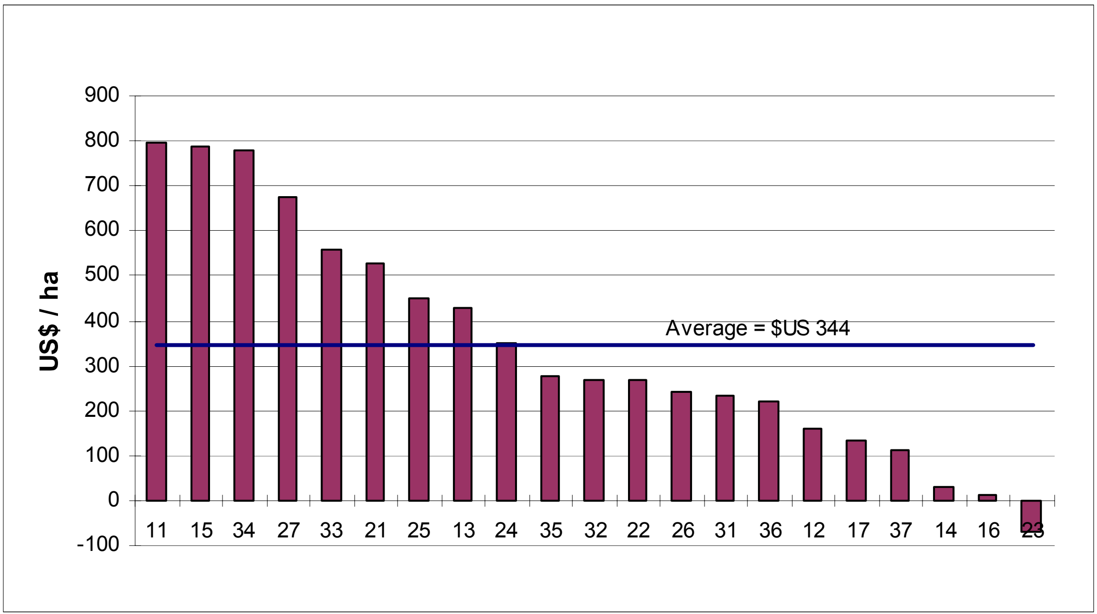


Figure 15 Profits from irrigated cropping for Twenty-one Kumasi farmers ($US/ha)

A more detailed examination of the factors leading to profits secured by individual farmers, reported in Cornish *et al.* (2001), indicated that financial profitability cannot be directly correlated with the use of agronomic inputs, labour or irrigation. Farmers making profits substantially above the average generally achieved average or above average yields for their dominant crop, but the greatest factor influencing their profit was the ability to sell consistently at above average prices. Some farmers securing good or very good yields obtained low prices for their produce, and low profits. Prices obtained over the season are the single most influential factor determining profit, but obtaining at least an average or better yield is the first step to a higher financial return. Section 7.2.2 compares the expenditure, revenue and profit of two similar farmers irrigating and selling cabbage.

6.2 Farm budgets - Nairobi

Table 18 summarises farmer expenditures, revenues and profits, converted to $US/ha, for the six farms studied in the detailed farm studies. Labour costs do not include the opportunity cost of family labour.

Table 18 Average costs, revenues and profits, Nairobi

Farm location	Cropped Area (ha)	Costs ($US/ha)		Revenue ($US/ha)	Profit ($US/ha)	Actual Profit ($US)
		Labour	Agro. Inputs			
Thiboro	0.109	1,275	899	2,128	-46	-5
	0.143	1,587	1,336	12,601	9,678	1,384
M. M. Bridge	0.041	0	1,439	1,659	220	9
	0.088	0	375	2,227	1,852	163
Maili Saba	0.032	0	31	1,969	1,938	62
	0.069	0	0	870	870	60
Average	0.0803	477	680	3,576	2,419	279

Actual profits covered a wide range, from a loss of $5 to large profit of nearly $1,400. The pattern of expenditure reflects the general impression gained of the type of farming at each of the three locations. Expenditure per ha is about $2,500 at Thiboro, $920 at Mau Mau Bridge and virtually zero at Maili Saba. Farming at Thiboro is clearly regarded as a business, whilst at Maili Saba it is seen as providing household food and a small income from any surplus produce.

The average revenue of around 3,500 $US/ha is larger than that reported in the farmer surveys ($US 1,696/ha), or by the nineteen farmers participating in the wealth ranking study, $US 3,040 /ha.
Both revenues and profits from IUPIA are much larger, in $US/ha terms, than in Kumasi. However, differences in the way plot sizes were estimated in the two areas may account for much of this apparent difference in per hectare revenues and profits. The average plot size in the detailed studies in Nairobi is just 0.08 ha (800 m^2) whilst those in Kumasi averaged 0.45 ha (4,500 m^2). When the *actual* revenues and profits of farmers in the two study areas are compared, the difference between the two is much reduced, as Table 19 shows, although it remains the case that the average costs revenues and profits in Nairobi are greater than those in Kumasi.

Table 19 Average cost, revenue and profit from irrigated cropping in the two study areas

	Average actual cost $US	Average actual revenue $US	Average actual profit $US
Nairobi	125	403	279
Kumasi	84	236	153

7. MARKETING

7.1 Marketing methods

Information on the mechanisms used by farmers to market their crops was obtained from the initial farmer surveys, and during the detailed farm studies (Cornish and Aidoo, 2000; Hide and Kimani, 2000 and Cornish *et al*. 2001). Comparative data collected from the farmer surveys are summarised in Table 20.

Table 20 Methods of marketing adopted in Kumasi and Nairobi

Mechanism	**% of farmers[1]**	
	Kumasi (410 farmers)	Nairobi (158 farmers)
Take produce to market	89	48
Consumer buys from field	34	70
Traders buy from field	55	65
Other	5	3

Note: 1. As farmers often sell at more than one location and by more than one method these %'s do not total 100%.

In Kumasi, the most common means of marketing produce is for growers to take their own produce to a market. Almost 90% of farmers sell some or all of their produce in this way, the principal market destination being Kumasi. Very few growers take their own produce to other market outlets. Selling directly to traders who visit the field is practised by 55% of growers, indicating that a relatively sophisticated marketing mechanism for vegetable produce has grown up in the region, with traders travelling from distant locations. 40% of traders come from Kumasi, 20% from Accra and smaller numbers from Obuasi, Takoradi and other local centres. (See Table 11 of Annex 1).

In Nairobi, a larger proportion of the crops are sold directly from the fields to local consumers, or to visiting traders. Nearly three quarters of farmers sell at least some of their produce directly to consumers from the field, and there are a number of local and central markets where crops can be sold. Analysis of unit prices quoted by farmers in the detailed farm study show differences of only around ± 10 % in the prices received for produce sold at the different outlets.

IUPIA farmers market mostly as individuals, as Table 21 demonstrates.

Table 21 Prevalence of individual and group marketing

Mechanism	**% of farmers**	
	Kumasi (410 farmers)	Nairobi (158 farmers)
Market as an individual	89	100
Market in an informal group	10	0
Member of a co-operative	1	0

Some Nairobi farmers reported that attempts to set up marketing co-operatives to obtain better prices had failed due to resistance from traders or dishonesty. In Kumasi, marketing co-operatives have a similarly disappointing record and as Table 21 shows, only a very few farmers now engage in any form of group marketing.

7.2 Marketing constraints

In Nairobi, most farmers do not perceive marketing of their crops to be a problem. Marketing was ranked last in a list of eight most important constraints in the preliminary farm surveys.

Kumasi farmers regard marketing arrangements as a major constraint, ranking marketing second in the list of constraints raised in preliminary interviews. The factors influencing the marketing of fresh vegetables in the Kumasi study zone were thus reviewed to gain an insight into marketing problems experienced by farmers. The review was based on available literature and discussions with key informants drawn from both irrigators and traders.

In summary, trading in the more popular vegetables is controlled by a complex network of small-scale operators, dominated by "market queens" who fix prices, settle disputes, and provide credit, support and advice to traders and farmers. Traders may be "traveller-traders" who visit distant centres to buy on the farm or at local markets, or armchair traders at Kumasi Central Market, who have an assured supply from local farmers. Both types of trader are subject to the authority of market queens. The full findings are set out in Cornish *et al.* (2001).

7.2.1 Marketing tomato and garden egg - Kumasi

Farmers are more vulnerable to cheating and price manipulation in the marketing of tomato and garden egg than other crops. Well-organised marketwomen's groups in Kumasi control marketing of these crops and exercise a strategic influence over prices. The pre-financing arrangements that traders have with some farmers give the traders the ability to dictate sale prices.

Traders in Kumasi Central Market play the role of a sales agent for marketing of tomatoes, sponsoring farmers and selling their produce for a commission. As the commission is fixed within specified price ranges, the market woman negotiates with the visiting trader to secure the best commission for herself but neither has any incentive to push the price higher within the band. Because the farmer is excluded from this negotiation, he or she is often the loser.

Farmers' revenues are further reduced through a number of informal levies, paid for discharging the produce, to carriers, cleaners and to the market queens. The levy is taken in the form of specified numbers of tomatoes from a box. Farmers often carry one or two boxes as reserve, to provide top-ups after these levies have been taken.

7.2.2 Marketing cabbage, lettuce, carrots and cucumber - Kumasi

These crops are not suited to transport over long distances or storage over an extended period. As they are also relatively new or exotic crops to the area, central market women and their queens tend to avoid trading in them. Marketing of these vegetables in Kumasi Central Market occurs only on Mondays and Thursdays when traders from Accra, Obuasi, and Takoradi-Sekondi arrive by train to do business. The market for exotic vegetables on other days is small, and prices highly erratic. No farmer, therefore, wants to sell any of these vegetables in Kumasi on the non-specified days.

Farmers, and middlemen who buy directly from the farms, thus explore other market opportunities in restaurants, institutional canteens, and street eating-places. Prices are set by bargaining and depend on the market forces of supply and demand. The lack of formal market mechanisms and trade groups for these crops means that transportation and marketing of produce are undertaken on an individual basis although it is not unusual for one farmer to take several growers' produce for sale in Kumasi, with each bearing his/her share of transportation charges.

Most farmers sold their produce in Kumasi market on the two weekdays when "exotic" crops were sold. However, one farmer secured a very good profit from the sale of single heads of cabbage, priced according to size, direct from the field to a trader from Accra. The large impact this made on his profit is illustrated in Table 22 below, which compares the costs, revenue and profits of two cabbage farmers.

Table 22 Costs, revenues and profits of two cabbage growers, Kumasi

Item	Farmer a	Farmer b
Total labour hours /ha	2538	1537
Irrigation hrs / ha	1133	437
Inputs/ $US /ha	179	120
Land rent $US /ha	0	31
Revenue $US / ha	193	926
Profit $US / ha	- 68	645

Farmer (a) invested relatively more on labour and irrigation hours and spent more on inputs, yet by marketing in Kumasi only secured a low revenue from his sales. As the two farmers reported sales in different units, it is not possible to compare the yields. However, the massive difference in revenues between the two is unlikely to be attributable to differences in yield. The comparison provides compelling evidence for the importance of marketing in securing financial success.

7.3 Potential for improvements in marketing arrangements

Several measures that could improve farmers' revenues from the sale of crops were discussed in the project workshops. However, none seems very realistic at present. They include:

- Formation of farmer co-operatives capable of negotiating better prices with the traders and market queens. To avoid being undercut, the co-operatives would need to be large and gain the support of most farmers. This has proved difficult to achieve in practice, and this suggestion was not received very enthusiastically by farmers attending the Kumasi workshops.
- Establish agro-processing industries to absorb the bulk of vegetable production. This was often raised by farmers but it is difficult to demonstrate the commercial viability of such a project.
- Establish a parastatal marketing company for the purchase of vegetables at guaranteed prices. As government is disengaging from the marketing of other agricultural commodities, such a move is unlikely to have government support.

8. CREDIT

8.1 Use of Credit by IUPIA farmers

Access to credit was raised as the leading constraint to irrigated production by Kumasi farmers in the farmer surveys, and also during farmer workshops, but did not appear to be an issue in Nairobi. In Nairobi, only 4½ % of farmers used a credit arrangement to start irrigated agriculture, and no farmers reported using credit in 2000. Table 23 summarises the response to questions on the use of credit from the farmer surveys.

Table 23 Use of credit by farmers in Kumasi and Nairobi

	% Farmers	
	Kumasi (410 farmers)	**Nairobi (156 farmers)**
Used credit when irrigation started	29	4.5
Use credit now	38	0

Of the Kumasi farmers using credit in 1999, 34% reported that they obtained it from family relatives or friends, 29 % from middlemen dealing in crops, and 18 % from moneylenders. Very few farmers obtained credit from banks, co-operatives or NGOs. There was no difference in the use of credit between men and women, nor evidence of credit being more widely used by farmers with larger landholdings. Farmers who used pumps (mostly hired) were more likely to use credit than manual irrigators were. The main problems reported with obtaining credit were its availability or that interest rates were too high.

In view of the importance attached to credit and financing issues by farmers in Kumasi, credit issues were reviewed using published literature and interviews with key informants in the villages studied during the wealth ranking study. The detailed study findings are reported in Cornish *et al*, (2001).

8.2 Informal credit from traders and market women in Kumasi

Informal credit from traders was reported by key informants to be the most widespread and frequently used credit facility.

Traders and market women provide credit or advances at the outset of the season against all produce from the farm. The arrangement may be cash but it could also be purchase and delivery of farm inputs such as fertilisers and agro-chemicals. The trader's money attracts neither interest nor collateral. It is based on the mutual understanding that the produce will sold exclusively to the pre-financier. Loan repayment is by gradual deduction. If the season's harvest is insufficient to defray the loan, the outstanding amount is carried forward to the next season with the farmer also taking a fresh loan.

Apart from production credit, market women extend financial assistance to cover off-season consumption and emergency demands as well. This makes it a unique offer open to the vegetable growers. The disadvantage is that it creates a monopolistic condition that ties the farmer to a particular trader, possibly for years, and gives him or her no say in the determination of the commodity price. Manipulation of farmers by the traders is reported to be pervasive and is difficult to avoid under the present circumstances. A further drawback is that of the traders seeking to “service” as many farmers as possible. As most farmers require credit support at the same crucial periods, it is not unusual for the farmers’ needs to outstrip what the trader can supply. As a consequence, the use of a needed input is delayed or foregone, with damaging consequences on the timing and amount of production.

8.3 Conclusions concerning access to credit in Kumasi

- If farmers had a reliable source of credit, they could time the planting and marketing of their produce to avoid the price manipulation that currently exists.
- All the communities shared a common opinion that the vegetable farmers should form co-operative associations to strengthen their bargaining powers for formal financial assistance. Although this opinion was stated in interviews and discussion, there are only a few cases where this approach has been successfully adopted, and, like the formation of groups for improved marketing, it was not received very enthusiastically by farmers at the project workshop.
- Credit could be better provided through formal and semi-formal micro-credit arrangements purposely tuned for IUPIA and channelled through the banks or well-established NGOs. Impartial monitoring and control would be essential to ensure that the facility achieves its purpose.

9. WATER QUALITY STUDIES

9.1 Water quality for irrigation

Very little systematic data are available describing the quality of water used by peri-urban irrigators located downstream from African cities. Targeted water sampling programmes were thus carried out in both study zones to obtain basic data on the quality of water being used for irrigation. This information can be compared with guidelines set by the World Health Organisation (WHO) and others, to provide an indication as to the scale of the risks to irrigators and consumers.

The World Health Organisation's guidelines for microbiological quality for wastewater use in agriculture, are based on "epidemiological evidence of actual risks to public health, rather than on potential hazards indicated by the survival of pathogens on crops and in the soil", (Mara and Cairncross, 1989). They were formulated for use in the design of wastewater treatment plants, but have subsequently influenced the standards for wastewater reuse for agriculture adopted in many countries.

Westcot (1997) addressed the question of how the WHO guidelines can be applied when there is little or no treatment of urban wastewater before it is used to irrigate crops. He suggests that, in the absence of better information, it is prudent to use the WHO standards for faecal coliforms as the quality standard. Shuval *et al.* (1986) concluded that the presence of helminth eggs in irrigation water (specifically roundworms of the species Ascaris and Trichuris1) posed the largest risk to health. They have long persistence in the environment, require only a small number to cause infection and there is little possibility of immunity occurring in the human population. However, there are no routine and simple techniques available to monitor helminth egg numbers in water samples, and Westcot considered it impractical to use the helminth guideline in routine monitoring of water quality for irrigation.

The London School of Health and Tropical Medicine and others have carried out epidemiological studies in developing countries with the aim of assessing the validity of the WHO guidelines as standards in assessing the quality of water used for irrigation. Arising from this work, Blumenthal *et al.* (2000) recommend some minor revisions to the limits for faecal coliforms and nematodes, which are reproduced in Table 24.

The WHO guidelines focus on the microbiological aspects of wastewater quality, and make only passing reference to risks from trace elements and heavy metals. Mara and Cairncross (1989) assert that the health hazards due to chemical pollution are of only minor importance when considering the reuse of domestic wastes. It is widely accepted that levels of trace elements and heavy metals in irrigation water are likely to be toxic to plants at concentrations below that at which they pose a significant risk to human health. This provides a degree of protection to irrigators and consumers, in that plants will fail to thrive and farmers will abandon the polluted source before pollutant levels present a risk to human health. However, there is continuing concern over the possible long-term accumulation of some heavy metals in soil as a result of wastewater irrigation (Kaddous and Stubbs, 1983; Siebe and Cifuentes, 1995).

Table 24 Recommended revised guidelines for treated wastewater use in agriculture [a] (After Blumenthal et al. 2000)

	Reuse conditions	**Exposed group**	**Irrigation technique**	**Intestinal nematodes[b] (eggs/litre[c])**	**Faecal coliforms (FC per 100ml[d])**
A	Unrestricted irrigation A1 Vegetable and salad crops eaten uncooked, sports fields, public parks [e]	Workers, consumers, public	Any	≤ 0.1 [f]	≤ 10^3
B	Restricted irrigation Cereal crops, industrial crops, fodder crops, pasture and trees [g]	B1 Workers (but no children <15 years), nearby communities	Spray/ sprinkler	≤ 1	≤ 10^5
		B2 as B1	Flood/ furrow	≤ 1	≤ 10^3
		B3 Workers including children <15 years, nearby communities	Any	≤ 0.1	≤ 10^3
C	Localised irrigation of crops in category B exposure to workers and the public does not occur	None	Trickle, drip or bubbler	Not applicable	Not applicable

a) In specific cases, local epidemiological, socio-cultural and environmental factors should be taken into account and the guidelines modified accordingly.
b) Ascaris and Trichuris species and hookworms: the guideline is also intended to protect against risks from parasitic protozoa.
c) During the irrigation season (if the wastewater is treated in WSP or WSTR, which have been designed to achieve these numbers, then routine effluent quality monitoring is not required).
d) During the irrigation season (faecal coliform counts should preferably be done weekly, but at least monthly).
e) A more stringent guideline (≤ 200 FC/100ml) is appropriate for public lawns, such as hotel lawns, with which the public may come into direct contact.
f) This guideline can be increased to ≤ 1 egg/litre if (i) conditions are hot and dry and surface irrigation is not used, or (ii) if wastewater treatment is supplemented with anthelmintic chemotherapy campaigns in areas of wastewater re-use.
g) In the case of fruit trees, irrigation should cease two weeks before fruit is picked and no fruit should be picked off the ground. Spray/sprinkler irrigation should not be used.

There are currently no guidelines for permissible levels of trace elements and heavy metals in wastewater used for irrigation which relate to the potential risk to human health. Most authors cite either a table of phytotoxic thresholds prepared by the National Academy of Sciences (1972) and Pratt (1972), or refer to the WHO drinking water guidelines (WHO, 1993). These data are reproduced in Table 25.

Reliable detection of heavy metals, at the concentrations encountered in municipal wastewater, requires use of sophisticated laboratory equipment and trained staff. The difficulties and cost of measurement, and the understanding that heavy metals are unlikely to pose a threat to human health through consumption of irrigated vegetables, indicate that monitoring of heavy metals in irrigation water does not have a high priority. However, this study had access to appropriate analysis facilities and so samples were monitored for some heavy metals. The results indicate that there is little risk to irrigated crop production from the concentrations observed in Kumasi. In Nairobi, the concentrations of manganese measured in this study, and some other heavy metals measured in a study carried out by UNEP, could be toxic to plants. (See Cornish *et al*. (1999) and Hide, Hide and Kimani, (2001)).

Table 25 WHO and EU drinking water quality guidelines for heavy metals and threshold values leading to crop damage (mg/l).

Element	WHO drinking water guideline [a]	EU drinking water guideline [b]	Recommended maximum concentration for crop [c]
Arsenic	0.01	0.05	0.1
Cadmium	0.003	0.005	0.01
Chromium	0.05	0.05	0.1
Copper	2	0.1 – 3.0	0.2
Iron	0.3	0.2	5.0
Mercury	0.001	0.001	-
Manganese	0.5	0.05	0.2
Nickel	0.02	0.05	0.2
Lead	0.01	0.05	5.0
Zinc	3	0.1 – 5.0	2.0

Sources:
a WHO (1993)
b Cited by Chapman (1996)
c Cited by Pescod (1992)

In this summary report, levels of faecal coliforms are used as the indictor of the safety of water for irrigation of vegetables.

9.2 Water Quality, Kumasi

The natural drainage of Kumasi runs from north to south, as shown in the schematic plan in Figure 16, which also shows the locations at which water quality samples were collected in this study.

The principal streams converge into the Sisa, which flows into the Oda approximately 9 km south of Kumasi. A small portion of the northwest of the city, including the environmentally important Suame Magazine vehicle breaking area, drains to the northwest into the catchment of the Owabi dam and thence into the Ofin River. There is no readily available flow gauging data for any of the streams in the urban area.

Salifu and Mumuni (1998) report that the Kumasi metropolitan area has mains sewerage for less than 4% of its population. Between 250-350 m^3 of septage and night soil are collected daily by trucks, and until 1999 this material was discharged into poorly maintained waste stabilisation ponds adjacent to the Subin River. Due to the accumulation of sludge in these ponds, retention time was very low, and essentially untreated sewage passed directly into the Subin. Dumping at this site ceased with the completion of temporary waste stabilisation ponds 7 km south of Kumasi, north of Asago village on the Sisa river. While there are plans to construct a new, permanent site for wastewater treatment, even with effective waste stabilisation ponds in place, much of the domestic sewage and industrial effluent from Kumasi will continue to be discharged directly into streams passing through the city.

The major sources of industrial effluent in the city are two breweries, a soft drinks bottling plant and a soap factory. Effluent from these industries is discharged into surface watercourses without pre-treatment. Light industrial activities at the Suame Magazine complex - draining to the northwest - and sawdust mounds at sawmills also generate significant amounts of waste oil and leachate, respectively.

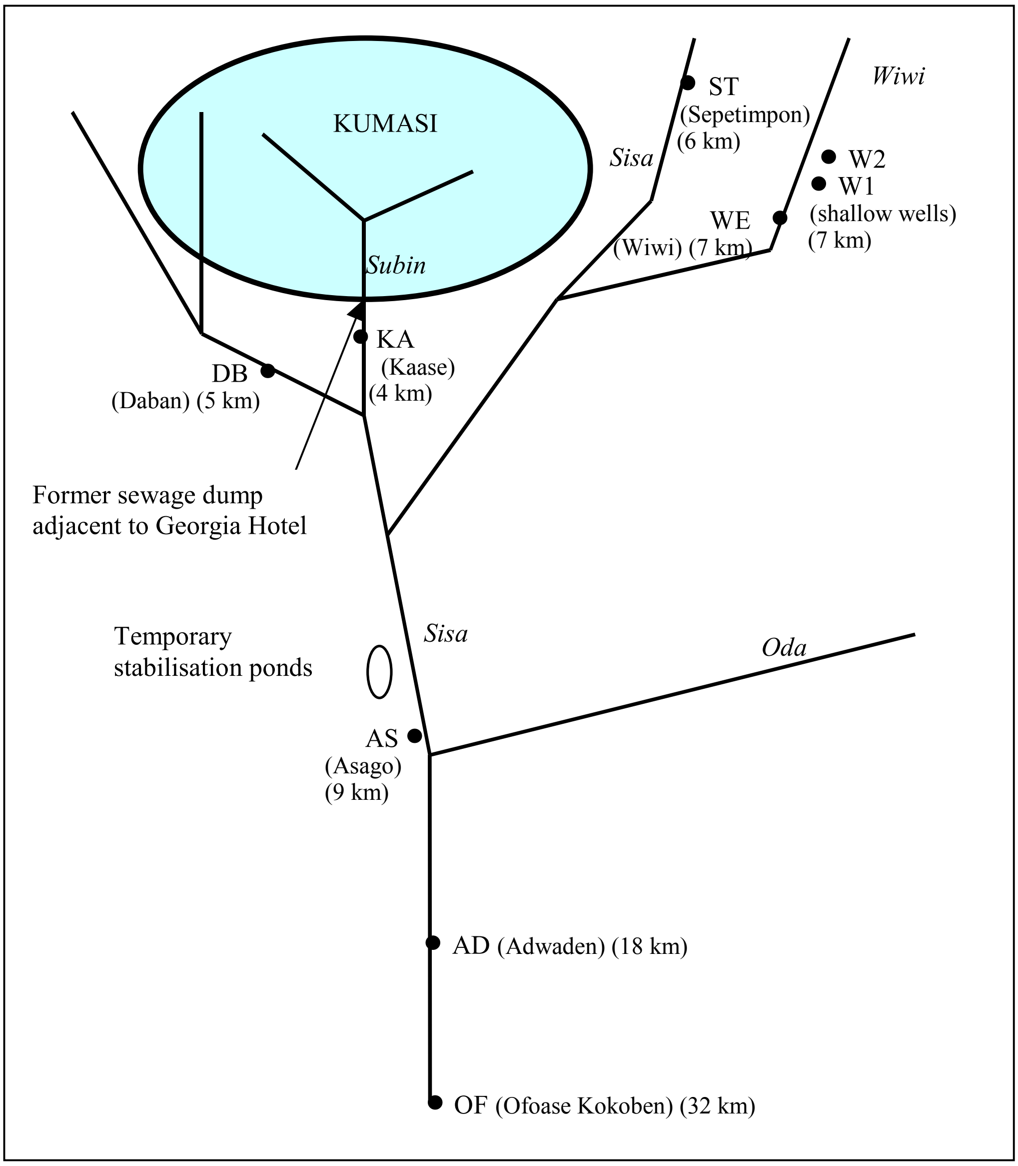


Figure 16 Principal streams and water quality sampling locations, Kumasi
Figures in brackets give distance from central Kumasi

9.2.1 Results - Kumasi

Seven river sampling sites were selected to quantify the levels of pollution at sites thought to be highly polluted, and to gauge the extent of auto-purification at sites further downstream. Two shallow wells were also sampled to provide a comparison between the water sources most widely used for irrigation. Sampling sites are shown in Figure 16.

Samples were taken on five occasions between February 18th and March 16th 1999, i.e. at the end of the main dry season when river flows are at their lowest, and there is least dilution of municipal and industrial discharges. Water quality in the rivers is likely to be at its worst during this period, which also coincides with widespread irrigation activity.

Counts of faecal coliforms over the sampling period are shown in Figure 17.

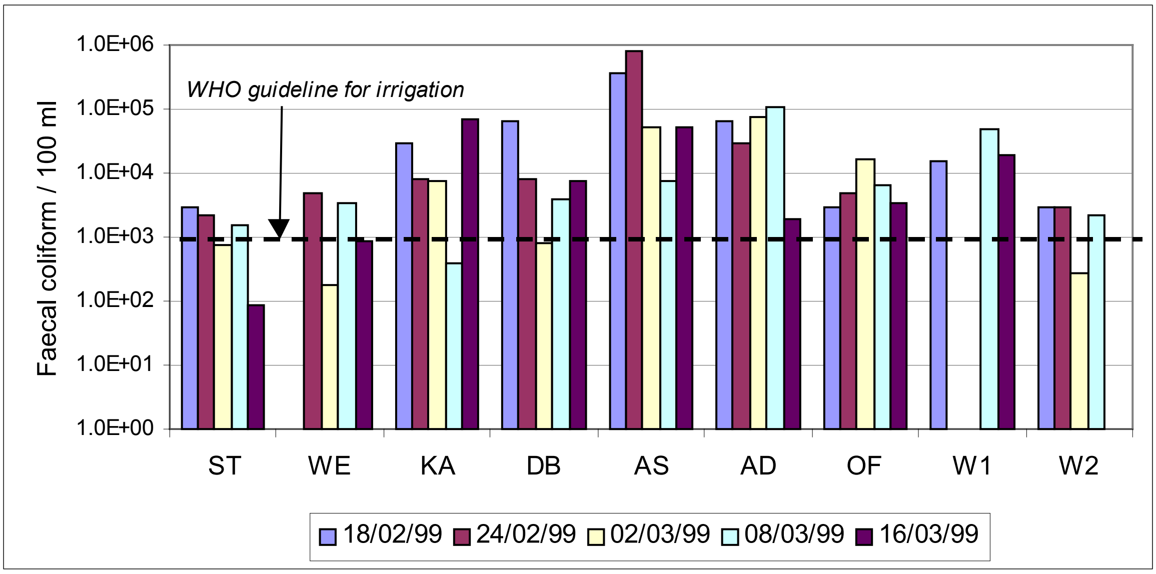


Figure 17 Faecal Coliform counts, Kumasi sampling sites

The first seven sampling sites shown in the figure are arranged according to their location in the catchment – moving from left to right represents a move from upstream of central Kumasi to sites downstream of the city. W1 and W2 are the shallow wells, adjacent to the River Wiwi at the WE sampling site. There is a pattern of increasingly poor water quality moving from the Sepetimpon (ST) and Wiwi (WE) sites, upstream of the main urban centre towards the most microbiologically polluted site at Asago (AS), 9 km south of the city at the confluence of the Sisa and Oda rivers. Further south of Asago, at Adwaden (AD) and Ofoase Kokoban (OF), the numbers of faecal coliform are lower but remain above the WHO guideline value for unrestricted irrigation.

From this data set and the results of earlier sampling carried out in study zone (see Table 12 of annex 1), it is concluded that irrigation practised on the Sisa and Wiwi rivers, upstream of Kumasi, could pose a threat to the health of consumers. Faecal coliform numbers are close to or slightly exceed the limit for unrestricted irrigation recommended by the WHO (1989) and Blumenthal *et al*. (2000). The very high counts at the river sites further downstream give cause for greater concern as they considerably exceed limits for irrigation of vegetables and approach Blumenthal *et al.*'*s* (2000) maximum limit for <u>restricted</u> irrigation of cereal crops etc. The mean count at Asago is two orders of magnitude larger than the guideline limit and there are many farmers irrigating with river water in this area. The data from Ofoase Kokoben (OF) indicate that 32 km downstream of Kumasi faecal coliform numbers are still five times the guideline limit.

The data for the two shallow wells tend to refute claims that unprotected wells provide better quality water than the rivers, but firm conclusions cannot be drawn on the basis of data from just these two wells located close to a major road, in an area of frequent human activity. A wider study of the water quality in shallow wells used for irrigation would certainly be required before any firm recommendation could be made in their favour.

A similar picture emerges from results of more recent sampling in Kumasi and elsewhere in Ghana. (McGregor *et al*. 2001; Mensah, 2001). Beernearts (2001), reports that no surface water source within metropolitan Accra used for irrigating vegetables meets the WHO quality guidelines.

9.3 Water Quality, Nairobi

Urbanisation is occurring in Nairobi at a rapid rate. Large quantities of raw sewage and untreated household and industrial effluents drain directly into the city's rivers, and solid waste is dumped along river banks. The rivers are heavily polluted, and there is well-founded concern that their waters are unsuitable for irrigation, particularly downstream of the city's industries. The practice of breaking sewage lines and use of raw sewage for irrigation in places such as Maili Saba is clearly a potential major health hazard.

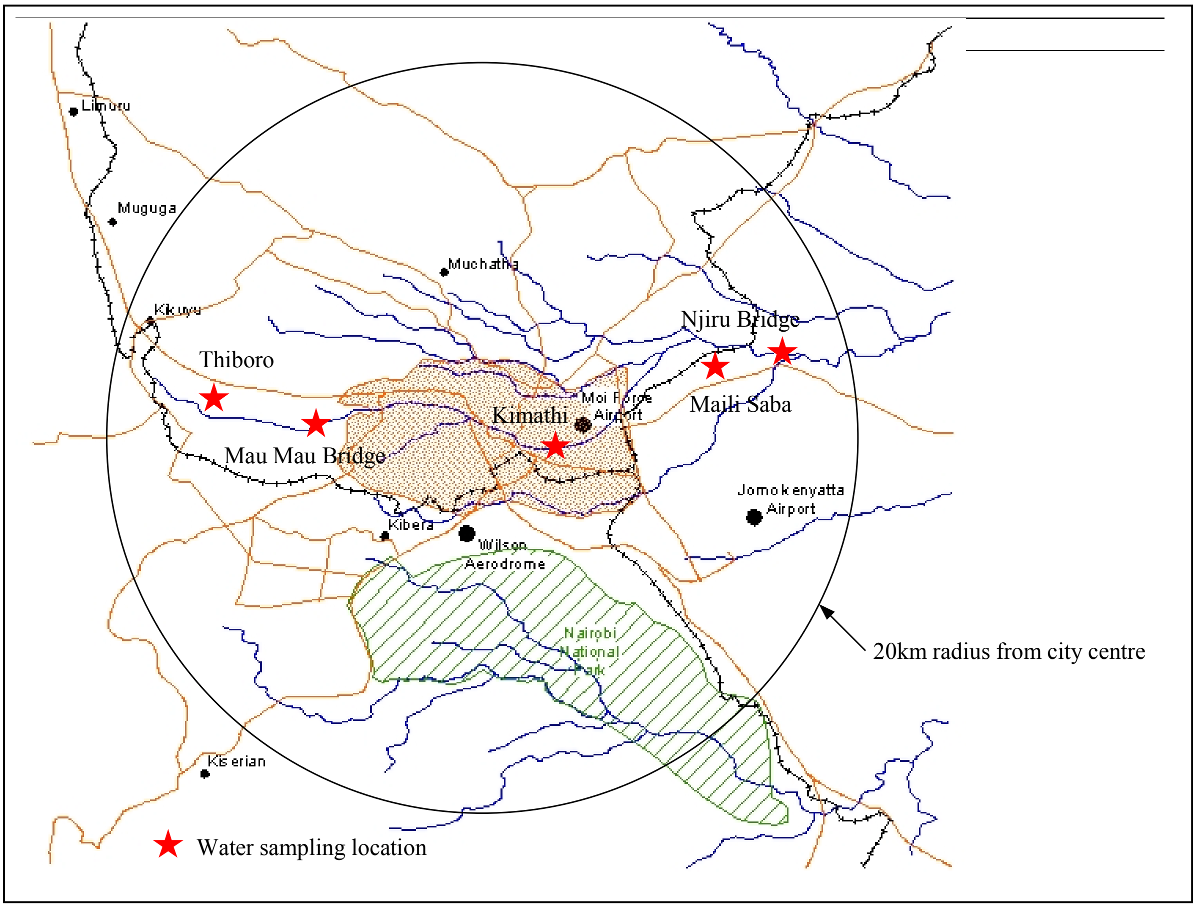


Figure 18 Principal rivers and water quality sampling locations, Nairobi

Water quality monitoring was carried out over a seven week period during August and September 2000. This coincides with the end of the dry season, when irrigation is widely practised, river discharges are low and pollutant concentrations are high. (Following several years with lower than average rainfall, river flows were particularly low during the monitoring period.) Five sites were selected for water quality sampling. Four were located along the Nairobi River, with a fifth at Mali Saba, where samples of raw sewage used for irrigation were collected (See Figure 18). Water samples were tested for microbiological, physical, and chemical quality parameters at the Nairobi City Council, Kabete Central Laboratory.

Figure 19 shows results for faecal coliform. The variation within results at each location is not very large, suggesting that the results are consistent. Counts increase moving downstream, and rise to a maximum of 10^7 FC/100ml, four orders of magnitude larger than the WHO limit for unrestricted vegetable irrigation. The average number of faecal coliform in the water samples taken from the dug-out at Thiboro was 6×10^2 FC/100ml which is just within the WHO guideline figure of 10^3 FC/100ml (Mara & Cairncross, 1989). At all other locations, counts are many times larger than the WHO guideline figures, with counts at the two downstream river locations being similar to that obtained from raw sewage at Mali Saba.

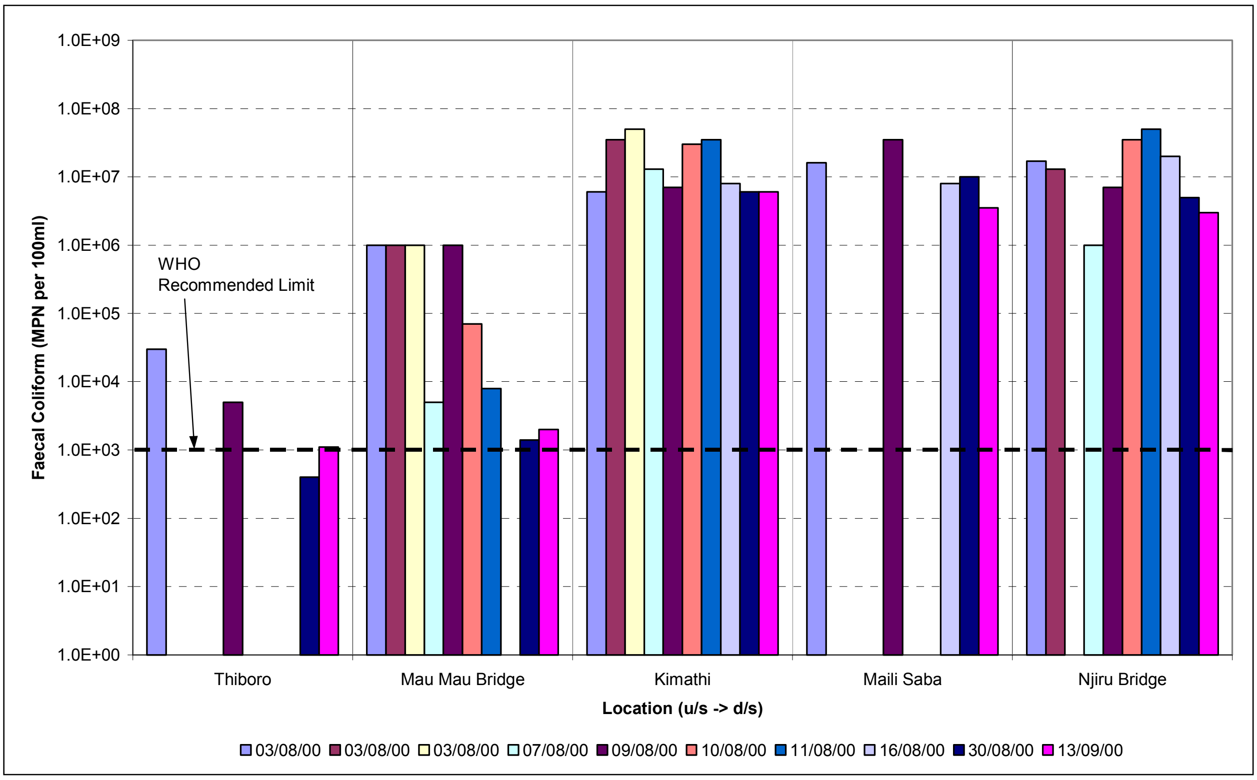


Figure 19 Faecal coliform counts at Nairobi sampling sites

The mean faecal coliform counts for raw sewage at Maili Saba (1 x 10^7) and typical values for sewage inflows at the Nairobi Ruai sewage works (around 3 x 10^7) are similar, providing some verification of the reliability of the coliform counts measured in this study.

Water quality tests in Nairobi were also undertaken by UNEP under their "Save the Nairobi rivers" project. UNEP collected samples from a wider range of locations and tested for a wider range of parameters than this study, but only single samples were collected at 24 locations along three rivers. The UNEP samples contained very much lower levels of coliform than the samples collected in this study, ranging between 30 to 1800 Total Coliform/100 ml. We have no convincing arguments that explain this very large discrepancy between the two sets of results. The UNEP data were collected in November 1999 when river flows would have been higher than during the sampling carried out in August/ September 2000. However, the difference in flows, and hence in dilution of pollutants, cannot be large enough to explain the very large differences between the two data sets. As comparison between other measured parameters (reported in Hide, Hide and Kimani, (2001)) are broadly similar, it seems possible that the coliform data reported by the UNEP study may be erroneous. Further measurements will be needed to resolve this issue.

9.4 Implications of water quality results

Based on these high levels of faecal contamination of water used for irrigation, the risks to the health of irrigators who come into regular contact with the water are beyond dispute. Where fresh salad and other vegetables likely to be eaten raw are irrigated there is also a clear danger to consumers and, even where produce is cooked before consumption, there remains a risk of disease transmission from the handling of dirty crops. Accurate data on consumers' use of vegetables – cooked or eaten raw – and the distribution of crop types linked to water quality, remains to be obtained. However, in Nairobi for example, it is known that salad vegetables such as celery, cucumber and lettuce are grown in Makadara, an area using sewage effluent for irrigation.

Although the situation gives cause for concern, it is not easy to identify simple interventions that are likely to be acceptable to growers, consumers and municipal agencies. Many growers depend on the use of polluted water to sustain their livelihoods and any action to ban or restrict their production is unlikely to be effective. Possible policy and technical interventions are reviewed in section 11.

10. FARMERS' PERCEPTIONS OF CONSTRAINTS

Farmers' perceptions of their constraints to production were investigated in the initial surveys carried out at both locations (Cornish and Aidoo, 2000; Hide and Kimani, 2000.)

The most important constraints listed by farmers in the two cities are shown in Figure 20.

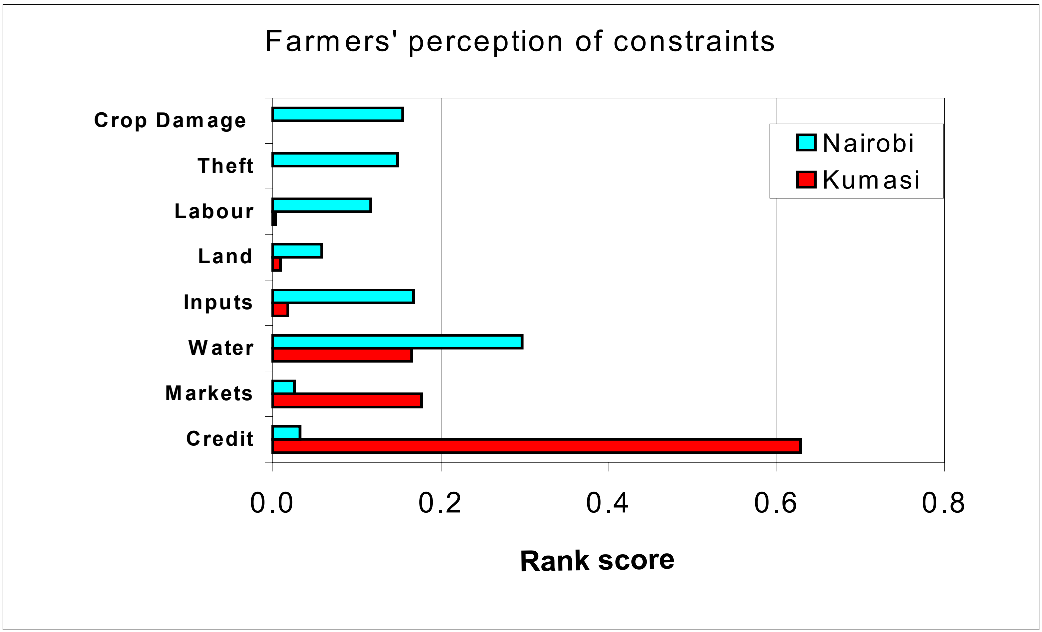


Figure 20 Farmers' perceptions of constraints to production

Note: The rank score in this plot is the proportion of farmers listing the constraint as their leading constraint

In Kumasi, the shortage or unavailability of credit is the outstanding constraint identified by all farmers, irrespective of their irrigation method, followed by marketing and access to water. Concerns over the unavailability of labour or land are of least concern for all farm types.

Amongst Kumasi farmers using pumps, the second constraint after credit is produce marketing. This is understandable where these farmers cultivate a larger area than those relying on carried water, and have higher levels of production which require marketing. The use of a pump implies that water is less of a constraining factor.

For the much larger group of farmers reliant on manually carried water, access to water ranks as the second greatest constraint after credit. 80 to 85 % of the farmers questioned believe they are constrained by their water supply – they cannot apply as much as they would like, their yield is affected by water shortage or water supply limits the area they cultivate. Amongst farmers reporting water as a constraint, 72% identified the effort or cost involved in obtaining water as being the limiting factor, with only 28% referring to scarcity of water at the source.

In Nairobi, obtaining an adequate supply of water is ranked as the primary constraint. Obtaining other inputs, such as seed and agro-chemicals, is also a serious constraint. As the farms included in this study are close to the urban centre, theft of crops and equipment and damage to crops are also significant issues. Over two-thirds of the farmers reported that crops are stolen from their plots and just over a quarter had had equipment stolen from the field. Availability of labour is also seen as a significant constraint.

Given that a significant proportion of farmers are squatting on government land, it is perhaps surprising that availability of land around Nairobi is not perceived as a major constraint. Only one farmer reported being harassed for cultivating on government land, suggesting that the authorities operate a laissez-faire policy towards peri-urban farmers. In contrast to Kumasi, neither credit nor marketing is seen as a significant constraint.

10.1 Farmers' priorities for intervention (Kumasi)

At the 2001 Kumasi workshop, local farmers' priorities for beneficial interventions were explored. Twenty-nine farmers, drawn from the communities participating in the study, attended the workshop. They were asked to vote on the list of interventions generated from group discussions involving both farmers and other participants, to select interventions that should have the highest priority.

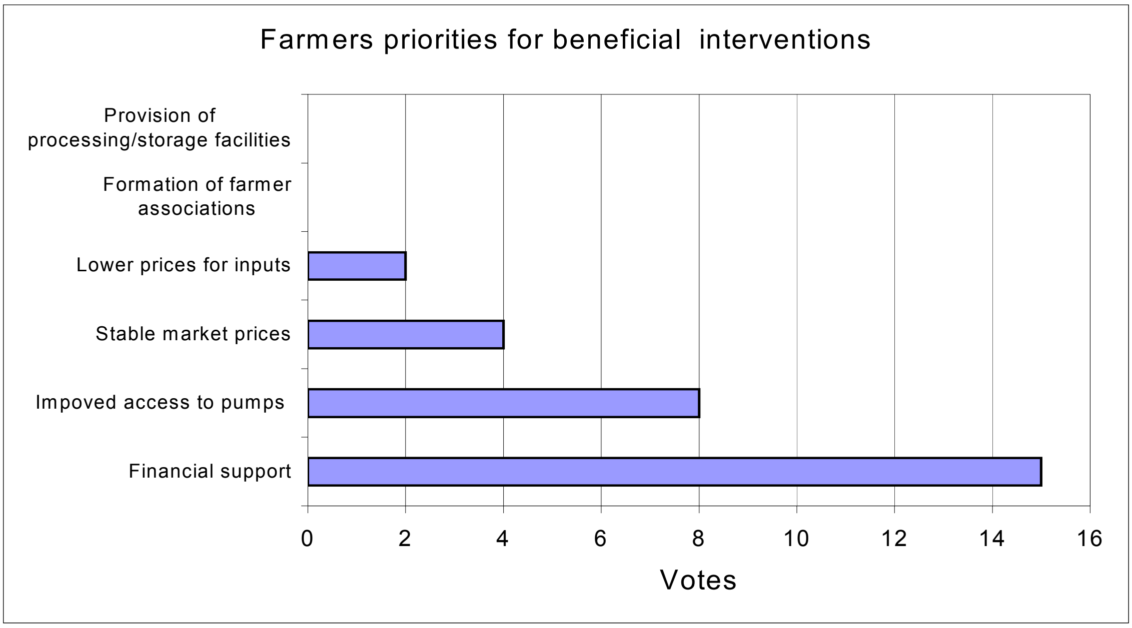


Figure 21 Farmer priorities for beneficial interventions

Unsurprisingly, Kumasi farmers' priorities for interventions generally reflected their prioritisation of constraints, with provision of financial support (credit) being by far the most popular intervention, followed by pumps (access to improved water lifting/moving), and stable prices (marketing). It is notable that, although formation of farmer associations to improve access to credit, marketing arrangements and purchase of inputs etc, was identified in the group discussions by farmers as a necessary or desirable intervention it received no votes in the ranking process.

11. OPTIONS FOR IMPROVEMENT

The field studies and stakeholder workshops carried out in the course of this project led to the following conclusions:

- Informal Urban and Peri-urban Irrigated Agriculture (IUPIA) is widely practised, providing an important source of cash income to thousands of poor households in the urban and peri-urban zones of Nairobi and Kumasi.
- Despite this finding, and the level of interest in urban and peri-urban agriculture amongst donors and researchers, aspects relating specifically to irrigated cropping are widely overlooked by government ministries because:
  - Irrigation infrastructure is minimal and individual plots are small so it falls outside the remit of government irrigation departments.
  - Proximity to urban centres, combined with the focus on non-traditional crops, result in the sector being overlooked by over-stretched agricultural extension services that focus on traditional food and cash-cropping systems
  - City administrations are ill-equipped to address the needs of the sector and choose to ignore it or act against it when bylaws are infringed, infrastructure is damaged or concerns over consumer health are raised.
- Agronomic practices, including land preparation, crop husbandry and water management are often poor and farmers have little access to good information or demonstrations of good practice.
- Water sources used for irrigation are often highly polluted, posing a threat to the health of producers and consumers.
- Water scarcity or the lack of appropriate means to convey water from source to crop is often a critical factor that limits farmers' production.

In the light of these findings, a range of potential actions or interventions can be identified. They have different objectives, are targeted at different end-users, but can be grouped under the main issues, as summarised Table 26. Many of the interventions are relevant to several issues and may be targeted at more than one user-group or audience. Column 4 in the table indicates whether the intervention focuses on the formulation of policy, immediate action to bring about change or where further research is needed to verify benefits. For several of the interventions, particularly those bearing on water quality, actions need to be taken in parallel, as part of a larger programme. For example, a crop certification programme cannot be launched without parallel actions to provide clean water for irrigation.

11.1 Policy and water quality

11.1.1 Acknowledge the existence and extent of IUPIA

Policy makers and government departments will only formulate supportive policies and release resources for interventions when they recognise the scale and importance of IUPIA. This requires that they have reliable information on both the benefits that it brings – contributions to the urban food supply and household income generation – and the health risks associated with the use of polluted water for irrigation.

This project has drawn together quantitative information that can contribute to raising the awareness of policy makers and government departments, pointing them towards areas for practical action. However, informal irrigation is only one activity amongst many that are together described as Urban and Peri-urban Agriculture (UPA). Although this sector is receiving considerable attention from UN agencies, NGOs and the research community, it still has to vie with the demands of other sectors when seeking the attention and resources of policy makers and government departments. IUPIA is an important part of urban and peri-urban agriculture, producing a large proportion of the fresh vegetables consumed in cities and providing the major source of cash income for thousands of households. At the same time, because many of the water sources used are heavily polluted, both growers and consumers are at risk from bacterial and helminth infections.

Table 26 Interventions to sustain and enhance the productivity of IUPIA

Intervention	Issue					Actors				Possible Actions			Primary Objective
	Water quality	Water availability	Agronomic practices	Credit	Marketing	Policy makers	Government departments	NGOs	Farmers	Change gov/municipal authority policies	Test Pilot Inteventions	Research to verify impact	
Acknowledge existence and extent of IUPIA	✔	✔				✔	✔			✔			Safer, increased production
Raise public awareness of water quality issues	✔					✔	✔	✔	✔	✔	✔		Safer production
Improve river water quality	✔	✔				✔	✔			✔	✔		Safer production
Crop restriction	✔					✔	✔		✔	✔	✔		Safer production
Controlled reuse of effluent	✔	✔				✔	✔	✔	✔	✔	✔		Safer production
Water and crop certification	✔				✔	✔	✔		✔	✔	✔	✔	Safer production
Use of protected wells	✔	✔					✔	✔	✔			✔	Safer production
Alternative irrigation methods	✔	✔		✔			✔	✔	✔		✔	✔	Safer, increased production
Small-scale local water treatment	✔					✔	✔	✔			✔	✔	Safer production
Targeted agronomic/irrigation extension			✔			✔	✔	✔	✔	✔	✔		Increased production
Improved water lifting technology		✔		✔			✔	✔	✔		✔		Increased production
Small dams for water storage		✔				✔	✔	✔	✔		✔		Increased production
Provision of alternative credit mechanisms				✔				✔			✔		Improved incomes
Better market knowledge					✔		✔	✔	✔		✔		Improved incomes
Alternative marketing arrangements					✔			✔	✔		✔	✔	Improved incomes
Form farmer groups	✔	✔	✔	✔	✔		✔	✔	✔		✔	✔	Improved incomes

This combination of significant benefit and risk should motivate policy makers and government departments to actively review the actions that might be taken to enhance the benefits and reduce the associated health risks.

11.1.2 Co-ordinated interventions to address water quality

All but one of the policy "interventions" deal with aspects of water quality and they are therefore discussed together. The linking of water quality interventions with policy reflects the scale of intervention required to bring about change and safer production for both producers and consumers.

Use of water with levels of microbiological pollution well above WHO guidelines for irrigation is commonplace. However, bringing about improvements in current practices is not straightforward, given the nature of IUPIA, where thousands of farmers work independently of one another, drawing their water from many unregulated sources.

Any programme aimed at reducing the health risks associated with IUPIA must be broad-based, combining several of the interventions listed in Table 25. Such a programme must provide an incentive for producers and consumers to change current practices and make change possible, without those groups incurring high additional costs. The technical and institutional resources needed to eliminate the use of polluted water for crop irrigation by informal irrigators should not be underestimated. Westcot (1997) describes the characteristics of such a programme, based on a successful intervention in Chile and Beernaerts (2001) describes how elements of the same approach might be applied in Accra.

11.1.2.1 Raising public awareness

Raising the awareness of producers and consumers of the health risks associated with the use of polluted water for vegetable irrigation can provide an incentive for change amongst consumers, traders and growers.

Where consumers are made aware of the potential link between consumption of produce irrigated with polluted water and the incidence of diarrhoeal disease within their households, they can pursue one of several options:

- Accept the situation, making no change to their buying or food preparation practices.
- Buy the same produce but take precautions in its preparation – i.e. thorough washing or cooking.
- Reduce their consumption of those food items.
- Demand alternative produce which is certified to be safe. Some consumers may be willing to pay a premium for this improved quality.

Studies of irrigated vegetables grown in Accra (Maxwell and Armar-Klemesu, 1998) have shown that greater bacterial contamination occurs through poor hygiene during crop marketing and distribution than during production in the field. In view of this, campaigns to raise public awareness may be better focused on consumer food hygiene rather than on irrigation water quality.

Traders may be encouraged to maintain improved levels of hygiene in the storage, washing and presentation of produce – for example avoiding the use of dirty water to freshen produce. To achieve this, market traders must have easy access to clean water supplies. The traders may also pass on the demand of consumers to growers, seeking only to buy produce from farmers using clean water.

Where farmers are pressed by traders to supply "clean" produce or where premium prices are paid for "safe" produce, they have an incentive to use clean water sources. However, alternative, cleaner water sources must be available to them and, if premium prices are to be paid, consumers need some form of assurance, through a policed system of certification, that produce has been grown using clean water.

11.1.2.2 Provision of clean water sources

a) Use of protected wells

The provision of alternative, clean water sources is a major challenge in many locations. Water drawn from shallow wells or dugouts might be expected to be less polluted than that in rivers draining urban centres. However, water quality studies in both Kumasi and Nairobi (Cornish *et al*. 1999; Hide *et al.* 2001) showed the mean faecal coliform count in all monitored wells to exceed the WHO guideline of 1000 FC/100ml for unrestricted irrigation. The source of pollution in these wells is not known but there is a need for field research to determine if simple protection measures, combined with awareness raising amongst farmers, can raise the water quality from these wells to a level that consistently lies within, or at least closer to the WHO guideline.

Where farmers are using motorised pumps to lift water from polluted rivers or other open water bodies, shallow dug-outs do not provide a viable alternative unless the sustainable yield of the well matches the pumping rate, which is seldom the case. Good quality water may be available from specifically constructed well-points, but such wells are expensive and would tie a farmer, or, more realistically, a group of farmers, to one site.

b) Improving river water quality

In the long term, improving the microbiological quality of rivers and other water bodies will be the best solution but in many urban and peri-urban locations this remains an unrealistic goal in the short to medium term.

c) Controlled re-use of effluent

In some situations, it might be more appropriate to promote the controlled reuse of treated effluent. Where sewage treatment infrastructure already exists adjacent to potentially cultivatable land, it may be practical to encourage farmers to relocate from sites where they are using unsafe water to a new site where they have access to treated effluent. To be successful, such an intervention requires that:

1. There is sufficient treated effluent to satisfy predicted irrigation demands
2. Quality of the effluent is regularly monitored and the treatment process consistently delivers water that is "safe" for irrigation
3. Suitable land is available and farmers are willing to relocate. This carries major implications regarding housing, access to other services, access to market, etc.
4. Consumers are confident that produce irrigated with treated effluent is safer than existing produce.
5. Clear policy decisions are made to ensure that these needs are met as well as continuing expenditure of resources to maintain the treatment infrastructure and regularly monitor effluent quality. This last point again identifies the possible role of a water and crop certification programme.

d) Water and crop certification

Westcot (1997) discusses certification programmes and their attendant policy issues in detail. Certification that a water source is safe for irrigation is most easily applied where many farmers draw water from a common source. Such a situation occurs on a formal irrigation scheme where water samples at the scheme intake can be monitored. It might also apply where the effluent from an existing treatment plant is to be used. Routine certification of water quality is much more difficult where many, small-scale farmers draw their water from numerous streams and shallow wells. To overcome this, there would need to be clear market incentives and appropriate technical interventions to motivate small, independent farmers to come together in groups or associations for whom a single, safe and monitored water source can be provided.

Where water certification is to be coupled with a formal labelling and crop certification programme, there would be a need for farmers to work together in organisations that would bear responsibility for securing and maintaining certification of their water sources. It is clear that an intervention of this type

– water certification and crop labelling – requires sustained activity by an independent agency in which consumers and producers can have confidence.

e) Crop restriction
Although listed as a possible intervention, the application of a crop restriction programme, i.e. ensuring that only selected crops, such as fodder or grain crops or produce that will be processed and cooked before consumption, are grown, is likely to be unworkable under the conditions prevailing in IUPIA. For crop restriction to be effective, Westcot (1997) suggests that all of the following conditions must apply:

1. Irrigation using wastewater occurs only in well defined sites (formal irrigation schemes) which have strong central management
2. Strong mechanisms to enforce the restriction regulations are in place and are respected
3. There is adequate demand and good prices for the crops permitted under the restrictions
4. There is little market demand for excluded crops.

None of these conditions prevail and mandatory crop restriction is not a sensible option to pursue when attempting to improve the health of producers and consumers of IUPIA produce.

11.1.3 Simple interventions to address water quality

With the exception of evaluating / piloting the use of protected wells as a source of clean water, all of the foregoing interventions require policy decisions and actions to be taken on a large scale. Policy makers and government departments are therefore the focus of these interventions, which would require a co-ordinated approach to be successful. The remaining interventions addressing water quality can piloted or implemented on a smaller scale without the need for policy makers to be involved at the outset.

11.1.3.1 Alternative irrigation methods

Use of localised irrigation, which applies water to only a fraction of the field surface adjacent to the crop, with water delivered through a network of pipes, reduces the need for the irrigator to come into contact with polluted water. The crop will also be less exposed than when overhead irrigation, by watering can or "sprinkler", is used. However, given the low levels of investment that most informal irrigators presently make in production inputs, it is not clear if they would be able to invest in irrigation equipment of this type. When it is well-managed, localised (drip) irrigation offers other potential advantages such as water saving and improved yields and these incentives might make the technology attractive, particularly where water is scarce or is carried manually over considerable distance.

A factor that must not be overlooked, is that drip irrigation generally requires physically and chemically clean water to avoid clogging of the small dripper orifices. Some NGOs and commercial manufacturers are currently evaluating low-cost or affordable drip irrigation technologies for smallholder farmers, but it is too early to say whether they will be an appropriate technology for many informal urban and peri-urban irrigators.

Pressurised, piped, sprinkler irrigation again reduces the amount of contact that irrigators have with polluted water, when compared with surface irrigation or the use of watering cans or buckets. However, crops and thus consumers are still exposed to the same risks. Sprinkler irrigation could therefore only have a role in safer production where crop restriction was enforced, i.e. no irrigation of crops eaten raw.

11.1.3.2 Small-scale water treatment

Rose (1999) presents a review of community-based technologies for domestic wastewater treatment. These include both on-site (household level) and off-site (neighbourhood level) systems. The former comprises various types of composting toilet and small-scale reedbed systems. The latter includes larger constructed wetlands and use of various aquatic plant species and the more widely used waste stabilization ponds. All of these technologies seek to capture and treat domestic sewage before it enters rivers or other urban watercourses. After treatment, the effluent may then be safely used for crop irrigation, if land is available adjacent to the point of treatment. These technologies can only have their effect on the quality of existing rivers and drains, which are presently used by irrigators, where they are adopted on a sufficiently wide-scale to significantly reduce the quantities of untreated waste entering rivers.

Once pollutants have entered a river, it is seldom practical to intervene to attempt to clean the whole river flow. Rather, reliance is placed on natural biological processes of oxidation and ultraviolet effects to remove pathogens. This process may occur over many kilometres, the rate of rejuvenation being influenced by the flow rate and velocity, the amount of agitation that occurs over riffles or other falls and the permeability of the water to light.

To provide existing irrigators with a water source of improved quality, some form of simple and low cost treatment must be available at the point of use, i.e. after water is abstracted from the watercourse and before application to the crop.

Actions such as short-term retention of water in pools and the current practice of holding water in field side drums before applying it to the crop merit further evaluation to determine their effects on levels of pathogen die-off. Approaches such as these merit research and field evaluation with farmers, but actions must be low cost, or, where this is not possible, the farmer must be able to receive a premium for the financial and labour investments made in cleaning the water supply.

11.2 Improving water availability

Interventions to improve water availability include:

a) Making better use of what is already available by improving water use efficiency in the field
b) Allowing the farmer to have access to larger volumes of water

Evaluation and introduction of alternative irrigation methods address the first of these objectives, whilst use of improved water lifting technologies and small dams address the second.

11.2.1 Alternative irrigation methods

Some alternative irrigation methods have already been referred to with reference to their potential contribution to reducing the health risk to producers through use of polluted water. Low cost drip systems can offer water savings of 30% or more when compared with conventional surface irrigation methods. However, the existing manual irrigation methods, using watering cans or buckets and tins to pour water around the base of individual plants, are already highly water efficient. In these circumstances, low cost drip may offer greater benefits through labour savings and the potential to apply more water for a given labour input.

Many of the low cost drip systems currently under evaluation can only irrigate plots of between 100 and 600 m^2 and cost between $US 2,000 – 2,500 / ha. Local field testing of these products is still required to determine if they offer sufficient benefits to farmers to justify the investment required. To achieve effective uptake, wider issues such as local manufacture, effective marketing, farmer training/support and possibly credit provision also need to be addressed.

Earlier field studies in Kumasi (Cornish and Aidoo, 2000) identified potential intervention to improve irrigation practice amongst farmers making regular use of motorised pumps. Present pump irrigation practice described in section 5.1.3 can be considerably improved by either:

a) The use of surface channels to direct water to level basins. Water would be pumped to one or two high points on the plot and distributed in earth channels from there. This would require initial investment of labour to layout and construct the network of beds and channels, particularly on irregular, uneven ground but once complete, improved water distribution would be possible.

Or,

b) Use of simple, portable draghose sprinkler systems in combination with the pumps. A four sprinkler system, suited for use with smaller 2kw (2½ hp) pumps, may cost about $US 300 where the pump is an existing, sunk cost. This might be targeted particularly towards those farmers who own and hire out a pump. By hiring out the pump and sprinkler system they could recoup their investment cost and those hiring the equipment would benefit from improved application uniformity and reduced labour inputs to oversee irrigation.

11.2.2 Improved water lifting technology

In Kumasi, 70% of respondents to the questionnaire survey stated that physical effort or the cost of paying labour limited the amount of water applied to crops. In Nairobi, only 12 % of respondents said that the effort of irrigation limited their cultivated area, whilst 24% referred to the water source drying up. 64% of the Nairobi farmers said that neither the amount of water available nor the effort required to apply it to crops constrained their production. Thus, in Kumasi in particular, the effort of irrigation severely constrains production while in Nairobi water scarcity is a greater constraint.

From these data, there appears to be considerable potential, particularly in Kumasi, for demonstrating and evaluating the acceptability to farmers of low-cost water lifting devices such as treadle pumps. These pumps can reduce the drudgery and effort required of those carrying water and considerably improve the productivity of irrigation labour. Unlike motorised pumps, they can be used in combination with shallow dugouts – one of the most common sources of water.

11.2.3 Small dams for water storage

There was no evidence in either Nairobi or Kumasi of small dams being used by communities or farmer groups to retain water for dry season irrigation. Construction of such dams requires adequate technical supervision in site selection, dam design and construction, but these skills exist within public sector agencies – ministries of irrigation and public works departments – and in NGOs and private sector engineering companies. It should not prove too difficult to use these agencies to implement such an intervention to improve the availability of water for IUPIA. Small dams would probably be owned and managed by local irrigating communities following the model successfully adopted by NGO’s in rural communities. Special attention would need to be given to ensuring that irrigators would welcome such a form of intervention and developing the arrangements needed for maintaining the dam and sharing the water. While the number of technically appropriate sites will be limited in some localities, the introduction of small dams is an intervention worthy of further evaluation by both government departments and NGOs.

11.3 Improved agronomic practices

Knowledge of good agronomic practices, from the preparation and care of nursery beds, planting densities, weed and disease control, and water management through to the maintenance or improvement of soil fertility by use of manures, compost and inorganic fertilizers, is generally poor amongst informal urban and peri-urban irrigators.

Because irrigators farm very small plots and work as individuals, they are often invisible to the state agricultural extension services. For effective dissemination of information on improved agronomic and water management practices, farmers need to seek information or advice as groups and extension services need information and training in order to support the farmers. Such training is particularly needed where extension workers have traditionally only focused on rainfed food and traditional cash crops.

By encouraging farmers to work together in groups to receive and evaluate extension advice, it would be possible to use extension techniques such as farmer field schools, which are regularly shown to have better impact than traditional one-to-one training methods. Developing and promoting good extension materials and establishing farmer groups to receive and evaluate extension advice is probably one of the most effective short-term interventions, with the objective of increasing productivity and improving farmer income from informal irrigation, that is available.

11.4 Provision of credit services and improved marketing

The study in Kumasi revealed that many farmers are tied into informal, pre-financing arrangements with market traders, thereby linking these two aspects of production. These two issues of credit and marketing were identified by Kumasi farmers in the original questionnaire survey, and again at two subsequent workshops, as their top two concerns. By contrast, Kenyan farmers ranked these issues lowest when asked to identify practical constraints to production and income.

There may be scope for the provision of credit where it is tied to the introduction of a particular technology such as the treadle pump, sprinklers or low-cost drip irrigation. Where farmers are making a capital investment an initial down payment can be made, a repayment schedule agreed and, if repayment is not made on time, the capital item can be repossessed. However, the provision of credit to meet expenditure on seasonal start-up costs – seed, pesticides, labour, etc – is more problematic.

Because farmers in Kumasi are frequently bound into what they perceive to be disadvantageous marketing arrangements when they secure informal credit from traders, they highlight this as an issue requiring the attention of outside agencies. This study has gone no further than to identify that it is a complex issue where any intervention must be carried out with great caution. There do not appear to be many immediately promising options to pursue in this area.

Kumasi farmers reporting of marketing problems and their desire to see intervention in that field reflect a number of complex issues, not least of which is the control of the Kumasi central market by the market queens and traders, with farmers forced to pay a number of commissions and levies. Bypassing these existing market systems on a large scale through the provision of parallel market systems would require major political and policy level intervention. A more feasible and smaller-scale intervention would be to gain greater understanding of how some farmers make contact with travelling buyers from other urban centres, who appear to pay better prices than the traders selling into Kumasi.

The most immediately practical intervention under this theme may be to study medium and short-term price fluctuations for key irrigated products and to provide information to assist farmers to plan production to coincide with price peaks. This presupposes that such training can be provided to farmers through some form of extension or advisory service.

11.5 Group formation

The formation of formal or informal farmer associations is a mechanism by which several interventions could be established and through which farmers could improve their access to credit, extension advice, or improved market opportunities. Despite the apparent benefits arising from group formation and action, there were almost no effective formal or informal farmer groups identified by the studies in either Kumasi or Nairobi. In workshop discussion groups, farmers from around Kumasi accepted the suggestion that group actions could bring benefits, but proposals to form groups were always given a low priority when farmers ranked their "preferred" interventions. In Ghana, at least, the forming of groups or co-operatives has come to be strongly associated with politics and party control within the community, which explains in part, the unpopularity of such groups.

Effective group formation is not a spontaneous event. There appears to be considerable potential for intervention by a neutral agency such as an NGO that can provide training and support to farmers to overcome their misgivings and form effective group structures. Defining group objectives should be in the hands of the group members and not imposed from outside. However, Table 25 identifies a range of areas where group co-operation could be effective. These are:

11.5.1 Controlled re-use of effluent

An intervention of this type, where farmers are settled on a "formal scheme" downstream of a sewage treatment plant, would require effective farmer co-operation to manage water allocation and the operation and maintenance of infrastructure. These are the normal management tasks undertaken by water user groups or associations on any formal irrigation scheme. If farmers were relocated onto such a scheme from sites where there was previously no need to co-operate to manage shared resources, then particular care would be needed to ensure group cohesion and effectiveness.

11.5.2 Water and crop certification

The certification of a water source as being safe for unrestricted irrigation and certification (labelling) of crops grown with clean water presupposes that the water source is used by an organised group of farmers, responsible to the certifying agency. Monitoring and certifying individual farmer's water sources is not likely to be a practical option. Thus, a major component of the water and crop certification approach to safer irrigated produce depends on farmers sourcing their water and marketing their crops as organised groups.

11.5.3 Small-scale water treatment and small dams for storage

The construction of physical works such as small storage ponds or reedbeds to treat polluted surface water before irrigation, or the construction of small earth dams for water storage, are only likely to be viable interventions when farmers agree to work together to carry out or assist with construction and then maintain the asset. Group co-operation is also needed for effective management and allocation of the treated or stored water.

11.5.4 Agronomic and irrigation extension

The need for farmers to come together as groups to seek the support of extension services has already been referred to. Individual irrigating farmers are often widely scattered and cultivate only small plots, such that it is impractical for extension staff to visit or support single farmers. By forming a group and petitioning the extension service for support – including paying the reasonable travel costs of the agent if necessary – then the needs of this farmer group are more likely to be recognised.

11.5.5 Improved water lifting technologies

The purchase cost of even a "low cost" technology such as a treadle pump may be beyond the means of an individual household. Certainly, the cost of simple drag hose system to improve the application uniformity achieved with a motorised pump is likely to beyond the reach of many households. By bringing together two or three households for a treadle pump or four or five for a set of pipes and sprinklers, it may be possible to raise the capital needed to make the purchase. However, care is needed in such arrangements to ensure that there is explicit agreement amongst all the participants over how the resource will be shared, how routine maintenance costs will be met and how any accidental damage will be paid for.

11.5.6 Alternative credit mechanisms

The issue of credit was touched upon in section 8.4. The situation in Kumasi is described more fully by Cornish *et al.* (2001). Existing, formal micro-credit provision through the Poverty Alleviation Fund is widely discredited as being too politicised. If alternative credit mechanisms are to be proposed, one approach would be to extend credit to formally registered farmer groups. Such groups do exist for the production of other crops such as rice but there is no evidence to date of credit provision being made for vegetable irrigators.

11.5.7 Better market knowledge and alternative market outlets

There is potential for farmers to work together to plan production schedules to coincide with periods of price peaks but, more particularly, to regularly obtain and compare price information from several market centres. Where farmers can avoid being "locked in" to selling into a single market, access to such market information, provided it can be coupled with access to traders from the alternative markets, could enable farmer groups to exploit regional variations in supply and demand of fresh produce.

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Annexes

Annex 1

Summary data tables

Table 1 Summary data characterisation of farmers involved in IUPIA

Characteristic	Kumasi	Nairobi
Percentage of farmers who are women	14%	63%
Mean farmer's age, (years)	Men 37 Women 44	Men 40 Women 33
Percentage of farmers originating from outside the Ashante or Nairobi central regions.	12%	45%
Numbers in Household	7.1	4.6
Percentage of respondents listing "farmer" as main occupation	92%	86%
Average length of time practising irrigation (years)	10	7
Percentage of farmers recording irrigated vegetable production as the primary source of household income.	84	84

Table 2 Land Holdings and Tenancy

Parameter	Kumasi	Nairobi
% Farmers who farm only irrigated crops	20%	55%
Mean area of irrigated plot (ha)	0.94	0.60
Number of years farming present irrigated plot (mean)	5.8	7.8
% Farmers farming plot for 2 years or less	30%	30%
% Farmers farming plot for 10 years or more	12%	23%
% Farmers who own irrigated plots	29%	31%
% Farmers who are share tenants	3%	4%
% Farmers who are cash tenants	53%	15%
% Farmers who are squatting	0%	39%

Table 3 Sources of water used for irrigation

Water source	% of farmers using source	
	Kumasi	Nairobi
Perennial river	28	48
Stream pool	8	1
Shallow dug out	21	4
River or stream pool supplemented by dug out when source dries out	34	0
Sewage water	0	29
Deep well or borehole	3	4
Piped mains	3	3
Stream/ river and sewage	0	6
Other	3	5

Table 4 Water conveyance methods

Water conveyance method – source to field	% of farmers using conveyance method	
	Kumasi	Nairobi
Manual carrying –(Bucket or watering can)	73	17
Motorised Pump	14	33
Manual carrying supplemented with pump hire	10	1
Gravity supply canal	0	35
Hose pipe from mains	2	1
Other combinations of conveyance method	1	13

Table 5 Water application methods

Water application method	% of farmers using application method	
	Kumasi	Nairobi
Furrow /basin	0	39
Bucket or watering can	76	17
Sprayed from hand held hose	14	16
Sprinkler	2	9
Combination of methods	8	19

Table 6 Basic irrigation data Kumasi farmers

Farmer ID	Irrigation season	Effective Vol. Applied (m^3) [1]		Mean irrigated area (m^2)	Average irrigation frequency (days)	Effective irrigation depth (mm)	Rainfall (mm)	Total depth of water supplied (mm)	Average crop water demand (mm)	Distance to water source (m)
		Pump	Manual							
11	25 Nov – 18 March 114 Days	Nil	110	2,800	1.6	39	105	144	350	20
12	2 Dec – 31 March 120 days	29	343	1,400	2.4	266	180	446	350	36
13	22 Dec – 15 March 84 days	144	45	4,000	2.9	47	69	116	330	12
14	15 Dec – 17 March 93 Days	604	4	6,000	4.8	101	93	194	350	20
15	22 Dec – 17 March 86 Days	172	247	5,700	2.1	73	93	166	330	10
16	13 Dec – 29 March 107 Days	547	77	5,000	1.5	125	180	305	360	20
17	15 Nov – 27 March 133 Days	338	42	4,000	2.5	95	207	302	360	90
21	20 Dec – 13 March 84 Days	Nil	7	2,000	3.3	3	69	72	330	-
22	1 Dec – 28 March 118 Days	Nil	230	8,100	1.6	28	180	208	370	180
23	24 Dec – 3 April 101 Days	Nil	49	2,000	2.8	24	194	218	330	40
24 [2]	17 Dec – 6 April 111 days	Nil	10	4,000	2.4	2	268	270	360	10
25	20 Nov – 29 March 130 days	Nil	77	8,100	1.1	9	196	205	400	20
26	24 Dec – 6 April 104 days	Nil	113	6,200	1.4	18	268	286	330	20
27	19 Dec – 3 April 106 days	Nil	39	1,200 [3]	2.6	32	195	227	360	15
31	17 Dec – 5 April 110 days	Nil	80	4,000	1.5	20	268	288	360	20
32	6 Dec – 26 March 111 days	Nil	33	6,000 [4]	1.6	5	179	184	360	50
33	10 Dec – 16 Feb 68 days	Nil	17	1,000	2.2	17	62	79	350	300
34	10 Dec – 1 March 82 days	Nil	20	6,100	2.7	3	69	72	330	25
35	3 Dec – 14 March 102 days	Nil	11	4,000	2.0	3	69	72	350	150

Farmer ID	Irrigation season	Effective Vol. Applied (m^3) [1]		Mean irrigated area (m^2)	Average irrigation frequency (days)	Effective irrigation depth (mm)	Rainfall (mm)	Total depth of water supplied (mm)	Average crop water demand (mm)	Distance to water source (m)
		Pump	Manual							
36	25 Nov – 13 March 109 days	Nil	22	4,000	1.4	5	79	84	360	300
37	25 Dec – 14 March 80 days	Nil	21	4,000	1.6	5	69	74	330	180

1. This is the volume after adjustment for assumed efficiency and area wetted. It therefore differs from the true volumes.
2. Much of farmer 24's irrigation was of nursery beds for garden egg. Little irrigation occurred after planting out as the plot was on marshy ground with a very high water table.
3. Farmer 27's area planted to cucumber was abandoned. The area here is the area under cabbage.
4. Farmer 32 planted 0.25 acre to tomato which was abandoned. The area here is that under garden egg and okra.

Table 7 Number of Farmers Cultivating Different Crops and Planted areas, Kumasi

Crop	Number of Farmers growing crop	Area (ha)
Tomato	193	99.3
Garden egg	177	84.1
Okra	153	77.7
Hot pepper	114	55.6
Cabbage	53	18.5
Cucumber	20	4.7
Green pepper	17	3.5
Lettuce	16	16.4
Carrot	12	2.9
Ayoyo	10	5.1
Green bean	9	1.7
Onions	7	2.0
Spring onion	6	1.1
Sulve	6	0.3
Water melon	6	4.1

Table 8 Number of Farmers Cultivating Different Crops and Planted areas, Nairobi

Crop	Number of Farmers growing crop	Area (ha)
Kales	81	30.1
Tomatoes	45	23.1
Spinach	38	12.5
Maize	28	12.1
Cabbage	21	11.6
Cowpeas	14	8.9
Lettuce	8	3.8
Beans	7	3.4
Fr beans	7	2.9
Onions	7	1.5
Arrowroots	5	1.4
Amaranth	4	1.1
Sugarcane	4	1.1
Egg plant	3	0.9
Cauliflower	3	0.9
Bananas	2	0.9
Broccoli	3	0.8
Nightshade	2	0.6
Sugar cane	4	0.5
Capsicum	2	0.4
Pepper	2	0.3
Chinese cabbage	2	0.3
Celery	3	0.2
Coriander	2	0.1
Pigeon peas	1	0.04

Note: Data refers to four most important crops on each farm

Table 9 Farmer expenditures on labour, inputs and marketing, ($US / ha) - Kumasi

Farmer ID	Labour	Equipment Hire	Agronomic inputs	Marketing	Total /ha	Actual spend [1]
11	61	0	4	0	65	18
12	606	5	77	28	716	101
13	54	31	0	21	107	43
14	62	106	38	1	206	125
15	147	33	5	14	199	113
16	269	44	46	24	382	193
17	214	156	10	35	415	168
21	146	0	14	7	166	34
22	41	0	33	32	107	86
23	51	0	179	56	285	69
24	95	0	31	11	137	193
25	125	0	43	32	200	162
26	63	0	43	25	131	82
27	108	19	120	2	250	101
31	53	0	72	15	140	57
32	18	0	12	5	35	25
33	257	62	131	60	511	52
34	32	9	48	53	142	86
35	19	5	10	14	47	19
36	98	9	38	20	165	67
37	60	5	33	9	106	43

Note 1. Actual expenditure in US$

Table 10 Cost, revenue and profit figures adjusted for plot size ($US/ha) – Kumasi

Farmer ID	Costs ($US/ha)	Land rent ($US/ha)	Income ($US/ha)	Profit ($US/ha)	Plot area (ha)
11	65	0	861	795	0.283
12	716	0	944	228	0.142
13	107	0	533	427	0.405
14	206	0	237	31	0.607
15	199	0	986	787	0.567
16	382	0	394	12	0.506
17	415	0	581	165	0.405
21	166	45	693	483	0.202
22	112	24	379	242	0.809
23	261	0	193	-68	0.243
24	137	45	485	303	0.405
25	200	0	652	451	0.809
26	131	0	373	242	0.627
27	250	31	926	645	0.405
31	110	0	292	182	0.405
32	35	0	303	268	0.708
33	511	0	1067	557	0.101
34	142	0	920	779	0.607
35	47	0	322	275	0.405
36	165	0	386	221	0.405
37	106	0	217	111	0.405

Table 11 Location and method of selling produce – Kumasi

	Takes to Market in:		Consumer comes to field from:		Trader comes to field from:		Other methods of selling	
Locally	28	6.5%	128	77.6%	24	6.8%	6	21.4%
Kumasi	317	73.4%	7	4.2%	143	40.5%	7	25.0%
Accra	9	2.1%	3	1.8%	72	20.4%	4	14.3%
Takoradi	2	0.5%	3	1.8%	26	7.4%	1	3.6%
Agona	18	4.2%	1	0.6%	5	1.4%	0	0.0%
Obuasi	19	4.4%	2	1.2%	28	7.9%	1	3.6%
Abroad	1	0.2%	0	0.0%	6	1.7%	0	0.0%
Other	38	8.8%	21	12.7%	49	13.9%	9	32.1%
Total	432	100.0%	165	100.0%	353	100.0%	28	100.0%

Table 12 Summary of existing water quality data – Kumasi

River	Location	Reference (See Cornish et al. 1999)	pH	Suspended solids mg/l	TDS Mg/l	DO mg/l	BOD_5 mg/l	Faecal coliform /100ml (geometric mean)
Subin	Georgia hotel	Gah (1991)	6.62	421	-	0	369	$9.3 * 10^{7}$
	Georgia hotel	Appiah (1991)	6.77	-	-	0	93	$2.2 * 10^{8}$
	-	Gov. of Ghana (1996)	6.62	451	-	0	440	-
	Kumasi Zoo	EPA (1997)	7.2	-	-	1.8	120	$2.0 * 10^{2}$
	Asafo market	EPA (1997)	7.6	-	-	0.9	210	$2.5 * 10^{2}$
	Ahodwo bridge	EPA (1997)	7.4	-	-	0.3	100	$6.6 * 10^{3}$
	Limex road	Salifu & Mumuni (1998)	7.37	-	809	2.35	-	-
	Mean Values		**7.08**	**436**	**809**	**0.76**	**114**	**$92*10^3$**
Aboabo	Accra Rd	Gah (1991)	7.39	147	-	0	57	$2.2 * 10^{6}$
	Accra Rd	Appiah (1991)	6.8	-	-	1.6	5	$3.7 * 10^{5}$
	-	Gov. of Ghana (1996)	6.73	121	-	0	180	-
	Accra Rd	Salifu & Mumuni (1998)	7.01	-	318	1.8	-	-
	Mean Values		**6.98**	**134**	**318**	**0.85**	**81**	**$902*10^3$**
Sisa	Accra Rd	Gah (1991)	6.78	32	-	0	16	$5 * 10^{4}$
	Accra Rd	Appiah (1991)	6.29	-	-	1.3	2	$1.16 * 10^{5}$
	-	Gov. of Ghana (1996)	6.22	56	-	0	37	-
	Asago village	EPA (1997)	7.88	-	-	0.2	990	$1.28 * 10^{3}$
	Asago village	Kasanga (1998)	6.78		38		-	TC > $1 * 10^{3}$
	-	Salifu & Mumuni (1998)	5.83	-	671	0	-	-
	Mean Values		**6.63**	**44**	**354**	**0.3**	**261**	**$9.3*10^3$**
Wiwi	Ayeduade Rd	Fleisher-Djoleto (1990)	6.4	-	-	6.5	60	-
	Wiwi/Kantinkronu confluence	Gah (1991)	6.32	27	-	.5	22	$1.26 * 10^{4}$
	UST campus	Appiah (1991)	6.23	-	-	2.3	2	$7.0 * 10^{3}$
	-	Gov. of Ghana (1996)	6.38	33		0.5	16	-
	UST Campus	Awuletey (1994)	6.54	18	-	5	6	$7.4 * 10^{3}$
	Mean Values		**6.37**	**26**		**3.0**	**21**	**$7.9*10^3$**