The Peri-Urban Interface:

a Tale of Two Cities

Edited by

Robert M Brook,
School of Agricultural and Forest Sciences,
University of Wales, Bangor

Julio Dávila,
Development Planning Unit,
University College London

Cite as: Brook, R. M. and Dávila, J. D. (eds.). 2000. The peri-urban interface: a tale of two cities. School of Agricultural and Forest Sciences, University of Wales and Development Planning Unit, University College London. 251 + vii pp.

This publication is an output from a research project funded by the UK Department for International Development (DFID) for the benefit of developing countries. The views expressed are not necessarily those of DFID.

British Library Cataloguing in Publication Data. A catalogue record of this book is available from the British Library.

ISBN: 1 842 200111

Copies of this book may be obtained from:
Dr Robert Brook, School of Agricultural and Forest Sciences, University of Wales, Bangor, Gwynedd, LL57 2UW, United Kingdom.
E-mail: r.m.brook@bangor.ac.uk Fax: +44 (0)1248 354997.

Dr Julio Dávila, Development Planning Unit, 9 Endsleigh Gardens, London, WC1H 0ED, UK.
E-mail: j.davila@ucl.ac.uk   Fax: +44 (0)20 7387 4541.

Natural Resources Systems Programme, HTS Consultants, Thamesfield House, Boundary Way, Hemel Hemsptead, Herts, HP2 7SR, UK.
E-mail: nrsp@htsdevelopment.com   Fax: +44 (0)1442 21886.

Printed in Great Britain by Gwasg Ffrancon Printers, Bethesda, Gwynedd, Wales.

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Introduction

The Kumasi Baseline Study (Holland *et al*., 1996a) provides a very useful and detailed overview of most of the relevant environmental as well as soil and water management issues.

The Inception Report for "Kumasi Natural Resource Management Project at the Watershed level" (R7330) also provides the some basic descriptions of the environmental features of the area around Kumasi: rainfall, soils, terrain (CEDAR, 1999, p.10). Kumasi Metropolitan Assembly (KMA) contains 77 villages (Nsiah-Gyabaah, 2000). A description of land use and farming systems is given (available in more detail in another document[1]). A useful list of data sources on the environmental around Kumasi is given. Access to primary data sources does not appear to be a constraint though there is a lack of understanding of processes in some areas – for example the interactions between source of pollution and pollution in the watercourses.

The Inception Report for R7330 contains a qualitative assessment of the farming systems and degree of urbanisation in the sample villages (CEDAR, 1999, p.42). It also provides a qualitative evaluation of environmental concerns and benefits of the various production systems around Kumasi, including how these relate to soil and water management (*e.g.* crops that help to protect the soil, pollution from fertilisers and agro-chemicals, use of contaminated water for cooking and processing, etc., manure production from livestock, etc., and contamination from processing industries such as oil palm and sugar). Contamination from agriculture is assessed.

Information is given for the sample of villages on population and demography; facilities (infrastructure, etc.); occupations; waste management and sanitation (considered to be generally inadequate).

Climate

The mean annual rainfall for Kumasi is 1345 mm (Holland *et al*., 1996a, p.13)[2]. The distribution is weakly bimodal with a major peak (usually) in June (peak varies from April to July) and a minor peak in September (varies from August to October). Data (11 years) are inadequate to analyse for long term trends. Mean monthly temperatures vary from 24°C to 28°C with minima and maxima ranging from 20°C to 33°C. Humidity varies from about 50% in the dry season to about 76% at the end of the main wet season. Tables are presented in Holland *et al*. (1996a) (Appendix IV).

Topography

Kumasi itself is about 282 m (Nsiah-Gyabaah, 2000) but altitudes in the PUI around Kumasi vary from 250 to 300 m (Holland *et al*., 1996a, p.13). The landscape is much dissected though the variations in height are rarely more than 50 m. Slopes are rarely over 7.5%. The climate is classified as semi-humid tropical.

Soil resources

The baseline study (Holland *et al*., 1996a, p.13-14) explains that the soils belong to the Forest Ochrosol great group. Though formerly high in organic matter, intensive agriculture has led to many areas now being low in OM. References to detailed studies are given. The following points are made:

- Macro-nutrients are very low and micro-nutrients are deficient in some areas.
- Clay minerals are predominantly kaolin so CEC is very low.
- Before intensive (over-) cultivation erosion, soil physical properties are favourable to crop growth but erosion is severe in some areas and physical properties are now poor.
- Structure becomes weak when OM is reduced.
- Seasonal waterlogging occurs in many valley bottoms the soils becoming hard and structureless when dry (some areas are used for rice cultivation).
- Erosion of topsoil can have a large effect on soil fertility;
- Regeneration of fallow cover is rapid in soils which are not too degraded.

The soils in six sample villages around Kumasi were surveyed and samples analysed (CEDAR, 1999), but no map of the soils in the villages have been seen. The soils are developed on granite or phyllites. The soils on the granites are quite acidic but those on the phyllites are less acidic. The dominant textures are sandy loams. Soil classes are: Ferric Acrisols (most common), Haplic Acrisols, Eutric Gleysols, Gleyic Arenosols and Gleyic Cambisols (FAO-UNESCO).

Nitrogen and organic matter content tend to be moderate to high, at least when they are newly cultivated after fallow. However the soils are often seriously deficient in phosphorous and potassium.

The farmers classify soils primarily on colour and position in the landscape. Different cropping capabilities for different soil types are recognised by the farmers. These are included together with a summary of the main properties of the soil series in the sample villages in Table 5.1. (CEDAR, 1999).

Land use and farm sizes

There seems to be little information on the relationship between land use and farm sizes around Kumasi though at the final workshop for the Natural Resource Management Project (R6799), Nsiah-Gyabaah (2000) noted that 90% of farms are less than 2 ha. It does appear there is increasing insecurity with regards to land tenure.

Research priorities include:

- Investigating ways of improving land security.
- Valuation of land for planning purposes (more use / adapting evaluation of existing land classification scheme and making larger scale maps and making maps more available).
- Investigate changes in the control and disposal of land.
- Completing the collection of necessary information on natural resource systems.

Use of soil ameliorants by farmers

It was noted that low amounts of fertiliser were used around Kumasi but that leaching was still taking place, partly due to timing of applications not being synchronised with plant demand, and partly due to "hot spots" where relatively high levels of fertilisers were being used such as intensive tomato production areas (CEDAR, 1999, p. 43). The use of compost also is not very widespread (see under Possible Strategies, later in this chapter).

Technical interventions to improve soil fertility are known though may need adapting. However, it is more important to develop agricultural systems from local to regional level which will ensure sustainable production. Research to identify the scope for improvements in land management processes in the traditional and state systems needs to be undertaken.

Water resources and utilisation

According to the Baseline Study (Holland *et al*., 1996a, p.15), three-quarters of the PUI around Kumasi are drained by the R. Sisa and the R. Oda. The remainder drains by a system of smaller streams into the Owabi reservoir. References to studies providing detailed flow data are given.

About 100 x 10^3 m^3 of water are required for domestic purposes in Kumasi itself (Holland *et al*., 1996a, p.60). Three quarters of this can be delivered from the current sources, Owabi and Borakese reservoirs. Use of Lake Bosomtwi, 28 km from Kumasi has been suggested.

CEDAR (1999, p.14 ff.) states that to characterise the water resources in an area, it is necessary to define the sources of supply; the quality of water at the sources; the range of uses of the water; the types and scale of abstraction; and the contamination of the sources, sinks, and pathways. Some preliminary findings on the eight study villages are presented (ibid, p.38 ff.) on water resources. However, in general little information is actually provided. The document notes that:

- The rainfall is sufficient for the maintenance of an integrated (flowing) stream network for most of the year.
- There is generally reduced flow in the dry season (low order streams may dry up).
- There is a plentiful supply of groundwater.
- Springs constitute a significant source of water in the catchments.

In a discussion with farmers who attended the Final Workshop (Brook, 2000, p.16) it was reported that they said that:

- Dry season supply is a problem (quality and quantity).
- Some farmers dig shallow (c. 1 m deep) ponds.
- Sometimes waterlogging is a problem during the rainy season.
- The farmers think that the government should construct more boreholes.
- The farmers believed that district assemblies should prohibit cultivation along rivers to prevent contamination of the water supply.

The delivery is unreliable at the end of the pipe system. In fact, very few of the PUI farmers benefit from piped water. There is a need to find ways of improving supplies for drinking, livestock watering and, irrigation.

Intensive horticulture in the valley bottoms is being carried out and in some cases, where available, piped water is used. Piped water must be paid for so very little is used for irrigation. Most water for irrigation is obtained from shallow wells and used for:

- Sole crop vegetable growing.
- Specialised valley bottom cropping systems (rice, water coco-yam, sugar cane).
- Trees (establishment or dry season irrigation).
- Backyard farms (water from wells, roofs, piped supplies).

The Community Water and Sanitation Agency exists for the area outside the area served by the Ghana Water Company (GWC). It is an enabling organisation to facilitate aid programmes but has no resources of its own. Consequently, boreholes and wells in the area are constructed either privately or by aid agencies. It appears there is little if any control of siting.

Researchable themes concerned with water supply and management include:

- Water conservation, storage and management for domestic use.
- Address overlapping management issues relating to GWC and village levels.
- Valuation of water used in agriculture.
- Develop/ adapt small scale supplementary ("insurance"; "life-saving") irrigation technologies.

There are conflicting views about the potential for boreholes (Holland *et al*., 1996a, p.61) and more research into both surface and groundwater resources is needed. Simple technologies to capture and store water at farm and village level are available but these need adapting and villagers need encouragement to adopt them.

Water quality

Pollution is a problem because controls on discharge are difficult to enforce. The rivers are used for washing (people, clothes and vehicles), and people drink from contaminated streams in times of shortage in more rural areas (CEDAR, 1999).

Potential water quality problems around Kumasi identified included:

- River pollution in and downstream from Kumasi (it is in the upper part of a catchment) from:
  - Untreated sewage and other domestic waste;
  - Hospital waste;
  - Industrial waste (chemicals, heavy metals, oils, sawmill waste, brewing waste, abattoir waste);
  - Urban and rural runoff (including agricultural chemicals and residues);
  - Leachate from groundwater entering the rivers;
- Contamination of boreholes and wells from the polluted rivers and pit latrines located nearby and/or upslope.
- Waste tipping (unplanned and unregulated) and inadequate management / mitigation procedures.
- Localised heavy resource with:
  - Sand winning (quarrying) for building;
  - Trees for fuel and wood;
  - Building operations for urban and peri-urban housing and industrial / commercial premises.

It is not clear how these issues were identified.

Some preliminary findings about water quality on the eight study villages are presented (CEDAR, 1999, p.38 ff.)[3].

Water quality measurements indicate:

- There is a relatively high sediment load in the more urbanised areas and downstream of Kumasi.
- The electrical conductivity and compounds of nitrogen are higher in these areas though are low in absolute terms.
- The nutrient status of the water is generally low.
- That overall quality meets WHO and EU standards except for turbidity and true colour.

Additional monitoring is required before a clearer understanding is achieved.

Particular sources of pollution of surface water are both small and large scale industries (vehicle repairs, breweries, abattoir, tannery, sawmills); semi-liquid human waste and agricultural chemicals. Of particular concern is the Owabi nature reserve which is suffering from pollution as well as encroachment (Holland *et al*., 1996a).

Table 5.1 Soil characteristics in relation to topography around Kumasi

Topo-graphy	**Summit and upper**			**Middle slopes**		**Lower slopes**		**Valley bottom**	
Soil series	Kumasi	Asuansi	Bekwai	Nzima	Akroso	Nta	Kokofu	Oda	Densu[3]
Parent rock	Granite		Phyllite		Granite		Phyllite		Granite
Local name	Asase korkor (red soil)			Asase tuntum (black soil)		Afonwea (sandy soil)		Aworaho (soils near streams)	
Capa-bility	Fertile. Almost all crops. Cocoa & citrus			Arable and vegetable crops. Also tree crops.		Tuber crops such as cassava. Vegetables & oil oalm		Sugar cane, taro, paddy rice, dry season vegetables	
PH[4]	4.3/4.2 (very acidic)	4.5 to 6.8 (v.acidic	5.5 to 5.9 (mod. Acidic)	5.7 (moderat e)	5.7 to 6.0 (slight-moderate	4.9 to 6.2 (slightl	4.8 to 6.1 (very to	5.4 to 6.4 (slight	4.7 to 5.0 (very to
Organic matter	3%/1.5% (moderat e)	2.8 to 5.2% (mod. To	3.5 to 6.6 (high to v.high)	6.6/3.0 v.high/hi gh	1.6 to 3.5% (mod. To	0.9 to 2% (mod.	1.7 to 2.4% (moderat	2.6 – 4.4/ 0.8 - 1	1.8/0.8 (mod./ v.low)
Nitrogen (%)	0.22/0.1 5 (moderat	0.22 to 0.27% high/mo	0.13 to 0.38% (mod.to	0.38/0.1 7 (high/mo	0.13 to 0.25% moderate	0.13 to 0.25% moder	0.15 to 0.22 moderate	0.18 to 0.24 high	0.24/ 0.04 (high/lo

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Phospho-rous (Bray) [ppm]	1.25/0.5 (v. low)	1.2 to 3.7 (v. low)	0.8 to 2.2 ppm (v. low)	"deficien t"	1.15 to 3.75 (very low)	1.6 to 19 (v. low to	1.6 to 4 ppm (very low)	3.5 to 28 very low to	0.6 / 0.6 (very low)
Potassium [ppm]	43.5 / 26.5 (deficien	58 to 136 (mod to	45 to 95 (moderate) / (low to v.	71/36 (moderat e)	86 to 145 ppm (mod. to	33 to 168 (v. low	48 to 165 ppm (low to	100 to 105 / 68 to	51 to 115 (high)
Exchan-geable bases	low	Low to mod. (K is v.	Moderate	mod. but K is low	moderate to low	low to moder ate	(low to mod.) / v. low	moder ate	low (but K is moderat
Cation Exchange Capacity	low	Low to mod.	low to (mostly) moderate	mod.	Low	very low	low	low to (mostl y) moder	low / low
Dominant textures	sandy clay / clay	sandy loam / sandy	loam / clay loam	loam / gravelly loam	coarse gravelly loam /	loamy sand / sandy	loam / sandy loam	sandy loam / sandy	sandy loam / loamy
Slopes	4%	2 to 10%	2%	10%	4 to 5%	0 to 4%	2 to 10%	1%	0.5 to 1%
Classifi-cation System	Ferric Acrisols				Haplic Acrisol	Gleyic Arenos ol	Haplic Acrisol / Gleyic Cambiso	Eutric Gleysol	

Future research should emphasise pollution prevention and management. Researchable constraints include (Holland *et al*., 1996a, p.64):

- Agrochemicals (extent and impact on ecology / produce / human health).
- Ways of improving farmers, management of agrochemicals.
- Reduce sewage and industrial pollution (technical and policy solutions needed).
- Impact of fuelwood collection and charcoal production on erosion and water resources.
- Develop community based management system for Owabi reserve.

Aquaculture

In 1995, there were 123 fish farms around Kumasi though not all have survived because of lack of technical advice (Holland *et al*., 1996a, p.51). An interesting integrated system developed locally has been to combine vegetable production on raised beds with fish production in pools between the beds. Risks from flooding are high as are the potential for poisoning from pesticides. More research is needed on the effect of agricultural chemicals on aquaculture. For further details, see Chapter 4.

Hubli Dharwad

Introduction

There seems to be relatively little information on soil and water management *per se* other than compost and waste utilisation. In particular there is a lack of information about agricultural tools and equipment used, soil erosion problems, irrigation methods and management. There is no evidence of soil maps being used in the planning process. Analyses of rainfall are rather basic, although more detailed than for Kumasi.

The main contribution to the characterisation of the production systems around Hubli-Dharwad was through R6825, the "Baseline Study and Introductory Workshop" project (University of Birmingham *et al*., 1998a, 1998b). The key themes of the study were the documentation of socio-economic characteristics, changes in land use and farming systems, renewable energy, water resources, and government planning.

To put the Hubli-Dharwad PUI into context, the Baseline Study (ibid) also describes the farming systems and climate in Karnataka state and Dharwad district.

The production systems for the two peri-urban case study villages were also characterised as part of the preparation for R7099, the "Urban Waste Utilisation Project in the Hubli-Dharwad City-Region" project (University of Birmingham *et al*., 1998c). In particular, data were collected on:

- Composts that farmers are presently using and why.
- What crops are they growing.
- What are the environmental conditions in which the agriculture is taking place.
- Where the crops are being marketed.

Table 5.2 (University of Birmingham *et al*., 1999a) summarises the environment and cropping systems of 10 farmers in the two villages participating in the trials to evaluate various forms of composted waste and illustrates the range of conditions around Hubli-Dharwad. There was no formal wealth ranking of the farmers to decide which would participate in the trials though there was an attempt to use the poorer farmers in each village. However Navalur is much nearer to Dharwad, has black (more fertile) soil and the farm sizes of the Navalur sample are much larger and so the farmers in Navalur are clearly much better off than those in Mugad. The lack of information about the wealth status of farmers has been referred to in other chapters of this book.

The labour economy of different cropping systems has also been summarised (Nunan, 2000). However, there is only a little information about the labour costs and constraints associated with the preparation and application of the various processed forms of USW (Nunan, 1999a: p. 73).

Climate

Rainfall seems to be increasing in Hubli-Dharwad by about 0.5% to 0.6% per year (contrary to what farmers claim). There is no evidence of increasing variability at a monthly resolution. However, the monsoons may be starting and ending slightly later, by a week or two. University of Birmingham *et al* (1998d) gives more detailed information on monthly mean rainfall, minimum and maximum temperatures and relative humidity.

Table 5.2. Comparison of environmental and cropping systems in two villages

	Mugad village	**Navalur village**
Climate		
Rainfall (mm / year)	950	800
Soils		
Dominant soil	red	black
pH	mostly acidic (<6.5)	mostly alkaline (> 7.5)
Organic matter	mostly low (0.5%) to medium (0.5 to 0.75%)	mostly low (0.5%)
Available nitrogen	low (<280 ppm) to medium (280 - 560 ppm)	low (<280 ppm)
Potassium	high (> 280 ppm)	high (> 280 ppm)
Land		
Mean farm size	1.9	3.0
Range of farm sizes (ha)	0.8 to 3.6	1.6 to 5.7
No. in sample	5	5
Average area leased (ha)	Nil	3.9
Range of leased land (ha)	-	1.6 to 6.5
Crops and their management		
Main *kharif* (monsoon season) crop	rice	potatoes (also greengram, maize, groundnut, cotton)
Percentage of sample farmers growing rabi crop	80%	100%
Main *rabi* (post-monsoon) crop	grams (grain pulses - mainly mung bean)	sorghum, chickpeas, wheat, safflower
Preferred soil ameliorant	pit compost	pit compost
Frequency applied	1 in 2 or 3 years	1 in 2 or 3 years
Percentage applying in year of study	60%	100%
USW use	None	1/5 this year; 3/5 in recent years
Use of inorganics	DAP at sowing, urea as top dressing	DAP at sowing, urea as top dressing
Proportion applying in year of survey	2/5	all
Use of insecticides and fungicides	nil	all

Soils

Soils are mostly vertisols or alfisols (University of Birmingham *et al*., 1998a). Their properties are briefly described in the document in perhaps a rather over-simplified form. More detailed information is apparently available but was not presented. Little use seems to be made of soil maps or land classification maps in planning.

The initial workshop [July, 1997] for the "Baseline Study Project for Hubli-Dharwad City Region" (R6825) identified the need to find ways of improving soil fertility.

Land use and farm sizes

Information on present land use and changes in land use is generally better in Hubli-Dharwad than Kumasi. During the baseline study (University of Birmingham *et al*., 1998b, p.178), 21 villages were sampled for a study of land pressure. It was found that 33% of the villages had average farm areas of less than 2 ha per household. One village had less than 1 ha per household. There seems to be no simple relationship between farm size and proximity to Hubli-Dharwad. Small landowners constitute 26 to 72% and large landowners constitute 4 to 37% of the total farmers; most of the latter practising dryland farming on the vertisols to the east, where farms tend to be larger.

The report also presented data collated from the 1981 and 1991 censuses, covering 372 villages across five taluka (sub-district administrative unit). The proportion of land under irrigation varies widely from 0.3% to 19% again indicating a large variation in wealth distribution both within and between villages. Pilot projects could examine the potential for increasing the area under irrigation in those taluka with least resources (Kundgol, Hubli, Dharwad).

Cultivable waste land occupies only 3% of the peri-urban area though there were 19 villages (of 372) where the proportion was over 25%. Land available for cultivation in 1991 was about 4% of the PU area, a decline of 34% since 1981 (University of Birmingham *et al*., 1998b, p.196).

Forest land (University of Birmingham *et al*., 1998a, p.182 ff.) occupied 0% to over 50% of land in the peri-urban area though between 60 and 100% of villages had no forests (and had none in 1981). No information is presented on forest ownership, yield, species, utilisation, management, density (for example the proportion of forest land with no trees). In only 12% of villages did forests occupy over 25% of the land. Even so, encroachment was rarely a problem (ibid, p. 183-184). Forests are a significant form of land uses only in more hilly, wetter areas south and west of Hubli-Dharwad.

Use of soil ameliorants by farmers

A survey of farmers in connection with the "Urban Waste Utilisation in the Hubli-Dharwad City-Region" project (R7099) revealed that all farmers understood the need for and applied soil fertility amendments (University of Birmingham *et al*., 1998a, 1999a, 1999b, 2000). Their preferred amendment is pit compost (manure and crop residue) applied before the rains and ploughed in after the rains have softened the soil (because compost improved water holding capacity and soil structure, so ploughing is easier). Farmers thought the residual fertility from compost would last up to three years. They were aware that compost improved soil structure, resulting in lower draught requirement. However it was revealed that composts are in short supply. Thus di-ammonium phosphate (DAP) and urea was often used, sometimes alone but often to supplement the compost, more as an unavoidable necessity because of the shortage of organic manure rather than because they preferred inorganic fertilizer. Cost was another factor limiting the use of inorganic fertilizer at the recommended (Department of Agriculture) rates. Farmers also thought that inorganic fertilisers require adequate rainfall to be effective and that the residual effects of inorganic fertilisers were short-lived (commonly thought to be about one year). Inorganic fertilisers were considered to affect soil structure adversely.

Some farmers use green manures (often neem or *Gliricidia* spp.) composted with grass and soil for one month (a recent Dept. of Agriculture recommendation). However their use does not seem to be generally widespread.

A typical application rate for compost is 10 t ha^{-1} y^{-1}. Cost comparisons for various forms of compost are presented in Table 5.3.

Pit compost thus had the advantage of having the same cost per unit of nitrogen content as DAP but having the added value of improving soil structure and water holding capacity. Any USW based product would have to have a similar price. Vermicompost is clearly not accessible to resource poor farmers because of cost. Those farmers who currently buy USW separate compostable material themselves, so decreasing purchase cost but increasing labour or opportunity costs.

Table 5.3. Cost comparisons per kg N between various forms of soil amendment used around Hubli-Dharwad.

Type of manure / compost	Cost per unit weight	Cost per kg of N
DAP (17 % N)	Rs 420 / 50 kg bag	Rs 19
Urea (46% N)	Rs 420 / 50 kg bag (estimated)	Rs 7
Pit compost (1% N)	Rs 175 to Rs 200 t^{-1} (mainly opportunity cost)	Rs 17.5 to Rs 20
Vermicompost (1% N)	Rs 2 kg^{-1} to Rs 4 kg^{-1}	Rs 200 to Rs 400

Source: Nunan (1999a) p. 28.

Water resources

Data are only available for Dharwad District (ibid, p. 104), and available resources are:

- 390 small reservoirs (tanks) sufficient for 55,575 ha.
- 31 lift irrigation schemes sufficient for 12,004 ha.
- 15 barrages sufficient for 4,098 ha.
- 434 minor irrigation schemes sufficient for 71,678 ha.
- Boreholes (number not known) are used mainly for domestic purposes.

It is not clear how much of these resources are being used for irrigation.

Water tax is collected by the head of each taluka on behalf of the Revenue Department. An Irrigation Committee is frequently appointed but the secretary is always a civil servant engineer. There is little information on how effectively these committees operate.

Common problems experienced are: timeliness of availability (often late); lack of structural maintenance (it is unclear at present whose responsibility this is, and farmers may think that it is the government's job); equitability of distribution and salinisation through excessive applications. No details are given of these problems and there is an information gap here. The introduction of Participatory Irrigation Management and Water Users Associations should be encouraged, as exist elsewhere in India. No details of such organisations in Hubli-Dharwad are given.

An evaluation of threats to water resources by urban development was undertaken by the "Natural Resources Valuation" project, R7269 (Nunan, 2000).

The survey concentrated on the impact of urbanisation of Unkal Tank between Hubli and Dharwad, which until 1996 was a major source of domestic water for Hubli-Dharwad. In 1996, the pollution of the tank had become so great as a result of under-regulated housing development that extraction for domestic water supply for Hubli-Dharwad was no longer possible and the extra water had to be obtained from Malaprabha Dam and Neeragager Tank, both some distance from Hubli-Dharwad and outside the municipality.

In this event, there were winners and losers. The main loser is the Karnataka Urban Water Supply and Drainage Board who now supply Hubli-Dharwad with the additional domestic water needed but who receive no additional payments. Malaprabha Dam is also a source of irrigation, so the loss of some of the water to replace the polluted domestic water in Hubli-Dharwad has presumably had an impact on these farmers. The amount of water actually extracted from Malaprabha Dam is not given but the total provided by Malaprabha Dam and Neeragager Tank is $2.3 \times 10^6 m^3$.

Unkal Tank is now used primarily for leisure activities, washing (vehicles and clothes). However private and commercial fishing (in roughly equal proportions) now takes place with an annual value of Rs 830,000[4]. The changes have made little difference to the previously illicit irrigation around the edge of the tank. The costs of any increased ill-health and damage to the economy are unknown.

Researchable issues on water resources and irrigation (University of Birmingham *et al*., 1998a, p. 105) include:

- Quality and reliability of drinking water supplies.
- Functioning of institutions providing water (identify ways for better co-ordination between domestic, industrial, agricultural supplies).
- Physical and economic constraints to increasing irrigation supplies.
- Sources of pollution and ways of preventing it.
- Groundwater supplies (quality, quantity, use, pollution, management).
- Tank construction and management (siting, use, trends).

The initial "Urban Waste Utilisation Project in the Hubli-Dharwad City-Region" project R7099 workshop (University of Birmingham *et al*, 1998a) suggested that it was necessary to address problems related to use of wastewater from urban centres particularly the control of weeds and pests in waste water systems. It also called for research on ways of improving moisture conservation, including use of waste water.

Trends and changes in land and water management due to urban growth

Kumasi

Introduction

Various projects have noted changes in land use patterns falling under the following headings.

Reduced duration of fallows and declining soil fertility

The length of fallows have been decreasing and in many instances, fallowing of land is now impossible because of land pressures (Holland *et al.*, 1996a, p.70; 1996b, p.30). However, bush fallow continues to be practised by some farmers even though fallows are now too short to maintain soil fertility (Holland *et al.*, 1996a, p. 64; Blake *et al.*, 1997a). Soil fertility is therefore declining rapidly[5] (Holland *et al.*, 1996a, p.70). There is an increasing tendency to adopt short term management strategies with fewer tree crops and increased “mining” of soil nutrients. Declining fallow lengths and reduced soil fertility are identified as major production constraints by farmers (Kasanga, 1998, p.69). Management of soil fertility is declining.

Fewer people in farming

The Inception Report for "KNRM at the Watershed Level Project" (R7330) notes that fewer people are now involved in agriculture in the peri-urban environment (CEDAR, 1999, p.12). Small farm areas from which it is difficult to make a living, insecurity of tenure and increased potential for urban employment have presumably all contributed to this change. This is partly due to population and thus land pressures. Many of the people remaining in agriculture are the poor who are unable to capitalise on the proximity to markets to intensify their operations. There is not enough known about the process and reasons for the abandonment of land by farmers though the principal reason seems to be the changes in land tenure.

Decreased security of access to land

It is considered that the apparent changes in security of access to land (see Chapter 6) is a significant factor in declining land husbandry practices. The greater feeling of insecurity is party due to the increasing practice of chiefs in selling off village land, thus denying farmers their traditional land rights (Adam, 2000b; Brook, 2000, pp.3-7). This is leading to increasing landlessness and homelessness. Women are possibly even more affected by the loss of their land than men.

In villages around Kumasi the land allocated for residential areas has increased rapidly, and the farmland has reduced (Blake *et al.*, 1997a). In Akokoabong, a village close to Kumasi, over 50% is allocated for housing and about 30% is left for farmland (Holland *et al.*, 1996b, p.19). Hardly any agricultural land remains for bush fallow (ibid, p.25) and intensive sharecropping is common. At the end of the four year term the land is rented out again immediately with no fallow, which is said to be decreasing fertility (ibid, p.19). Change since 1983 was noted: reduction in the amount of farmland and increase in the amount of residential land. Eleven percent of villages said there was virtually no farmland left in the villages (Blake *et al.*, 1997a, Holland *et al.*, 1996b, p.35). New land developments in villages tend to be single villa-type houses surrounded by yards. This consumes land less efficiently than traditional housing in the villages, but it offers opportunities for some small-scale backyard farming (Blake *et al.*, 1997a). The problem is exacerbated by new building outside the city which is not adequately planned. Unauthorised building by the middle classes on community institutions (such as schools) and on land belonging to the "rural poor" is reported (Holland *et al*., 1996a).

Slow development of agricultural entrepreneurs

For a relatively few farmers, the improved opportunities for marketing has led to higher value enterprises such as horticulture and poultry units although Nsiah-Gyabaah (2000) was of the opinion that the main change was from large scale plantations to food crop production for home consumption.

Hubli-Dharwad

Introduction

Changes in the land economy are described for Hubli-Dharwad in University of Birmingham *et al*. (1998a, 1998b).

Land pressures

Researchers have suggested there is a possible link between changes in land use and socio-economic indicators, and that socio-economic data collected in 1997 indicate increasing pressure upon land. This conclusion seems to rely upon increasing land values between 1987 and 1997 (University of Birmingham, *et al.*, 1998a, p.42), yet the values have not been adjusted for inflation, so this argument may not hold. Variations are high and complex. Information was not obtained on the number of sales taking place (ibid, p.33).

There has not been remarkable population growth in Hubli-Dharwad during the period 1981 to 1991, only 23% (University of Birmingham *et al.*, 1998a, p.14), and the increasing land pressures in the PUI not related in a simple way to distance from the urban areas. The pattern of growth and change is dynamic and complex to the west and north of the city, but rather stagnant and more agrarian elsewhere. Varying degrees of land pressure may be one of the factors, plus new opportunities for irrigation and changing cropping patterns and new opportunities for working in the city (University of Birmingham *et al.*, 1998a, iii, p.19). But some of the growth in population and economic activity in the rapidly changing taluka of Dharwad and Kalghatgi could possibly be explained by greater land availability, rather than proximity to the city (University of Birmingham *et al.*, 1998a, p.20). In Kundgol taluk there seems to have been an increase in the land available per cultivator. An important factor to keep in mind is that the growth of Hubli-Dharwad may not be a strong force for change. It is rather difficult to draw definite conclusions due to the number of gaps in information, for example, there is no information on the amount of land that is converted to urban use for Hubli-Dharwad.

Changes in land use

Over the interval between the 1981 and 1991 censuses, unirrigated cultivated land varies from 51 to 90% of taluka, the average in the PU area being 75% (University of Birmingham *et al*., 1998b). There was an average decrease of 0.2% p.a. in unirrigated cultivated land (varying from 0.03 to 0.3% p.a.). However, 40% of villages experienced an increase as opposed to 51% experiencing a decrease. In three of the five taluka, there has been an increase in the culturable waste areas by 100% to 650% over the decade, 1981 to 1991, but it is not clear what process is contributing to this.

There may be abandonment of farmland close to the city (University of Birmingham *et al.*, 1998a, p.22); however, this seems to conflict with the notion of general increase in pressure on land. Land not available for cultivation in 1991 was about 4% of the PU area, a decline of 34% since 1981 (ibid, p.196). Land used for urban purposes is included in this category along with water bodies and quarries (ibid, p.22). This is difficult to explain; possibly land previously considered too poor for cultivation has now been brought under production. Clearly there are complicated and still poorly understood dynamics at work. It is not certain whether urban pressures are the driving force behind observed changes.

The area irrigated remains relatively small, but has increased by 32% overall, but again variability is high, Kundgol taluk experiencing a decline. Dharwad taluk has the largest number of villages with increases in irrigated land over the decade and the largest increases in area irrigated, but irrigation is only extensive in Navalgund taluk. Nevertheless, many villages in the city-region showed a decline in irrigated area which may be linked to the increase in land available per cultivator (University of Birmingham *et al.*, 1998a, p.21).

Forests are significant users of land only in the hillier wetter areas south and west of Hubli-Dharwad. Forest encroachment is reported to not be a major problem (University of Birmingham *et al.*, 1998a, p.21). Rather surprisingly, forest area on average increased over the decade by 2.7% but the variation is high, some areas experiencing a decline in forest cover. There is no indication of the number of trees, the species or the beneficiaries of the new forest land.

Overall, the picture is complex and changes in land use and factors driving change seem to be poorly understood.

Change in occupations and village populations

To summarise (University of Birmingham *et al.*, 1998b), over the period between the 1981 and 1991 censuses:

- Whilst the number of labourers has increased by about 30%, the number of agricultural labourers has increased by only 16% and so agricultural labourers as a percentage of the total has declined.
- The number of non-agricultural artisans living in villages has increased by 42% over 1987 to 1997.
- Some village populations have increased while others have decreased, changes depending on land pressure, changes in agricultural practices, employment opportunities and possibilities for commuting.

All villages experienced a decline in the average land per household (ibid, p.178). In contrast, in 24% of the villages, land per cultivator increased over the same period (even though land for the corresponding households had decreased). This indicates a decrease (on average) in the number of people in the households in those villages who are engaged in agriculture. Again there is no simple relationship between proximity to the city and the decline in the number of agriculturalists.

The farm area per person is declining between 1.3 and 2.9% p.a. whilst the farm area per household is declining faster at 2.0 to 3.3% p.a. Median values for average area per household in a village varies from 3 ha to 4.5 ha. However the proportion of villages with (an average of) of over 5 ha varies from 12% to 40% indicating a wide variation in wealth of farmers. The reasons for the variation seem as yet poorly understood (University of Birmingham *et al*., 1998b, p.182).

Changes in crops grown

Crops currently grown are briefly presented in University of Birmingham *et al*. (1998a) together with changes in cropping systems since the mid-1950s. This is considered in more detail in Chapter 3.

Changes in waste processing for compost

Institutional changes in Hubli-Dharwad that have affected utilisation of urban waste are considered in detail in Chapter 2 and are outlined here only briefly. They are reported more fully in University of Birmingham *et al* (1998a, 1998b).

Waste collection management is changing. On an experimental basis, committees were set up to organise the collection of separated waste by casual workers. The organic matter is used for vermicompost and the inorganic matter put into the corporation bin. This experiment has met with only limited success. The Hubli-Dharwad Municipal Corporation (HDMC) recently has begun door-to-door collection of waste from commercial and residential properties. A tipper truck will be purchased to reduce the need for handling. Waste from the hospital is to be collected separately. The council hopes that the householders can be persuaded to use separate bins for different kinds of waste. The trial separation scheme has so far been of limited success as it is difficult to employ people, and households are unwilling to pay for collection The council may ban certain types of waste such as plastic bags. It is possible that HDMC may offer a discount to poor farmers for processed waste, but there are a number of difficulties:

- How can the extra cost to the HDMC be recouped?
- Who are the poor?
- Subsidies will be difficult to remove later
- There is increasing commercialisation of waste management. A commercial company has leased land from the municipality and plans to produce vermicompost. The company separates the waste which is then used for compost. Farmers are concerned about the higher costs of vermicompost as the unsorted USW is much cheaper.

A number of institutional constraints and concerns remain:

- The increased pressure to become more environmentally safe.
- Financial constraints on HDMC.
- Doubts about whether the source separation scheme at community level will be adopted on a large enough scale.
- There are conflicting demands on HDMC by farmers and the commercial sector.

Summary of changes

The picture is one of increasing pressure on land, complex rearrangement of settlement patterns (not simply movements into the cities), reduced dependency on agriculture as a sole source of income, and perhaps some degree of intensification of farming systems. However, at this stage these are poorly characterised.

Principal stakeholders characterised

The stakeholders who are or could be concerned with changes in soil and water management are well understood. The project baseline studies, inception reports and final technical reports are particularly important sources. Some of the stakeholders for different aspects of soil and water management are shown in Table 5.4. Shaded cells under a particular activity are those groups who are affected by or who may have an interest in the activity.

There are records on land ownership which seem to be difficult to access. Little information exists on who is involved in land transactions. Government actors in land planning and other land management activities are obviously known locally, yet they seem to be largely ineffective and may not figure as important stakeholders (University of Birmingham *et al.*, 1998a, p.106-118).

The Census does not provide information on who owns lands, including absentee landlordism with rented plots or share cropping (University of Birmingham *et al.*, 1998a, p.23). However, the village surveys obtained some information. These provide only general impressions of what types of purchasers are buying land, whether it is farmers for other villages or urban dwellers buying land for investment or speculative purposes. Village informants quantified landowners in various categories for 1987 and 1997 (ibid, p.33). Land records exist which provide information on each plot of land within a village, but they are in several forms and in several places (ibid, p.116).

Table 5.4 Stakeholders for different aspects of soil and water management

PUI agricultural development generally[6]	**Use of waste and sewage for composting - all areas**	**Sewage treatment**	**Urban expansion and land use changes**
Taxpayers	Ultimate source of revenue, some are beneficiaries		
Municipal councils & national government departments	Administrators; waste managers; planners engineers. In Kumasi: Kumasi Metropolitan Authority	Administrators, planners; engineers. In Kumasi: Kumasi Metropolitan Authority	Kumasi: Kumasi Metropolitan Authority; Lands Commission Land Evaluation Board. Hubli-Dharwad Urban Development Authority (HDUDA)
Traditional leaders and local government			In Kumasi: chiefs District Co-ordinating Committees; Regional Co-ordinating Committees
Companies potentially or currently involved in waste recycling	Commercial recycling companies in Hubli-Dharwad.		
Farmers in general	Better off farmers may benefit from processed composted waste more than poorer farmers due to cost.		Farmers who are displaced.
Producers of waste such as poultry farms, dairies - potential extra income / reduction of disposal costs	Demand for manures may change (up or down), affecting income of manure producers.		

Table 5.4 (continued) Stakeholders for different aspects of soil and water management

PUI agricultural development generally[7]	Use of waste and sewage for composting - all areas	Sewage treatment	Urban expansion and land use changes
Farmers on irrigated land	No interactions reported yet	Those with access to sewage polluted stream water.	
Inorganic fertiliser marketing companies whose trade may be damaged by increased use of organics.	No interactions reported yet	Farmers using sewage waste streams use no inorganic fertilizers, but pesticide use increase (Hunshal *et al.*, 1998).	
Research institutions (environmental scientists; economists; soil scientists; farming systems specialists; social scientists agronomists	Kumasi: University of Science and Technology (ILMAD); Environmental Protection Agency. Hubli-Dharwad: University of Agricultural Sciences, Karnatak University.		
Extension workers in ministries	No involvement yet, or only preliminary.		No involvement yet, or only preliminary.
Consultants, overseas agencies	Several, including DFID, FAO, IBSRAM.		
NGOs	Kumasi: BIRD; CEDEP; GOAN. Hubli-Dharwad: BAIF		
Banking and Rural Credit organizations	No involvement yet, or only preliminary.	No information	No involvement yet, or only preliminary.

Effects changes of land use, soil and water management upon livelihood strategies of resource-poor farmers

The specific strategies adopted by resource-poor households with regards to soil and water management have not been adequately characterised in either Kumasi or Hubli-Dharwad.

Effects of land use changes on poor in relation to soil and water management

As above, the effects of changes in land use on the poor have been poorly documented in Hubli-Dharwad. Non-farm employment has increased in the three taluka closest to the twin cities. This was particularly so for men (University of Birmingham *et al,* 1998a, ii. p.29). The greatest increases were in industrial and construction labourers working outside their villages. Construction workers were sometimes in brickworks and stone quarries outside the city (University of Birmingham *et al.*, 1998a, p.29), but these can activities can be assumed to depend upon a market for their outputs in the city.

Participation by women in the labour force increased particularly rapidly for women in the three taluka nearest to Hubli-Dharwad. However, female non-farm employment increased much more slowly than male, indicating that most women were finding work in the lower paid farm sector (University of Birmingham *et al.*, 1998a, p.19).

Relevant knowledge of strategy options for land use and production

Introduction

The emphasis has been on composting and the use of this and waste in soil ameliorants. Reviews of the use of waste generally have been undertaken by several teams and a summary of their observations is given below. The potentials for using waste for animal feed or aquaculture have not been adequately studied. However, quite a lot is now known about the processing of waste for soil amelioration composting, but there is still a need to continue trials of the most promising methods over several years. Potential for soil contamination over the long term, particularly in Kumasi, should be looked at more carefully.

Institutional as well as technical means of enabling the poor to benefit from composted waste have yet to be found. The municipalities have to manage disposal of waste anyway so perhaps the costs of producing compost from waste could be subsidised. It could be argued that the future of soil fertility maintenance has to be with combinations of organic matter and inorganic fertilizers. Not enough is known about the optimum combinations of these from the points of view of economics, soil fertility, soil physics and toxicity.

Irrigation with contaminated water should be an important theme for future work. The contaminated water is high in nutrients and stream water is more available to poorer people than borehole water. Possible research topics include: ways of using or managing the water in-field, safely (as practised in China and elsewhere), characterising risks, benefits and beneficiaries, effects of sewage treatment upon cropping system nutrient balance. The use of sewage contaminated water could perhaps be seen as part of the dynamic changes in the PUI and only adopted during early phases of development, to be phased out later as the sewage stream is cleaned up or consumer resistance increases.

Green manure does not have much of a future in the urban environment unless hedgerow material can be used (e.g. *Tithonia diversifolia*) but farmers will probably find the extra labour requirements difficult to meet. Application rates of 10 tonnes / ha are suggested; even for *Tithonia* there would be a problem of obtaining sufficient material for any but the most valuable (probably horticultural) crops.

The development of farm equipment, tools and post-harvest processing innovations that proximity to workshops in the urban centres should be able to encourage. has been almost totally ignored. For example, the development of a low cost compost or manure transporter for use round Kumasi may encourage uptake of use of poultry manure (also see Chapter 3).

Other areas where not enough is known include:

- Surface and groundwater hydrology in the areas and how urban expansion is affecting the water table, pollution, seasonality of flow, or yield.
- Interaction of sewage contaminated water and fish in ponds, of which there are > 100 around Kumasi.

If farmers are to steward the land more enthusiastically, the improvement of security of tenure is an important area that needs to be addressed, especially in Kumasi.

Soil maps and land capability and land use maps are not adequately used in the "planning" - if any takes place - of urban expansion. Use of GIS keeps maps and mapping among the elite. The whole process of land capability and land use mapping has to be taken to the people in the villages and the urban fringe. There has been considerable experience of the participatory production of soil and land use maps elsewhere. GIS has a rôle but it should not become an end in itself (see Chapter 7).

Use of waste and sewage in the PUI - literature reviews

Introduction

There have been a number of reviews of use of waste and sewage in the PUI. In 1998. Allison *et al*. (1998) conducted a review of the use of urban waste in the PUI in general. Other documents have included reviews of the topic. For example the Inception Report (University of Birmingham *et al*., 1998c) and Final Technical Report (Nunan, 2000) of the "Urban Waste Utilisation Project" (R7099) noted that despite waste being widely used in India, there are few documented sources of information, especially on the quality of USW as a soil amendment such as its contribution to soil nutrients and the human health aspects. It was clear that research into the health risks of using organic waste such as that derived from USW had been minimal.

Examining the use of waste around Kumasi, Harris and Smith (1998) provided a useful literature review, outlining the sources, ownership, utilisation, economic value, market, distribution system of processed products, soil fertility value, competing uses of waste, constraints to utilisation, processing, alternatives to processed waste.

Potential for use of waste in agriculture

Summarising the findings of the reviews conducted by Allison *et al*. (1998) and Harris and Smith (1998) they found the following different uses for waste:Waste as animal feed (especially in urban as opposed to peri-urban environments).

- Solid municipal waste, nightsoil and sewage as constituents of soil improvers
- Waste as fuel.
- Waste for aquaculture (faeces encourages growth of algae, rotifers, crustaceans).
- Waste for mushroom, yeast, algae growing.
- Waste water for irrigation.
- Recycling of waste.

It may be noted here that so far, only waste solid waste as soil improver, nightsoil as soil improver and (to a lesser extent), waste water for irrigation has been examined in the PUI projects even though waste as animal feed was one of the original purposes

Technical benefits of composted waste

What little work has been published on the fertility value of composted USW indicated (Harris and Smith, 1998, p 24; University of Birmingham *et al*, 1998c) that compost improved the physical and chemical properties of the soil, reduced disease and if applied to the surface as a mulch, reduced weed growth and conserved soil moisture. Composted USW affects the physical soil properties through increased soil porosity (and thus increases infiltration of rain, and decreases runoff and erosion) and increased water holding capacity and aeration. Soil structure (which improves water holding capacity and decreases susceptibility to soil crusting) is improved.

Composted waste also supplies primary nutrients (quoted values for USW from India are 0.5% N, 0.3% P, 0.3% K (Nunan, 2000, p.33), increases enzyme activity and decreases leaching of nitrogen. These benefits can be improved by adding rock phosphate, urea, and/or inoculating with *Azobacter chroococcum* or *Aspergillus awamori*. Wood ash in compost can reduce Ca deficiency (for example, groundnuts at flowering) or K deficiency (for example, tomatoes at flowering). Rice husks in compost can reduce silicon deficiency. Adam (2000b) notes that the uptake of nitrogen is more efficient from inorganic fertilisers than organics though the uptake of phosphorous is more inefficient. As crop residues constitute 90% of the total nutrients, proper recycling of crop residue is beneficial for soil nutrition. Modalities for use, rates, combinations for composted waste are seriously under-researched.

It was also reported that composted waste can act as a delivery agent for the microbial control of pests (citing citrus in California) and so can have an inhibiting effect on soil borne plant pathogens. It also contributes to the suppression of nematode populations. Holland *et al.* (1996a) quotes several authors who suggest that organic mulch controls septoria leaf spot and that green mulch controls nematodes.

Factors affecting use of waste in soil ameliorants

The review (Allison *et al*., 1998) goes on to examine the factors affecting the use of waste in agriculture such as type of agriculture (farming system, rural livelihoods, crops, livestock); markets (for farm produce and for waste); knowledge, perceptions, preferences, social and cultural factors; land tenure and availability, and geography. It also discusses the institutional and policy factors. A bibliographical database on urban waste is included.

Constraints and opportunities for use of waste as a soil ameliorant in Hubli-Dharwad

The R7099 Inception report (University of Birmingham *et al.*, 1998c) reviews what little documentation on use of waste exists in India. It notes that the informal sector (mostly poor people) plays an important role in the southern cities. The gender dimensions of waste collection are poorly understood though it has been pointed out above that women are increasingly entering paid employment including farm labour. As source separation within households and waste picking generally is done by women (and children), changes in the labour dynamics or the market for organic waste will affect women's livelihoods.

"Wet" organic waste is considered to be religiously polluting so waste pickers tend to be poor and / or low caste. Cultural concerns about aesthetics and odour are important constraints. Waste pickers prefer to work independently and not to be employed formally. However, there is considerable potential for NGOs to link the formal (private and municipal) and informal sectors.

Source separation is the key factor in producing good quality compost. To change habits, education is important as most separation in India is at household level. However household commitment to separation and collection has been poor in Hubli-Dharwad. Households do not want to make additional payments for more organised waste collection as it is considered to be the job of HDMC.

Some centralised composting plants were built in the 1970s and 1980s but many of these closed due to high production costs (land, labour, transport); inadequate maintenance and poor marketing of composted products.

Neighbourhood composting schemes exist in some areas of India - waste is collected in separate containers and committees organise collections by people employed by the scheme and who are funded by the households themselves, by NGOs or by the Municipal Authorities.

The use of waste to provide soil conditioners are affected by a number of economic, technical, human health, cultural and institutional constraints (Harris and Smith, 1998). These constraints affect resource-poor farmers particularly.

There may be alternative uses for waste that may be more profitable. Costs of labour (if available), separation, collection and transport may be too high. Increasing labour shortages / costs (due to competition from other employment opportunities) occur at dump sites (to dig pits) and for farmers (to empty pits and sort the waste). These economic factors may make compost unaffordable by farmers especially if alternative (inorganic) soil ameliorants are available more cheaply. Commercial vermiculture is now increasingly common in India to compost wastes and the product is sold to gardeners and farmers.

Composts are in increasingly short supply. Because of this, some farmers till the soil earlier to adapt to changes in availability of composts. Also the use of animal manure for composting is becoming more problematic because of:

- Continuing competition for its use as a fuel as well as compost component;
- A declining availability of animal manure as a result of mechanisation;
- Proposed legislation that would evict cattle from cities of over 500,000 inhabitants.

Farmers may thus turn to inorganic fertilizers although the above also means that the use of USW for compost may be more attractive. Unfortunately, the declining quality (for example, because of increasing amounts of plastic) makes use by farmers decreasingly viable without source separation. The declining quality (especially increasing amounts of plastic) means that farmers without tractors are increasingly reluctant to hire them for low quality material. Only 35% of municipal waste is now compostable.

The possibilities of phyto-toxicity (ammonia "burning", salt, phenolics, low molecular weight organic acids) or nitrogen immobilisation due to high C:N ratios mean there are some technical risks involved in the use of waste.

There are obvious risks to human health and safety and environmental pollution. However, research has established that composting kills off almost all pathogens if the temperatures of the compost is high enough or the waste is stored for periods of about a year (University of Birmingham *et al*., 1998c, p.17). There is, nevertheless, a need for more research to establish the minimum requirements.

Perhaps the greatest constraint is the lack of institutional support, especially in the area of legislation regulations and control of waste disposal and environmental pollution and in such issues as land tenure (as farmers are reluctant to invest in insecure holdings).

Despite these constraints, the Hubli-Dharwad inception report (University of Birmingham *et al*., 1998c) found that farmers were quite experienced in using composts, including USW but that it was the wealthy farmers who have been the main purchasers of compost. In particular, the proposed vermi-composting of USW by commercial sector (in Hubli-Dharwad) will be even less accessible to resource-poor and marginal farmers.

Processing of waste into compost

The advantages of composting are that it:

- Sanitises waste.
- Reduces waste volume.
- Reduces phytotoxic properties (*e.g.* High C:N ratio).

Aerobic systems are favoured as anaerobic systems produce methane (although if controlled, this could be captured in the form of "biogas"), use more complex technology, are more difficult to manage and are slower than aerobic systems.

Aerobic systems include:

- Open systems.
- Windrows in lines 2 to 3 m high and turned regularly.
- Static piles aerated using pipes (pumped air or atmospheric pressure).
- In-vessel systems (healthier and quicker but expensive).
- Vermicomposting.

The review (Harris and Smith, 1998) discusses the pros and cons of various scales of composting from household to municipality level (Table 5.6) and different management / financing options (private, public). Processing constraints include: land availability, technology and management required (such as sieves and magnets needed for larger scale operations), climate, matching supply with capacity, lack of institutional support, legislation, regulations, control, and public acceptability.

Recommendations

Harris and Smith (1998) recommended increased use of poultry manure and compost, application to vegetables and other high value crops, and municipal and community level composting.

Urban waste as a soil conditioner around Kumasi

The baseline study (Holland *et al*., 1996a, p.52) and the consultancy report (Harris and Smith, 1998) give evaluations of waste around Kumasi. The latter considers:

- The present availability of waste (Holland *et al*., 1996a ,Table 5.4).
- The present utilisation of waste (Holland *et al*., 1996a, Table 5.6).
- Alternative uses of waste (Harris and Smith, 1998, p.39).
- Potential for development (Harris and Smith, 1998, p.39).
- Suitability for different farming systems (Harris and Smith, 1998, p.43).

The availability of waste, possible management for agricultural purposes, usefulness for different farming systems and potential use of poultry manure in different farming systems are summarised in Tables 5.5 and 5.6. Data (annual figures) provided by Adam (2000b), quoting Kindness in Brook (2000) and the Baseline Study (Holland *et al*., 1996a, p. 52-57) have also been included.

Researchable constraints (Holland *et al*., 1996a, p. 65) are:

- Quantification of potential value of organic wastes for farmers.
- Investigation of potential use of food wastes (compost?,cattle-feed?).
- Development of further USW based composts.
- Investigation / development of organisation of waste processing / transport / privatisation / incentives.

The following three tables (Tables 5.5 to 5.7) present, in summary form, availability of waste, possible strategies for its use (particularly the potential for use of composted urban waste) in agriculture around Kumasi.

Animal waste in composts around Kumasi

Of the 4,800 t of inorganic fertilisers marketed in Kumasi, only 10% is used in the peri-urban area. Very little of the animal manures available is used as fertiliser except poultry manure. The main constraint seems to be transport costs.

Of the 34,000 t of poultry manure produced around Kumasi annually, about 67% is used as fertiliser in the peri-urban area. A summary of results of trials with poultry manure is presented in Chapter 3. Table 5.8 summarises the potential for use of poultry manure in farming systems around Kumasi.

The increased use of pig manure is suggested as a possibility in several reports (*e.g*. Nunan, 2000). Several authors have mentioned that pig manure could be more extensively used if the pigs were reared in pens.

Table 5.5. Availability of waste around Kumasi

Material	Availability	Comments
Municipal, domestic and commercial waste	425 to 500 t d^{-1} (100,000 t y^{-1})	Figure represents only c. 45% of the total. OM is 87% in Accra (75 to 90%? in Kumasi) but no data on spatial or temporal variation. Also used for land reclamation and animal feed in Kumai but mainly dumped in tips or land fill sites. Siting of latter a continual problem. Contamination of surface and groundwater resources is expected but there has been little research. Increasing problem of accumulating waste in the districts around Kumasi. KMA propose to compost waste as part of their waste management plans but the market for composted waste has still to be established. Because KMA has to dispose of waste, it may be economic to subsidise farmer use of composts produced.
'Black soil' (material decomposed *in situ* at dump sites)	?	Use is limited. Collected by individuals for topsoil / horticulture; time consuming to extract.
Night soil and sewage sludge	336 m^3 day^{-1} (250 to 350 t d^{-1}; 100,000 m^3 y^{-1})	43 truck loads. Present sewage facilities very inadequate. Mainly collected and dumped into rivers by municipality. Obvious hazard downstream. Mixing with sawdust has been suggested. Trials on combining USW or sawdust with nightsoil were suggested.
Market & hotel waste	80 to 85 t d^{-1} (20,000 t y^{-1})	Estimated to be 80% organic. Mostly from central market; contaminated by plastic bags and faeces. Mainly dumped. Mixing with sawdust has been suggested.
Slaughterhouse waste	Probably low	Disposed of in drainage system, horns used for crafts, bones for glue
Sawdust	15,000 t stockpile + 40 t day^{-1} (6000 t y^{-1} ?)	Use for compost thought to be unviable. Used for poultry bedding. Some industrial use.

Table 5.5 (continued). Availability of waste around Kumasi

Poultry manure	34 t day^{-1} for large units	There are c. 300 poultry farms around Kumasi of unknown size. Collection for compost could be a problem but many poultry units will deliver for cost of transport only (c. C300 to C 1000 per tonne?). Deep litter system using sawdust & shavings increases C:N ratio. Trials needed. Farmers reluctant to use as considered "unclean".
Other animal manures	?	Unknown potential for use of sheep, goat, cattle, pig, manure. Some used for fish feed.
Brewery waste	Low (6,000 t y^{-1} of grain; 30 t y^{-1} of yeast)	Some used for livestock feed.
Soap factory	Very low	
Food processing: palm oil by-products	135,000 t y^{-1}	Construction (palm fibre).
Food processing: cassava peel	?	Some used for livestock feed.
Food processing: cocoa shell	?	Fuel
Crop residues		GOAN (Ghana Organic Farming Netowrk) have been demonstrating and training farmers in the production of compost. It contains dry and fresh vegetables, cut grass, household waste and wood ash. The compost is produced in heaps (Field trip to Duase, Final Workshop, KNRMP). Holland *et al*. (1996a) reported that composting was not common around Kumasi. Demonstrating composts may be a better strategy than trying to introduce people to composting

Table 5.6. Possible strategies for the use of waste in agriculture around Kumasi.

Strategy	Comments
Use of urban waste	Does not include the required 'composting' aspect for crop protection. Limited opportunity to manipulate quality. Major disadvantages as discussed above (Table 5.5)..
Urban home composting	Often traditionally practised in an "unintentional" way with back garden heaps or pits. Mainly household waste/ livestock wastes some crop residues. Limited capacity to deal with large amounts of urban waste. Many urban producers don't have gardens to use the compost. Resistance because of attraction of flies. Rats and snakes. Relies on raising awareness.
Peri-urban backyard composting	Widely practiced in India. Limited opportunity to manipulate quality. Doesn't address the problem or potential of urban waste.
On-farm composting	Usually relevant to farm wastes from livestock and crop residues hut may also include household waste. Labour a major constraint. Doesn't address the problem or potential of urban waste.
On-farm composting with waste input from peri-urban community or urban areas	Has worked in some areas where farmers receive/collect wastes. Offers possibility of selecting higher value wastes for co-composting. Labour a major constraint, only possible with minimal labour requiring techniques. Likely cultural constraints to handling certain waste types. Transport a major problem: contrary to principle of composting as close as possible to site of waste production/ collection.
Peri-urban community composting	Doesn't address the problem or potential of urban waste. Very few villages have their refuse collected by the local authority or district assembly: therefore, waste is available Land is unlikely to be a constraint. Rubbish dumps are currently usually maintained by the women in the village: may need some additional/ voluntary labour. Limited opportunity for commercial development.
Peri-urban community composting with other urban & peri-urban input	Many urban producers don't have gardens to use the compost. Offers possibility of selecting higher value wastes for co-composting such as surplus chicken manure some of which is available in peri-urban areas. Offers possibility of deliberately manipulating composting process to enhance crop protection aspects. Likely cultural constraints to handling certain waste types. Transport a major problem; contrary to principle of composting as close as possible to site of waste production/ collection. General pros and cons of community composting discussed below.

Table 5.6.(continued). Possible strategies for the use of waste in agriculture around Kumasi.

Strategy	Comments
Urban community composting	Successful in some areas. Requires effective community organisation or NGO activity; more difficult than in village communities. Difficulty in sustaining voluntary labour. Limited commercial prospects. Likely mismatch between producers of waste and users of compost. Appropriate in areas inaccessible for refuse collections or where collections are unreliable. Offers possibility of selecting higher value wastes for co-composting livestock, market, organic household. agro-industrial wastes. Offers possibility of deliberately manipulating composting process to enhance crop protection aspects. Waste separation at source .ay be possible in higher income areas. May encounter resistance from municipal authorities who see waste management as their business. Likely to encounter difficulties in access to adequate land and water resources. May experience difficulty in disposing of low value non-compostables in the waste. General pros and cons of community composting discussed below.
Private enterprise (small/ medium scale)	More likely to be on urban fringe than in outer peri-urban area. Poorly understood waste streams. Currently very poorly developed market for organic fertiliser. Offers possibility of selecting higher value wastes for co-composting; livestock market; organic household; agro-industrial wastes. Offers possibility of deliberately manipulating composting process to enhance crop protection aspects. Waste separation at source may be possible in higher income areas; Requires significant investment, even for low tech options.
Municipal large scale	Land available and secure. Assumes municipal collection service. Close link, physically and administratively, between collection/delivery sites, composting and landfill. Possible subsidy, direct or hidden from municipal authorities. May generate revenue at least to offset costs. Likely to have (or train) staff to a reasonable technical level and better able to handle more difficult wastes such as nightsoil + sawdust. Can achieve good sanitation of wastes. Possible separation of major categories only, such as market wastes, for composting. Large volume production, but depends on maintaining level of technology. Tends to become bureaucratic and inefficient.

Table 5.7. Potential use of composted urban wastes in different farming systems around Kumasi.

Farming system	Potential for use of composted urban wastes	Opportunities & constraints
Bush fallow mixed	Very low	Traditional bush fallow system for subsistence plus surplus. Limited current use of inputs.
Sole crop cereals	Low	Bush fallow system but often more for cash income. Limited fertiliser inputs, relatively large scale farms. Likely to encounter major logistical constraints. Very impressive short-term soil fertility crop protection benefits would have to be demonstrated and very favourable cost-benefit relationships .
Sole crop vegetables (dry season)	Low/ medium	Sometimes opportunistic cultivation as part of bush fallow rotation. Opportunities and constraints as above. Greater requirement for pest and disease control and higher value of crops may increase potential.
Sole crop vegetables (irrigated)	Medium/high	Especially where this forms an intensive use of land over several years.
Specialised valley-bottom cropping	Medium/high	Continuous cropping of cash crops close to urban markets and sources of compost. Considerable potential for increasing yields. Likely to be favourable cost-benefit relationship.
Tree crops	Low/ medium	Perennial crops which can benefit from applications as mulch.
Backyard farms	Medium	Continuous cropping, mixture of perennial and annual crops. Opportunity for long-term building of soil fertility. Production may be mainly for home consumption with less concern for yield and less willingness to purchase/ transport centrally produced compost. Natural place for using products of home compost and small scale community compost products.

Table 5.8. Potential use of poultry manure in different farming systems

Farming system	Potential for use poultry manure	Opportunities & constraints
Bush fallow mixed cropping	Very low	Limited current use of inputs.
Sole crop cereals	Medium	Less logistical constraints than with compost. Growing commercial agricultural sector?
Sole crop vegetables (dry season)	Medium	Possibly as an alternative to chemical fertilisers.
Sole crop vegetables (irrigated)	Medium / high	Especially where this means an intensive use of land over several years.
Specialised valley-bottom cropping	Medium / high	Continuous cropping of cash crops close to urban markets and sources of compost. Considerable potential for increasing yields. Likely to be favourable cost-benefit relationship.
Tree crops	Medium	May be selected because of perceived medium / long term effect of manures
Backyard farms	Medium / high	Convenient and easy to use in the same way as a fertiliser

Source: Harris and Smith (1998).

Potential for use of waste as a soil conditioner around Hubli-Dharwad

The potential use of municipal solid waste (USW) as a soil conditioner around Hubli- Dharwad was investigated by the " Urban Waste Utilisation Project" (R7099). The aim was to investigate not only technical aspects but more importantly the institutional and policy issues. These latter have been summarised and evaluated elsewhere.

The trials

Field trials were conducted on 10 farmers fields in two villages, following composting trials conducted in Phase 1 of that project. Details of the pit and compost preparations are given in University of Birmingham *et al*. (1999a, 1999b) for Phase 1 and for Phase 2, respectively. Only composts generated in Phase 2 were used for field trials. The treatments used for the composting trials were:

- Sorted USW [Phases 1 & 2].
- Sorted USW + 25% Distillers Sludge (DS) [Phases 1 & 2].
- Sorted USW + vermicomposting (V) [Phases 1 & 2].
- Sorted USW + 25% night soil (NS) [Phase 2 only].
- Sorted USW + 50% DS [Phase 1 only].
- Sorted USW + 75% DS [Phase 1 only].
- Sorted USW + vermicomposting (V) + 50% DS [Phase 1].
- Sorted USW + *Azospirillium* bacteria + rock phosphate [Phase 1].
- Sorted USW + 5% cattle manure [Phase 1 only].

In the trials with distillers sludge and night soil, 1 kg culture of each of the bacteria *Bacillus polymyxa* (phosphorous solubilising) and *Azospirillum* spp. (nitrogen fixing) were added/t USW (University of Birmingham *et al*., 1999a). It was apparent in the trials that 90 days was a sufficient length of time for the composting to take place but there is a need to determine the optimum time and conditions. A summary of the chemical analyses of the various treatments compared to pit compost (PC) is given in Table 5.9.

No treatment stands out in terms of nutrient levels and their performance from a nutrient point of view would depend on the soil and crop. Generally, the additions of night soil or brewers sludge improved the USW as did vermicomposting. Nitrogen and potassium were both lower for all the treatments than for PC and only USW + V and USW + NS had slightly higher P values. The EC indicates that all the treatments are marginally saline. There may be some potential for salt build up, especially in the black soils which have impeded drainage.

Levels of Mg, Cu and Mn are all much higher in the treatments than the levels in PC but are not thought to be a problem. These may be beneficial though little is known about the existing micro-nutrient status of the soils or the uptake by the crops. More research on heavy metal aspects of USW based products is required. In particular metals such as mercury, lead, cadmium and chromium need to be assessed.

Table 5.9. Comparison between properties of farm yard manure (probably pit compost) and sorted municipal solid waste in Hubli-Dharwad experiments.

Analysis	FYM	Comparison of treatments with FYM
pH	7.2	all slightly more alkaline (USW alone was the highest (8.0)
EC ds m^{-1}	0.2	5 to 13 times higher (USW + DS highest)
N%	1	40% (USW alone) to 70% (USW + DS) of PC
P%	0.5	USW & USW+DS were 70% of PC, USW+V & USW+NS were 10 to 20% higher
K%	0.8	all 25% to 30% higher than PC
Ca%	0.2	all 15% to 24% higher than PC
Mg%	0.15	all 5 to 12 times PC
S%	0.2	25% less to 25% higher than PC
Cu ppm	0.45	about 20 times PC
Mn ppm	110	15% to 25% of PC
Fe ppm	35	about 50% to 70% of PC
Zn ppm	25	about 20% of PC

Source: Nunan (2000)

It was estimated (University of Birmingham *et al*., 1999a) that USW itself in Hubli-Dharwad consisted of:

- 35% compostable waste.
- 35 to 40% of plastics, glass, rubber.
- 15 to 20% of building debris.
- 5% of metal.
- 5 to 10% of woody biomass.

The proportion of the latter four items vary by season. No actual analysis of constituents or chemical analyses for the USW, night soil or distiller's sludge used are presented. This may make applications of the research to other parts of the world more difficult. It may also have clarified the most important processes

involved if further treatments in which the bacteria were added to the USW alone[8] was included and if the two species of bacteria were added singly as well as together. It is difficult to know to what extent the improvements observed are due to the bacteria and those due to the night soil or distillers sludge.

Comparison of treatments

Overall performance of the different treatments on four different crops in 10 villages (Nunan, 2000, p.35) were (in order of performance):

- Sorted USW + night soil.
- Sorted USW + vermicomposting.
- Sorted USW alone.
- Sorted USW + distillers sludge.
- Farmer's own practice.

The trials each ran for only one season but it was suspected that benefits were not necessarily obvious in the first season. Longer term trials would be needed to address this question. Results are presented in Chapter 3 (Table 3.1). Night soil or vermi-composting seem to be the most advantageous treatments and this was supported by analyses of nutrient uptake.

Social and institutional aspects

The research on waste (Nunan, 2000) reinforced the view that a tradition of using compost exists in the area of Hubli-Dharwad. In fact farmers prefer organic fertilisers to inorganic sources of nutrients. However, there are a range of constraints that discourage the expansion of waste use such as cost, transport and decreasing quality.

One of the most important constraints is that it is difficult to achieve significant commitment to separation at source at household level. Thus, separation is an important bottleneck, and consequently the different types of waste are not being collected separately. The municipality has an inadequate waste collection system and the dump sites are not managed / sited in an environmentally sensitive way.

Traditionally, farmers are allowed access to USW tips. Some are concerned that increasing commercialisation may halt this practice (though as pointed out above it is becoming less economic for farmers to collect and use USW). The private sector and NGOs could be persuaded to become involved in the separation, processing and distribution of waste products and that there is a range of products sold at different prices.

HDMC is addressing some of these problems but the R7099 project report emphasises that an integrated systems approach to waste management in which waste is perceived as a resource, is required. There is a range of different sources and uses of waste but there is a need to better understand the interactions between these. Different methods of composting need to be explored (as turning composts in pits is difficult) and the health and management of incorporation of night soil needs further exploration.

Use of municipal waste around Kano, Nigeria

It is interesting to compare the situation in Kumasi with that of Kano in northern Nigeria. Lewcock (1995) describes an earlier peri-urban DFID funded project there (Lewcock, 1994). He made the following points:

- Use of waste for agriculture is well established and has been practised for several centuries in Kano.
- In the 1960s, 25% of fertiliser needs in the peri-urban environment were met by reuse of municipal waste.
- By the 1990s, the area is which waste was used had increased, though after the replacement of the traditional donkey mode of transporting the waste with municipal tipper trucks in the 1980s and the subsequent deterioration of the lorries, supply difficulties were being experienced (projects developed for Hubli-Dharwad or Kumasi should note this).
- The waste was composed of:
    - Street and household waste;
    - Unmixed manure;
    - Other material (such as tannery waste, abattoir offal, waste water).
- The Challwa River is heavily polluted with household and industrial waste (as is the case in many other PUI), and it is an important source of irrigation water for horticultural crops.
- As in Ghana and India, the urban waste has decreased in quality (such as increased proportion of plastic bags).
- The perceived benefits, methods of use and preferences are similar to Hubli-Dharwad and Kumasi.
- As in Hubli-Dharwad and Kumasi, there is increasing private involvement.
- Waste is not formally composted in Kano and the affordability of composted waste by resource-poor farmers is questioned.

Use of sewage-contaminated water around Hubli-Dharwad

Introduction

An examination of the use of sewage contaminated stream water was not a specific purpose of the Hubli-Dharwad PUI projects. However there have been some incidental outputs such as Hunshal *et al*. (1997), a section in University of Birmingham *et al*. (1998d)[9] and comments in the baseline study (University of Birmingham *et al*., 1998a). There is no treatment of sewage around Hubli-Dharwad, even though it is estimated that 60 million litres of sewage per day are produced (Hunshal *et al*., 1997) Some liquid presumably drains to the water table, but much of the solid and liquid sewage finds its way into the surrounding water courses.

Impact on weeds and pests

A major drawback of the use of sewage contaminated water is increased levels of weeds and insect pests on crops (which, because of the high value of the crop, encourages farmers to use organo-phosphate/insecticides, often with no protective clothing).

Water quality

The stream water does not suffer from heavy metal contamination due to the absence of heavy industry in the area. However, total suspended solids are high (110 mg l^{-1}) and dissolved solids are also high (780 mg l^{-1}) and could affect salt sensitive crops[10]. The nitrogen concentration was around 12 ppm which partly explains why the yields of stream irrigated crops are (anecdotally) 25 to 30% higher than those irrigated from boreholes. A summary of some of the chemical analyses of the water (Hunshal *et al.*, 1997) is given below in Table 5.10.

Table 5.10 Properties of sewage contaminated irrigation water, Dharwad

Parameter	Quality assessment
pH	neutral to slightly alkaline
Biological Oxygen Demand (BOD)	2 to 19 times acceptable limits for potable water
Chemical Oxygen Demand (COD)	2 to 9 times acceptable limits for potable water
Suspended solids	Good: 20 to 120 g per tonne
Dissolved solids	some samples are marginally saline
Chlorine	slight to moderate chlorine hazard for crops

Source: Hunshal *et al*. (1997)

Health aspects

In a brief and poorly thought out study of 40 men in two villages near Hubli-Dharwad where fields were irrigated with sewage contaminated stream water (Hunshal *et al*., 1997), it was reported that the water had an adverse affect on irrigators' health. However, the men were simply examined for any health problems. Consequently many of the diseases listed (such as varicose veins!) are certainly not water borne. The conclusion that conjunctivitis, and dermatological and gastro-intestinal diseases are higher in populations exposed to contaminated irrigations water needs to be treated with some caution. Furthermore, the study had no control (40 men or women who had never been exposed to contaminated irrigation water) and thus the study would seem to be inconclusive. However, samples of irrigation water taken from one village exhibited the following micro-biological analyses:

Total bacterial growth:	12×10^6 ml^{-1}
E. coli (unspecified type(s)):	4×10^5 ml^{-1}
Total fungi:	2.8×10^4 ml^{-1}

Economic aspects of using sewage contaminated water

Producing vegetables for sale during the dry season means that farmers can sell for three to five times the kharif season prices. Also, as pumping from a water course is cheaper than from a borehole, it is more accessible to farmers with fewer financial resources.

It is not clear what the status of HDMC's attempt to get finance for processing is and what their treatment preferences would be.

Research requirements

This topic needs further research, especially: -

- Quality and quantity of sewage contaminated water available;
- Groundwater monitoring for contamination (wells and boreholes);
- Soil nutrition and toxicity aspects;
- IPM methods for managing the relatively high levels of pests;
- To clarify the human health hazards.

Sewage contaminated water around Kumasi

Kasanga (1998, Appendix 7) presented some analyses of water in the River Oda, at the confluence of the R. Oda and R. Seisa, at the public water draw-off point for the R. Seisa and R. Oda and at a point 100 m away from the public draw-off point. The water is slightly to moderately saline for irrigation purposes. BOD and COD are generally borderline moderate though the COD at one site was high. The Appendix refers to an (un-named) report which found that R. Seisa contained bilharzia and Guinea Worm vectors.

Green manures and mulches

Only a brief account of a trial with *Mucuna* sp. (species not mentioned) as a green manure is reported (Quansah *et al*., 2000). No details of application rates or trial design are given. It is concluded that:

- Mulches reduce evaporation by keeping surface cool and so conserve moisture.
- Yields are better (than slash and burn).
- Insects may hide in the mulch.
- Farmers are aware of the benefits of mulching.

There is clearly a need for better designed trials with Mucuna and other green manures and mulches. However it seems unlikely that green manures will pay a significant part in improving soil fertility in the PUI where land and labour are in such short supply.

Potential for using slaughterhouse waste in compost

Farinet and Dioh (1998) at a conference on peri-urban agriculture in sub-Saharan Africa in Montpelier described the 'Transpaille Process' developed by CIRAD for the production of biogas and compost "blocks". The blocks are composed of 75% compost and 25% sand with small amounts of fungicides and water-retaining chemicals. Seeds are planted and raised directly in the blocks. The blocks are increasingly used by peri-urban agriculturalists around Dakar in Senegal. The process could be tested in Kumasi.

Natural resource management at a watershed level (Kumasi)

The "Kumasi Natural Resource Management at the Watershed Level" Project (R7330) commenced in 1999 with the purpose of developing a framework for sustainable and equitable water resource management. It sets out to do this through participatory research and traditional monitoring methods (CEDAR, 1999, p.9) at a watershed level. The project will concentrate on examination of water resources in two sample watersheds in the Kumasi area (Owabi and Sisa-Oda). The project will minimise primary data collection and seek rather to integrate and collate what is already available. One aim will be to investigate how catchments upstream of Kumasi affect Kumasi and how Kumasi affects rivers downstream. PRAs will be used to characterise villages using transects, group narrative discussions, diagrammatic representations.

The project will also parameterise (using existing or easily collected data) diagnostic frameworks which will assist in identifying likely consequences of land use and cover changes or point pollution events on the hydrological and soil erosional systems. It is assumed that changed use will lead to pollution or land degradation (but this is not necessarily the case). Assessments will include: rapid field assessments, conceptual models and GIS manipulation, lumped parameter statistical models, distributed process-based simulation models; mainly the first two. Approaches to assessment of erosion risk, river network pollution and groundwater pollution models using GIS methods are discussed.

Although research into natural resource management at a watershed level may produce useful results, it seems unlikely at this stage that the administrative institutionalisation of natural resource management at a watershed level is a viable strategy.

The R7330 Inception Report (CEDAR, 1999) gives a list of further work required:

- Comparison of water quality sampling with perceptions of pollution which may lead to alternative, low-cost, management strategies.
- Land use changes and effects on the environment and health.
- Development of a methodology for monitoring land use changes.
- Basic hydrological data.
- Water use and management.
- Waste management, siting (and alternatives) and the effect on the environment.
- Tree planting data (or promotion).
- Information on relationships and responsibilities of government and local institutions vis-à-vis water / refuse / sewage.

Participatory planning

Participation needs to go further than the use of PRAs to help in characterisation of an area (Brook, 2000, p.13). In two of the case study villages, PRAs were undertaken to determine natural resource development priorities. Proposals from villagers included:

- Village level planning of village layout.
- Construction of a market.
- Protection of stream.
- Re-siting of refuse dump.
- Improved sanitation (latrines).
- Bore-hole and hand pump.

The villagers, with minimal help, subsequently undertook a stream protection project and a well construction project. This illustrates the need for increased emphasis on participatory methods. Little seems to have been done about the development of village level planning, the formation of self-help groups, institutionalisation of participation at village level despite the fact that the topic has been raised often during the workshop and elsewhere.

Formal planning and land management

Williams (2000) stated that in Kumasi, planning in the peri-urban areas should pay more attention to:

The possible loss of good agricultural land to housing (good agricultural land, especially irrigable land needs to be preserved);

- The loss of fuel wood and timber resources (tree belts (for fuel and windbreaks) around villages should be established and maintained, although it is not suggested who would be responsible for this;
- The impact of sand winning and quarrying on the environment and potential benefits (it is possible that sand winning sites be used for waste disposal);
- Soil erosion undercutting houses.

The mechanisms and technical inputs (GIS, soil/land classification maps) for such planning are not mentioned.

Priorities identified at workshop on urban and semi-urban agriculture, Accra, August 1999[11]

Some of the priorities for future research identified at this conference that relate to soil and water management are summarised below.

Water

Agricultural production should be made safer with focus on institutionalised water quality monitoring (including agrochemicals where necessary) and certification programmes, which should be transparent for the farmers. Sources of pollution should be identified and legal disincentives addressed for point source polluting activities (car wash facilities etc.). Community-based water management in urban and PU areas could be supported with community-based water treatment technology.

Sustainable use of lowlands (wetlands) should be developed, including:

- Ecological and hydrological impact studies of wetlands used for urban and peri-urban agriculture,
- Participatory technology development for urban and peri-urban wetlands.

Soil

The (community) knowledge bases on soil fertility decline and soil contamination in peri-urban farming systems and on the safe use of compost and adequate application methods including the monitoring of pathogenic contamination due to the use of non-matured compost, needs to be improved.

Use of waste and nutrient recycling:

- Gain an understanding of nutrient flows in existing PU farming systems.
- Typology of farming systems.
- Mapping nutrient flows in different farming systems.
- Attitudes, perceptions, and demand for waste stream products for soil fertility improvement within different farming systems.
- Quantify the amounts and value of materials available and assess the agricultural potential of urban waste materials by investigating.
- Different storage options, application rates, and mixtures.
- Long-term benefits, not just short-term fertilising value (may require methodology development).
- Short- and long-term negative effects on soil quality & fertility.
- Specific applications for different crops.
- Develop & test appropriate waste processing technologies for a range of purposes that are sustainable given current resource constraints.
- Improve research uptake and promotion pathways.
- Research solutions to institutional policy and fiscal issues.
- Address major gaps in the dissemination and extension of existing knowledge and research findings; ensure that appropriate and effective uptake pathways are incorporated into any research initiatives; include training and support of extension services.

Notes

[1] A paper presented at the FAO / IBSRAM International Workshop: "Urban and peri-urban agriculture: closing the nutrient cycle for urban food security and environmental protection", Accra, 2-6 August, 1999

(http://www.cityfarmer.org/africaworkshop.html)

[2] Nsiah-Gyabaah (2000) reported it to be 1,500 mm but this may have been a "guesstimate". A 55 year mean figure of 1488 mm is given for Kumasi Airport in

CEDAR (1999, p.11). There seems to be some doubt, possibly arising from location of meteorological stations.

[3] Results are being entered into KUMINFO but were not available at the time of the review. They will complement the data entered as a result of a consultancy by Gibbs Ltd (consultants) in 1999.

[4] Exchange rate February 2000: £1.00 = Rs 68.00.

[7] Reduced fertility and shorter fallows were reported in 1/3 of villages studied

[8] Based on a report presented at the FAO / IBSRAM International Workshop: "Urban and peri-urban agriculture: closing the nutrient cycle for urban food security and environmental protection", Accra, 2-6 August, 1999

(http://www.cityfarmer.org/africaworkshop.html)

[8] Based on a report presented at the FAO / IBSRAM International Workshop: "Urban and peri-urban agriculture: closing the nutrient cycle for urban food security and environmental protection", Accra, 2-6 August, 1999

(http://www.cityfarmer.org/africaworkshop.html)

[9] This was requested but never implemented

[10] Much of the data presented in this workshop were presented as tables with no or little interpretation.

[11] The Electrical Conductivity (in dS/m) should be approximately equal to the total dissolved solids [in ppm] x 1.5 /1000 but the actual EC was lower than this. This raises some doubts about the reliability of the analyses.

[12] http://www .cityfarrner.org/africaworkshop.html