Singapore Journal of
Tropical Geography

doi:10.1111/j.1467-9493.2011.00438.x

Resource management and agriculture in the periurban interface of Kumasi, Ghana: Problems and prospects

Duncan F.M. McGregor,[1] Andrew Adam-Bradford,[2] Donald A. Thompson[1] and David Simon[1]

[1]Centre for Developing Areas Research, Department of Geography, Royal Holloway, University of London, Egham, Surrey, UK
[2]Department of Geography, University of Sheffield, Sheffield, UK

Correspondence: Duncan McGregor (email: d.mcgregor@rhul.ac.uk)

This paper outlines pressures on agricultural land in periurban Kumasi, Ghana. A survey of agricultural practices underlines the recent and rapid transition from agricultural to urban land use in the periurban interface, and shows how farmers are reacting by reducing fallow periods. Farmers are also intensifying agriculture near streams and rivers through increased use of irrigation, in response to growing urban markets for a wider range of vegetables. We identify specific problems of water resource pollution and waste management, with particular reference to farmland irrigation. We report results of composting interventions as a community-based waste management strategy. We consider integrated organic waste recycling as a generic strategy to help protect periurban natural resources, to enhance food production through nutrient recycling, and to improve community sanitation.

Keywords: agriculture, Kumasi, periurban interface, resource management, waste management

Introduction

The periurban interface of cities in developing country contexts has received growing attention in recent years (e.g. Simon *et al.*, 2004; Lynch, 2005; McGregor *et al.*, 2006; Tacoli, 2006; DST, 2008), and was the focus of significant research effort by the UK Department for International Development's (DFID) Natural Resources Systems Programme from 1995 to 2006. Principal among effects of rapid urbanization has been conflict over land use in the periurban interface, between traditional forms of agriculture and the ever growing demand for housing and commercial premises. Loss of land for building has frequently marginalized periurban farmers, whose livelihoods are often prejudiced by insecure tenure. Short-term planning in this pressurized environment typically leads to agricultural intensification on remaining accessible land and insufficient attention to declining soil status. Significant challenges have emerged in terms of access to land, soil ameliorants, water and water quality (increasingly polluted by periurban waste, urban waste disposal and industrial activities) (Douglas, 2006). Yet urban and periurban agriculture is often claimed to be a key livelihood opportunity for many citizens (van Veenhuizen, 2006).

The challenges to agriculture in the periurban interface include adapting farming systems sustainably, managing water resources for agriculture in the face of rising nonagricultural demand, and exploring opportunities for waste recycling in order to protect soil fertility. This paper considers these issues in relation to the periurban interface of Kumasi, Ghana's second city.

The increasing pollution and waste disposal problems found in many sub-Saharan African cities, resulting from rapid growth and urbanization, widespread poverty, inadequate and weak local governance and limited financial resources (Onibokun, 1999; Adam, 2001a; Adarkwa & Post, 2001; Drechsel & Kunze, 2001; Simon *et al.*, 2001; 2003), have become distinctive features of Kumasi and its immediate periurban interface that pose major challenges to environmental protection, waste management, food security and urban and periurban agriculture (Brook & Dávila, 2000; Mensah *et al.*, 2001). The pollution and waste disposal problems are most acute in periurban areas, where waste management services are seldom adequate or provided despite rapidly increasing settlement densities (Adam, 2001a). Hence, substantial opportunities exist for community-based waste management strategies that promote nutrient recycling. These strategies turn organic waste into compost at community and household levels for use as agricultural fertilizer in urban and periurban agriculture. While not problem-free, such approaches have the potential to create a positive outcome overall by increasing urban and periurban agricultural production through appropriate soil fertility management; by protecting the environment through the recycling of organic waste; and by generating income and livelihoods, which in turn enhance urban and periurban food security (Allison *et al.*, 1998; Drechsel & Kunze, 2001; Leitzinger, 2001; Adam-Bradford *et al.*, 2006).

Periurban Kumasi

As in many rapidly developing urban regions, the Kumasi periurban interface is characterized by high rates of conversion of agricultural land to private housing and increasing pressure on natural resources through waste dumping, wood collection and sand winning/mining (Brook & Dávila, 2000; McGregor *et al.*, 2006). Land tenure is a complex issue in periurban Kumasi as land may be held by the government for public facilities, by families ('family land'), by the community ('stool land', controlled by the community chief) and by individuals. The debates around pressures of development have focused to an extent on community land (Brook & Dávila, 2000; Adam, 2001a; Kasanga, 2001; McGregor *et al.*, 2006). The role of the chiefs in controlling and selling land for development is critical. Customarily, the proceeds of stool land sales should revert to the community, and those farming these community lands should be compensated by access to appropriate parcels of alternative farming land. This has not always been the case, especially with progressive monetization of transactions and as the extent of suitable land not covered by buildings declines. Numerous conflicts have arisen, leading some farmers to abandon agriculture, and generating insecurity and short-term planning strategies among remaining farmers, often resulting in exploitative soil 'nutrient mining' approaches.

The city and its suburbs lie across a major drainage divide (Figure 1). The main watersheds in the area flow from more rural catchments across the periurban zone and into the city. Having passed through the built-up area, the main streams then flow through periurban Kumasi and then further out into more rural areas. As a result, a range of water quality and supply problems affects the periurban interface. Further, budgetary pressures have resulted in the inability of public services to meet waste collection demands in the periurban interface adequately, despite the construction of two new waste collection facilities since 2000. This has been partially due to a process of 'peripheral neglect', in which municipal and district authorities focus their resources in core rather than peripheral areas such as the periurban interface.

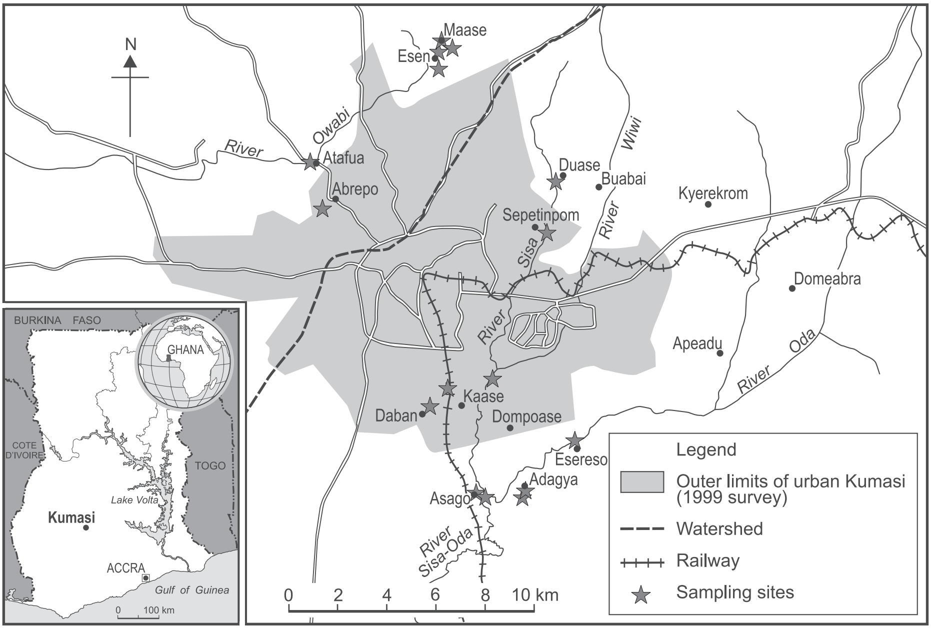

Figure 1. *Sampling sites and other locations mentioned in periurban Kumasi, Ashanti region, Ghana.*

This is set against a pattern of declining rainfalls in the Kumasi area, from the 1960s average of 1600 mm to that of about 1250 mm in the decade 1989–1998 (data obtained from Ghana Meteorological Service, Kumasi Airport station), a trend mirrored elsewhere in Ghana (Owusu & Waylen, 2009). However, rainfall totals have risen marginally since about 2000, if characterized by relatively high variability, with a fitted trend line rising from 1380 mm in 2000 to 1470 mm in 2009 (Ghana Meteorological Service, Kumasi Airport station). With significant population increase, from perhaps 200 000 (1960) to substantially over 1 million, and increasing periurban house building and groundwater abstraction, the necessity to protect agricultural land and to better manage water resources for agriculture becomes apparent.

Soils of Kumasi's periurban interface are developed over highly weathered phyllites, greywackes, schists and gneiss, and are predominantly reddish silty clays and silty clay loams, generally well drained but with low chemical fertility below a thin organic topsoil (Adu, 1992: 32). Adu (1992: 121–22) reports that these soils are deficient in phosphorus and that where cultivation has been carried out continuously for long periods soil nitrogen levels are 'very low'. Heavy leaching has depleted the soil of elements such as calcium and magnesium, resulting in relative concentrations of iron and aluminium compounds. Low organic matter content renders these soils susceptible to erosion and careful agricultural management is required.

The terrain is generally moderately dissected, with slopes of 5° to 15° and local amplitude of relief of up to 30 m. Summits are often relatively flat-topped, and underlain by laterized concretionary gravels (as noted, for example, near Adagya, where gravels were being quarried for road making materials). Adu (1992) asserts that improper cultivation practices, particularly on steep upper and middle slopes, have led to widespread accelerated erosion, in turn leading to the exposure of subsoil gravel and to shallow soil depths.

Research methodology

A range of scientific and social scientific research techniques was applied in studies carried out between 2001 and 2005 as part of a wider DFID programme (see McGregor *et al.*, 2002) and as part of Andrew Adam-Bradford's doctoral research. In order to determine the nature of the agricultural system, in-depth semistructured interviews, backed up where possible by systematic on-site observation, were held with a sample of 35 farmers (26 male, 9 female) in Adagya, Esereso and Maase. Following local custom, the village chiefs were approached to gain community access so that, inevitably, initial interviews were with their associates. But a cross-section of farmers was accessed subsequently via the snowballing method. Questions focused on identifying basic farming practices, including soil and water management, and investigating indigenous technical knowledge. Wherever possible, farmers were invited to conduct interview discussions in their fields, thus providing independent corroboration or otherwise of their statements via more participatory methods derived from participatory rural appraisal. All our interviews were conducted in English (while accompanied by a local interpreter).

Monthly water quality data were obtained for the period September 1999–September 2001 (McGregor *et al.*, 2002). Samples were analyzed at the Kumasi-based laboratories of the Ghana Water Company and Ghana Environmental Protection Agency, both using standard procedures associated with the portable laboratory 'Paqualab' systems. Heavy metal determinations were carried out at the Chemistry Department laboratories of Kwame Nkrumah University of Science and Technology in Kumasi.

In order to conduct composting experiments, household surveys in 6 periurban villages (Adagya n=52; Apeadu n=50; Asago n=58; Domeabra n=54; Esereso n=56; and Kyerekrom n=53) were undertaken to identify behavioural patterns, with respect to disposal of household refuse (Bradford, 2006). Villages were selected to ensure that a range of different periurban characteristics (environmental, geographical, social, economical and political) was represented. The single universal characteristic that applied to all selected villages was that open refuse dumps were used; that is, no waste collection services existed.

Focus group discussions were also held in study villages, including discussions with separate subgroups comprising of chiefs and elders, farmers, women, and village youth. A total of 18 (3 in each community) focus group sessions/workshops were held specifically related to the composting initiatives. Following action planning discussions, specific designs and types of household level composting micro projects were chosen. Sketches and diagrams were used to illustrate the principles of container composting, then suitable compost container designs were drafted for local construction. These consisted of simple and easily replicable demonstrations, distributed at prominent points in each village. Once the various containers had been constructed, their use was implemented, as noted above, through training workshops conducted by community-level facilitators and community-chosen representatives working with a Ghanaian non-governmental organization (CEDEP, 2005) on a DFID-funded livelihoods project, thereby also contributing to local empowerment through enhancement of the community facilitators' capacity to produce and analyze knowledge.

Agriculture in periurban Kumasi

The dominant farming system in periurban Kumasi is sedentary agriculture with mixed cropping and some rotation of cassava, maize, exotic vegetables, plantain and sugarcane, and relatively little monocropping. The most common rainfed strategy is intercropped maize and cassava. Cassava, maize and plantain are the main crops and urban and periurban backyard gardening features extensively. Many farmers around Kumasi have turned recently to irrigation (Danso *et al.*, 2006), particularly in bottom lands with access to water, and to year-round intensive cultivation of lettuce, tomatoes, spring onions, carrots, cabbage and other vegetables for the growing urban market.

Despite the important role of urban and periurban agriculture in contributing to food security and income generation, the sector faces many constraints. Inadequate water for dry season farming, low income levels, high costs of farm inputs and inadequate storage and processing facilities all hinder agricultural production. However, the loss of agricultural land for construction activities is a major constraint around Kumasi, destroying livelihoods and resulting in agricultural intensification on remaining farmland. Consequently, unsustainable nutrient depletion of soils and inappropriate use of chemical fertilizers occur. This poses particular problems as many female-headed and poor periurban households remain dependent on agriculture as their main livelihood (McGregor *et al.*, 2006).

As more farmland is lost, it might be assumed that the bulk demands of farming systems on water flows and availability should reduce. However, this has not happened because of the recent trend of declining rainfall, the current relatively high rainfall variability, and the increasing pressure on groundwater resources due to river pollution and increasing abstraction for domestic use. Also, the potential intensification of agriculture on land protected from urban sprawl, either by chiefs with a social conscience or by the marginal or sacred status of particular areas, needs taking into account.

Our interviews indicated that periurban Kumasi farmers have sound indigenous knowledge of soil assessment, both for estimating soil fertility and for judging when soil fertility is declining. Farmers were asked, unprompted, which indicators they recognized for these, and their responses were then elaborated in discussion. The indicators used by farmers, such as soil colour, soil texture (particularly changes towards more sandy textures), declining yields, and pest and weed invasion (Table 1), are very similar to those reported by Chokor and Odemerho (1994) in a Nigerian investigation.

Table 1. Indigenous indicators of soil fertility sampled among 35 periurban farmers in Kumasi, 2001.

Indicator	No.	Per cent
What shows that a soil is fertile?		
Soil colour	24	67
Soil texture	16	44
Fallow trees	10	28
Crop growth quality	9	25
Crop growth yields	9	25
Established fallow	5	14
What shows that a soil is declining in fertility?		
Declining yields	21	58
Pest invasion	16	44
Weed invasion	15	42
Sandy or coarse topsoil texture	7	19
Changes in soil colour	5	14
Changes in greenness of fallow vegetation	3	8

In our interviews, limited use of organic fertilizers (2 farmers – both male – using mostly chicken manure) was reported, but there was relatively common use of chemical fertilizers (11 farmers – 9 male, 2 female), almost exclusively on relatively high value crops such as tomatoes, okra, 'garden eggs' (aubergines) and peppers. Inadequate finance was most often quoted as a constraint on chemical fertilizer use. Three farmers were using herbicides incorrectly as pesticides, while 9 farmers admitted to using (banned) DDT. It is clear that farmers here use low amounts of fertilizer overall, the main reasons being continued reliance on fallows to restore fertility and inadequate resources to purchase fertilizer. This low application estimate conceals possible hot spots such as intensive tomato production near Maase, where excess fertilizers may well be applied and result in leaching into streams and groundwater (Adam, 2001b).

Use of fallow continues except in the most urbanized villages, although fallow periods are being reduced (see also Drechsel & Zimmerman, 2005). The average fallow period claimed by farmers was four–five years, though many said that this had reduced recently. On the other hand, one farmer had cultivated two plots alternately (one year fallow) for six years and three farmers admitted to a two-year fallow; the maximum fallow period claimed was six years. Permanent intercropping is more common in the relatively urbanized communities. Monocropping is uncommon, although many farmers perceive the market advantages of concentrating effort on cash crops such as lettuce and tomatoes.

Also notable from interviews is the imperfect perception of soil erosion problems. Only a third of farmers surveyed agreed that soil erosion is problematic, despite visual evidence of topsoil (and hence nutrient) loss during rains and developing gully systems, especially on slopes. Most farmers who recognized the problem declared that there was nothing they could do about it. Again, these figures closely parallel attitudes in Chokor and Odemehro's (1994) investigations (cf. McGregor & Barker, 1991, on Jamaican hillside farmers). It is clear that attempts at soil and water conservation among Kumasi's periurban farmers will require carefully planned awareness-raising and improved linkages to extension services.

Overall, our interviews suggested that the principal response to the progressive reduction in amount of farm land available has been reduction in, and even elimination of, fallow periods (see also Sarfo-Mensah & Adam, 1998). Maconachie (2007) has observed similar periurban patterns in Kano, northern Nigeria, where farmers have ceased using fallow. In periurban Kumasi this may well prove to be a more critical variable in the future of agricultural systems than declining water availability. Nevertheless, relatively low and currently variable total amounts of rainfall and increasing use of fertilizers are both factors which will require monitoring to ensure sustainable periurban agriculture.

Water use and agriculture in periurban Kumasi

Although the secular trend in rainfall since about 1960 is downward, despite a slight rise and relatively high variability in the last decade, there is still sufficient precipitation for traditional forms of rainfed agriculture in Kumasi's periurban interface. The trend towards irrigation to diversify and intensify cropping relies on use of Kumasi's streams and rivers, which is problematic.

Several short-term studies (e.g. Cornish *et al.*, 1999; Mensah *et al.*, 2001; Keraita *et al.*, 2003; Cornish & Kielen, 2004) and our longer-term study reported elsewhere (McGregor *et al.*, 2000; 2001; 2002) show a clear pattern of stream pollution, with chemical and human waste contamination present within very short distances (as little as 1 km) of source. Not only is river water heavily polluted, but significant levels of pollutants in hand-dug wells (as at Asago, about 150 m from the river) also indicate ongoing contamination of the floodplain aquifer. Although the limits for safe drinking water are not consistently exceeded, individual readings do exceed these limits (McGregor *et al.*, 2002). This is supported by Obiri-Danso *et al.* (2009) in a survey of water quality in wells and boreholes largely to the east of the present study area.

In terms of chemical pollutants, farmers surveyed generally believe that river water provides detectable fertilizer benefit to irrigated crops, and it would be expected that the polluted waters downstream of Kumasi would make a significant contribution to the nitrogen requirements of irrigated crops there. However, the use of nitrogenous fertilizers leads to both the export of nitrogen in crops and the build-up of nitrate in groundwater. The maximum accumulation of nitrogen is likely to occur in water-saturated landscapes, such as those valley bottoms in and around Kumasi, and downstream at Asago, where sugarcane and water cocoyam are grown (Adam, 2001b). The role of these areas in nitrogen cycling deserves further investigation.

Use of stream and wastewater for irrigation is growing in Kumasi's periurban interface. Where available, farmers utilize land where there is a high water table or close proximity to a stream. One farmer interviewed used irrigation extensively. He had rehabilitated a floodplain site close to Maase, which had had its topsoil permanently removed by sand winning, and was utilizing the high water table by digging a shallow well. He had incorporated sawdust and soil from adjacent river banks and anthills in an attempt to improve soil texture and encourage water retention, and was producing market vegetables (reportedly for both Kumasi and Accra) which needed constant water supplies for optimum growth and freshness.

Wider use of irrigation for fresh vegetables, a distinct possibility in view of increasing markets in Kumasi and Accra, is a potential source of increased agricultural demand on water in the periurban interface, which also may present a significant threat to human health.

Current health concerns

Current health concerns with respect to periurban water use for agriculture focus on problematic concentrations of faecal coliforms and helminth eggs, and potential build-up of heavy metals. Recent research (Keraita *et al.*, 2008) showed that farmers were aware of the health risks from irrigating with urban wastewater but that they perceived bad odour and skin infections to pose the greatest risks, rather than nematode infections and bacterial diseases which are usually associated with wastewater irrigation.

Obuobie *et al.* (2006) record that vegetable samples collected from Kumasi's markets show faecal coliform contamination well above the level (1×10^3 100 g^{-1}) recommended by the International Commission on Microbiological Specification for Food (ICMSF). Mensah *et al.* (2001) and Keraita *et al.* (2003) also express concern over use of urban wastewater in farming and vegetable handling in and around Kumasi. They also report high levels of faecal coliform contamination of vegetables sold in Kumasi's markets, though contamination could occur from a range of sources.

As Westcot (1997) points out, the presence in river water of faecal coliform concentrations above 1000 per 100 ml does not necessarily preclude the use of such water for irrigation, but concentrations such as those found in the rivers of Kumasi's periurban interface (averaging up to over 12 000 faecal coliform per 100 ml) suggest a potential risk (McGregor *et al.*, 2002). Cornish *et al.* (1999), McGregor *et al.* (2000; 2001; 2002) and Cornish and Keilen (2004) show that faecal coliform levels in some local hand-dug wells but throughout the Kumasi river system are already at or higher than WHO guidelines for unrestricted irrigation.

Cornish *et al*. (1999) also report that water upstream and downstream of Kumasi contains levels of helminth eggs above WHO (1989) guidelines. Further, Obuobie *et al*. (2006) note the consistent presence of helminth eggs in vegetables sold in Kumasi's markets. Although coliform bacteria are reduced by exposure to light, helminth eggs are more persistent and may represent a greater health hazard. In a study of survival of helminth eggs in compost comprising mixtures of faecal sludge with other organic materials at the sewage treatment plants at Buobai (Kumasi) and Teshie (Accra), Galizzi (2004) records that viable helminth eggs persisted under some composting conditions for up to four months.

The reality is that untreated wastewater remains a significant source of water for agriculture in Kumasi's periurban interface, and in Ghana in general (Keraita & Drechsel, 2004).

Heavy metal contamination

An investigation of heavy metals in the River Sisa at Asago, about 4 km downstream of the city edge, indicates that safe drinking water standards (WHO 1989; 2006) are exceeded by a range of heavy metals, and that there is a significant build-up of heavy metals in floodplain sediments (Table 2). Many heavy metals such as arsenic, cadmium, lead and mercury are not plant nutrients and if taken up by vegetation would tend to accumulate therein. The question of uptake rates is, however, not straightforward. For example, Drescher (1994) found that in some circumstances high heavy metal (cadmium, copper, zinc) concentrations in soil do not enter the food chain via vegetable cultivation. The standards used for crop production (Table 2) are, however, exceeded by

Table 2. Heavy metal analysis of samples taken from River Sisa at Asago village, January 2001.

Water Samples	mg.l^{-1}	mg.l^{-1}	mg.l^{-1}	mg.l^{-1}	mg.l^{-1}	mg.l^{-1}	mg.l^{-1}	mg.l^{-1}	mg.l^{-1}	mg.l^{-1}
	As	**Cd**	**Co**	**Cu**	**Fe**	**Hg**	**Mn**	**Ni**	**Pb**	**Zn**
W1b	2.400	0.420	0.000	0.000	5.946	0.773	0.386	0.000	0.218	0.202
W2b	1.238	0.840	0.000	0.066	16.520	0.781	0.546	0.000	0.368	0.530
W4b	0.986	0.006	0.000	0.000	9.480	0.851	0.064	0.004	0.112	0.276
Limits for drinking water*	0.01	0.003	–	2.0	0.3	0.001	0.5	0.02	0.01	3.0
Limits for cropping†	0.10	0.01	0.05	0.2	5.0	–	0.2	0.2	5.0	2.0
Soil and sediment samples	mg.kg^{-1}	mg.kg^{-1}	mg.kg^{-1}	mg.kg^{-1}	mg.kg^{-1}	mg.kg^{-1}	mg.kg^{-1}	mg.kg^{-1}	mg.kg^{-1}	mg.kg^{-1}
	As	**Cd**	**Co**	**Cu**	**Fe**	**Hg**	**Mn**	**Ni**	**Pb**	**Zn**
S1b	11.903	0.000	0.000	0.000	2701.685	0.448	9.217	0.000	6.739	29.435
S2b	13.965	0.000	0.000	6.544	3327.714	0.253	24.888	0.000	5.354	44.621
S8b	11.469	0.000	4.837	6.022	5081.935	0.252	42.843	4.640	14.018	65.350
S10b	13.048	0.000	0.000	0.395	654.563	0.522	10.010	2.748	1.766	9.323
S11b	16.150	0.000	0.000	2.572	2888.229	0.207	34.125	0.000	18.497	32.416

*WHO (1993); †WHO (2006).

river water at Asago for arsenic, cadmium and manganese; and for soil and sediment samples by arsenic, copper, manganese, nickel, lead and zinc. Although such levels of heavy metal accumulation here are not currently regarded as significant for human health (Keraita & Drechsel, 2004), the build-up in river/bank/floodplain sediments at Asago indicates that residence levels are high and may become toxic. For example, arsenic (which lowers human immune response to viruses), cadmium (a carcinogen), lead (a neurotoxin in high concentrations) and mercury (which causes sensory impairment and kidney damage) are all present in potentially undesirable concentrations. Increasing use of irrigation is a likely future contributor to these, particularly in the drier parts of the year when relative evaporation levels are higher and when there is the greatest need for irrigation.

Domestic solid waste and agriculture

Due to inadequacy of municipal refuse collection services in Kumasi's periurban interface, domestic solid waste accumulates in dumps in and around communities. Daily domestic waste is largely organic, consisting mainly of food scraps (cassava, yam and cocoyam peels, and plantain skins) and wood ash, and represents a potential source of nutrients for agricultural soils. Composting and reuse of organic waste is a means of recycling nutrients and restoring soil fertility (Drechsel & Kunze, 2001), particularly here with the high engagement (90 per cent) in local (less than 4 km from the household) agricultural activities and the need for soil ameliorants in these same areas (Nsiah-Gyabaah & Adam, 2001). Our household survey indicated high potential for a household-level waste separation and composting programme, reinforced by communities' willingness to participate and by their eagerness to improve village sanitation while also contributing to their agricultural livelihoods.

It should be noted that significant cultural barriers exist to the use of human excrement, however well-treated, as soil fertilizer. Experiments in Tamale, northern Ghana (Cofie *et al.*, 2005; Asare *et al.*, 2006), of the application of faecal sludge directly to fields or after composting in pits with crop residues, indicate that these barriers are currently significant throughout Ghana.

The main container composting method demonstrated was block-built compost bins, chosen because of the wide availability of building blocks, standard bricks or the traditional sun-baked blocks (Figure 2). Each double chamber compost bin is sufficient for a household with an extended family. Larger versions consisting of three high capacity chambers were also demonstrated, suitable for up to five households.

Other container composting methods demonstrated included the use of barrels constructed from locally sourced recycled materials. Aeration holes were made around disused 250-litre drums and a cover provided. Drainage holes made in the base allowed seepage to be collected and added to the decomposing organic matter, minimizing nutrient loss (Agromisa, 1999).

Anaerobic composting, where compost is produced in sealed plastic bags or in small piles covered with plastic sheeting (see Martin & Gershuny, 1992), was implemented in Kyerekrom. Rather than using small piles, a windrow roughly 1.5 m wide and 1 m high was formed, with organic waste added daily to the end. The windrow was covered with two (recycled) tarpaulins to protect the pile from livestock, rodents, flies and mosquitoes, and waterlogging during heavy rains, and also from drying out.

The most cost-effective containers were those constructed from recycled materials, requiring no financial inputs. These included barrel composting and unmortared

Figure 2. *Double chamber (top) and triple chamber (bottom) block-built compost containers.*

compost bins constructed from recycled blocks. The average construction cost of each double chamber block-built compost bin was approximately EUR 13 (USD 17 in late 2003 prices). The wide availability of building blocks (both modern and traditional sun-baked) increases the viability of block-built compost bins. However, if wider uptake

Table 3. Micro projects installed in survey communities (n=20) and number spontaneously taken-up after 3 months, and still in use after 12 months.

	Demonstrations	Take-up after 3 months	Total after 3 months	Total in use after 12 months
Adagya	3	2	5	4*
Apeadu	3	1	4	3†
Asago	4	4	8	5*‡§
Domeabra	3	1	4	4
Esereso	3	4	7	7
Kyerekrom	4	5	9	5†ℓ
Total	20	17	37	28

*lost interest as farm was too far; †lost to land use change; ‡never used; §person died; ℓnow community compost project at the *bola* site.

Table 4. Annual revenues (USD) generated in different farming systems in Kumasi, 2002

Farming system	Typical farmholding	Net annual revenue	
		Per ha	Per farmholding
Rainfed maize or maize/cassava	0.5–0.9 ha	350–550	200–450
Dry season irrigated vegetables only (garden eggs, pepper, okra, cabbage)	0.4–0.6 ha	300–350	140–170
Dry season irrigated vegetables and rainfed maize (or other vegetables)	0.7–1.3 ha	500–700	300–500
All-year-round irrigated vegetables (lettuce, cabbage, spring onions)	0.1–0.2 ha	2000–8000	400–800

Source: Danso *et al.* (2002).

of such techniques is to be promoted, assistance, either with finance or with materials, would be required, particularly for poorer households.

Early spontaneous uptake of the technology was encouraging, with the number of installations almost doubling within three months of project initiation (Table 3). However, the main obstacle to further uptake was cited as financial constraints. Furthermore, in the case of block-built compost containers, in the space of 12 months from micro project initiation the price of cement had doubled, thus placing these materials beyond the financial means of many periurban residents (Table 4). Despite this, an element of longer-term sustainability was demonstrated and using locally resourced materials such as cane or bamboo for container construction could reduce costs.

Aimed initially at the backyard gardening level, the potential of these methods to both reduce waste flows and enhance soil status has been demonstrated. The wider development potential of this strategy, based on concepts of integrated organic waste recycling, is now outlined.

Integrated organic waste recycling

Integrated organic waste recycling is essentially a holistic approach to organic waste recycling that uses a combination of methods at appropriate scales of intervention to manage organic waste sustainably. The holistic approach is aimed at closing the nutrient recycling loop by reversing the negative impact of periurban nutrient sinks, accomplished through maximizing nutrient exploitation of urban and periurban organic wastes (Drechsel & Kunze, 2001; see also Bradford, 2006; Cofie *et al.*, 2006).

Farmer responses to declining soil fertility have incorporated what are locally viewed as 'modern' farming methods including the adoption of monocropping techniques that are accompanied by the use of chemical fertilizers and pesticides. Furthermore, rapid land use changes have encouraged adoption of these so-called modern farming methods as farmers with insecure land tenure attempt to achieve short-term gains through nutrient mining rather than investing in alternative and longer-term soil fertility measures. Land tenure insecurity reduces the incentives for farmers to adopt organic-based soil amelioration measures. This then raises an important longer term sustainability issue that must be addressed when planning and developing integrated organic waste recycling strategies, particularly if there are no alternative markets to retail and distribute compost products.

In Kumasi, and indeed much of sub-Saharan Africa, closing the rural–urban nutrient cycle remains a largely theoretical concept, as municipal authorities have yet to exploit such options systematically. This situation contrasts with the outcomes achieved in the very different geopolitical and social conditions of Havana, Cuba, where nutrient recycling principles have been implemented and have proven very successful in practice (Cruz & Medina, 2003; Díaz & Harris, 2005; Viljoen & Howe, 2005; Wright, 2009).

Besides increased capture and storage of carbon, nutrients and water, other potential advantages from closing the nutrient recycling loop include reduction in the volumes of foodstuffs that are imported, reduced need for commercial/inorganic fertilizers (and pesticides) and increased environmental protection.

Three factors – scale, flexibility and agriculture – ensure that integrated organic waste recycling remains a highly practical and applicable option for the periurban interface. The combination of methods at appropriate scales of intervention means that a range of strategies designed for local geographical contexts can be implemented. In locations such as Asago and Adagya, the poor quality feeder roads reduce any potential for conventional waste collection services. In this context, community-based options (household and decentralized) become the only feasible option to manage domestic waste sustainably. Even where feeder roads are of good quality, many periurban villages still do not benefit from such services as their distant location from prioritized areas result in them being left in 'peripheral neglect'.

Livelihood generation

Community-based nutrient recycling interventions can also engender sustainable local agricultural- and horticultural-based livelihoods by decentralizing organic waste recycling interventions and using the organic waste as close to source as possible. From this, we can assert that the preferred level of entry is on-site (for either commercial or domestic organic waste). Only once this option has been exhausted, should municipal and district authorities consider the next scale of intervention, that of decentralized (community-based) approaches. These options remain relatively localized and thus also contribute to livelihood generation, unlike the centralized organic waste recycling interventions that are capital rather than labour intensive such as the Teshie compost plant in Accra, which never reached its full potential for compost production for various reasons (it broke down in the early 1990s and has produced compost only fitfully since) (Etuah-Jackson *et al.*, 2001; Hofny-Collins, 2006).

During our experiment, locally produced container compost from the micro projects was used for backyard gardening, maize and vegetable production, for planting teak and shade trees by a local plant nursery, and was even bagged and sold to a Kumasi guesthouse for use in their flower beds. Other than backyard gardening and vegetable production, the alternative uses were isolated cases but provide an indicator of the potential for compost products. While the market for compost has not been developed in Kumasi, it represents a significant livelihood opportunity in Accra where compost markets are well established (field observations, 2002–2004; Hofny-Collins, 2006).

Conclusion

This paper investigated problems of agricultural resource management in Kumasi's periurban interface and, on the basis of empirical research, proposed potential solutions. There can be no doubt that rapid land use change – from agricultural to urban/built-up – is having a profound effect on agriculture. In periurban areas where rainfed agriculture still predominates, the loss of agricultural land has resulted in reduced fallow periods and consequently lower overall soil fertility levels.

Ongoing pollution of the river system has significant implications for irrigation agriculture. The field surveys showed that more farmers are accessing river water for irrigation in response to increasing opportunities for selling a range of vegetables to urban markets, although results reported here and elsewhere indicate that both river water and groundwater are being polluted from a wide variety of sources. Chemical pollution may be broadly neutral in that it provides a source of nutrients for plants, but the undesirable levels of coliform bacteria and heavy metals are a concern. However, the build-up of heavy metals in floodplain sediments is potentially problematic in the longer term.

In summary, the prospects for periurban agriculture in Kumasi's periurban interface are not encouraging. This perhaps surprising conclusion stands in contrast to the oft-heralded potential of periurban agricultural development for promoting livelihoods and urban food security. Increasing pressures on agricultural land for building, variable and relatively low rainfall and decreasing water quality impose constraints on the agricultural system. The opportunities for marketing produce provided by Kumasi's increasing urban population being realized through a growing use of irrigation may prove to be an increasingly risky option. The problems here are not of people willing to cultivate the reducing pool of agricultural land, but of pollutants, toxicities and cultural constraints. This leads us to conclude that a more holistic, yet nuanced, analysis of the vulnerabilities and risks associated with periurban interface agriculture than has often hitherto been the case is indicated.

However, on the positive side, although there remains a problem to be addressed with respect to the persistence of helminths in compost, we demonstrated that separating and composting domestic waste at the household and community levels can lead to substantial decreases in waste outputs and thus contribute to a cleaner environment. Furthermore, composting domestic organic waste is a means of recycling nutrients and restoring soil fertility, contributing to humus and soil structure, increasing soil organic matter and improving the water-holding capacity of soils. It is also far cheaper and more environmentally appropriate than commercial fertilizer. However, such environmentally sustainable soil fertility management may require longer-term incentives for farmers such as secure land tenure for agricultural plots. This poses a particular problem in the periurban interface where land change from agricultural to urban use remains rapid, yet offers a significant, generic opportunity in situations where periurban waste collection services are inefficient or absent.

Acknowledgements

Project participation by the villages of Adagya, Apeadu, Asago, Domeabra, Esereso and Kyerekrom was crucial to our study. This paper is an output from project R7330 Peri-Urban Natural Resources Management at the Watershed Level: Kumasi, Ghana – funded by the UK DFID for the benefit of developing countries. The views expressed are not necessarily those of DFID. Andrew Adam-Bradford acknowledges receipt of UK Economic and Social Research Council Research Studentship No.R42200134386. The Ghana office of the International Water Management Institute collaborated and provided funding for the micro projects.

References

Adam MG (2001a) Definition and boundaries of the peri-urban interface: patterns in the patchwork. In Drechsel P, Kunze D (eds) *Waste Composting for Urban and Peri-urban Agriculture: Closing the Rural-Urban Nutrient Cycle in Sub-Saharan Africa*, 193–208. CABI Publishing, Wallingford, International Water Management Institute (IWMI) and Food and Agriculture Organization of the United Nations (FAO).

Adam MG (2001b) The Interface between Agriculture and Water in Peri-Urban Kumasi. CEDAR Kumasi Paper 4. CEDAR, Royal Holloway, University of London and IRNR, Kwame Nkrumah University of Science and Technology, Kumasi.

Adam-Bradford A, McGregor D, Simon D (2006) Community-based waste management strategies: peri-urban interface, Kumasi, Ghana. In McGregor D, Simon D, Thompson D (eds) *The Peri-Urban Interface: Approaches to Sustainable Natural and Human Resource Use*, 231–45. Earthscan, London.

Adarkwa KK, Post J (eds) (2001) *The Fate of the Tree: Planning and Managing the Development of Kumasi, Ghana*. Thela Thesis, Amsterdam.

Adu SV (1992) *Soils of the Kumasi Region*. Memoir No. 8. Kumasi: Soils Research Institute, Kwadaso-Kumasi.

Agromisa (1999) *Preparation and Use of Compost: Agrodok-series No. 8*. Agromisa Foundation and the Technical Centre for Agricultural and Rural Cooperation (CTA), Wageningen, Netherlands.

Allison M, Harris PJC, Hofny-Collins AH, Stevens W (1998) *A Review of the Use of Urban Waste in Peri-Urban Interface Production Systems*. Henry Doubleday Research Association, Coventry.

Asare I, Kranjac-Berisavljevic G, Cofie O (2006) Faecal sludge application for agriculture in Tamale, Ghana. *Urban Agriculture Magazine* **10** (4)**,** 32–3.

Bradford AM (2006) Assessing the Potential for Community-based Waste Management Strategies: Action Research in the Kumasi PUI, Ghana. PhD thesis, Department of Geography, Royal Holloway University of London, Egham.

Brook R, Dávila J (eds) (2000) *The Peri-Urban Interface: A Tale of Two Cities*. School of Agricultural and Forest Sciences, University of Wales, Bangor and Development Planning Unit, University College London.

Centre for the Development of People (CEDEP) (2005) *Final Technical Report of DFID Project R8090, Boafo Ye Na (BYN)*. Centre for the Development of People, Kumasi.

Chokor B, Odemerho F (1994) Land degradation assessment by small-scale traditional African farmers and implications for sustainable conservation management. *Geoforum* **25,** 145–54.

Cofie OO, Kranjac-Berisavljevic G, Drechel P (2005) The use of human waste for peri-urban agriculture in Northern Ghana. *Renewable Agriculture and Food Systems* **20** (2)**,** 73–80.

Cofie O, Adam-Bradford A, Drechsel P (2006) Recycling of urban organic waste in urban agriculture. In van Veenhuizen R (ed) *Cities Farming for the Future: Urban Agriculture for Green and Productive Cities*, 209–29. RUAF Foundation, IDRC and IIRR, Leusden. Available at http://web.idrc.ca/openebooks/216-3/ (last accessed September 2011).

Cornish GA, Kielen NC (2004) Wastewater irrigation – hazard or lifeline? Empirical results from Nairobi, Kenya and Kumasi, Ghana. In Scott CA, Faruqui NI, Raschid-Sally L (eds) *Wastewater Use in Irrigated Agriculture*, 69–79. CABI Publishing, Wallingford.

Cornish GA, Mensah E, Ghesquire P (1999) An Assessment of Surface Water Quality for Irrigation and its Implications for Human Health in the Peri-urban Zone of Kumasi, Ghana. Report OD/TN95 for DFID on KAR Project R7132. HR Wallingford Ltd, Wallingford.

Cruz MC, Medina RS (2003) *Agriculture in the City: A Key to Sustainability in Havana, Cuba*. International Development Research Centre, Ottawa.

Danso G, Drechsel P, Wiafe-Antwi T (2002) Income of farming systems around Kumasi. *Urban Agriculture Magazine* **7,** 5–6.

Danso G, Drechsel P, Thomas W-A, Gyiele L (2006) Income generated by farming systems in and around Kumasi. In van Veenhuizen R (ed) *Cities Farming for the Future: Urban Agriculture for Green and Productive Cities*, 205–7. RUAF Foundation, IDRC and IIRR, Leusden.

Desakota Study Team (DST) (2008) Re-imagining the Rural-Urban Continuum. Understanding the Role Ecosystem Services Play in the Livelihoods of the Poor in Desakota Regions Undergoing Rapid Change. Research gap assessment prepared by the DST Institute for Social and Environmental Transition–Nepal (ISET-N), Kathmandu. Available at http://www.nerc.ac.uk/research/programmes/espa/documents/Final%20Report%20Desakota%20Part%20I.pdf (last accessed September 2011).

Díaz JP, Harris P (2005) Urban agriculture in Havana: opportunities for the future. In Viljoen A (ed) *Continuous Productive Urban Landscapes: Designing Urban Agriculture For Sustainable Cities*, 135–45. Architectural Press, Oxford.

Douglas I (2006) Peri-urban ecosystems and societies: transitional zones and contrasting values. In McGregor D, Simon D, Thompson D (eds) *The Peri-Urban Interface: Approaches to Sustainable Natural and Human Resource Use*, 18–29. Earthscan, London.

Drescher A (1994) Gardening on garbage. *ILEIA Newsletter* **20** (4)**,** 20–1.

Drechsel P, Kunze D (eds) (2001) *Waste Composting for Urban and Peri-urban Agriculture: Closing the Rural-Urban Nutrient Cycle in Sub-Saharan Africa*. CABI Publishing, International Water Management Institute (IWMI) and UN Food and Agriculture Organization (FAO), Wallingford, Colombo and Rome respectively.

Drechsel P, Zimmerman U (2005) Factors influencing the intensification of farming systems and soil-nutrient management in the rural-urban continuum of SW Ghana. *Journal of Plant Nutrition and Soil Science* **168,** 694–702.

Etuah-Jackson I, Klaassen WP, Awuye JA (2001) Turning municipal waste into compost: the case of Accra. In Drechsel P, Kunze D (eds) *Waste Composting for Urban and Peri-urban Agriculture: Closing the Rural-Urban Nutrient Cycle in Sub-Saharan Africa*, 84–95. CABI Publishing, IWMI and FAO, Wallingford, Colombo and Rome respectively.

Galizzi K (2004) Co-composting reduces helminth eggs in fecal sludge: a field study in Kumasi, Ghana, June–November 2003. Sandec Switzerland, Duebendorf. Available at http://www.eawag.ch/forschung/sandec/publikationen/ewm/dl/helminth_in_CoCompost.pdf (last accessed September 2011).

Hofny-Collins AH (2006) *The Potential for Using Composted Municipal Waste in Agriculture: The Case of Accra, Ghana*. PhD thesis, Swedish University of Agricultural Sciences, Uppsala.

Kasanga K (2001) Peri-urban Kumasi, Ghana: urbanisation, land markets and gender insecurity under matrilineal property rights. In Ishani Z, Lamba D (eds) *Emerging African Perspectives On Gender in Urbanisation: African Research on Gender, Urbanisation and Environment*, 66–91. Mazingira Institute, Nairobi.

Keraita B, Drechsel P (2004) Agricultural use of untreated urban wastewater in Ghana. In Scott CA, Faruqui NI, Raschid-Sally L (eds) *Wastewater Use in Irrigated Agriculture*, 101–12. CABI Publishing, Wallingford.

Keraita B, Drechsel P, Amoah P (2003) Influence of urban wastewater on stream water quality and agriculture in and around Kumasi, Ghana. *Environment and Urbanization* **15,** 171–8.

Keraita B, Drechsel P, Konradsen F (2008) Perceptions of farmers on health risks and risk mitigation measures in wastewater-irrigated urban vegetable farming in Ghana. *Journal of Risk Research* **11** (8)**,** 1047–61.

Leitzinger C (2001) The potential of co-composting in Kumasi – Quantification of the urban and peri-urban nutrient balance. In Drechsel P, Kunze D (eds) *Waste Composting for Urban and Peri-urban Agriculture: Closing the Rural-Urban Nutrient Cycle in Sub-Saharan Africa*, 150–62. CABI Publishing, IWMI and FAO, Wallingford, Colombo and Rome respectively.

Lynch K (2005) *Rural-Urban Interaction in the Developing World*. Routledge, London.

Maconachie R (2007) *Urban Growth and Land Degradation in Developing Cities: Change and Challenges in Kano, Nigeria*. Ashgate, Aldershot.

Martin DL, Gershuny G (eds) (1992) *The Rodale Book of Composting*. Rodale Press, Emmaus, Pennsylvania.

McGregor D, Barker D (1991) Land degradation and hillside farming in the Fall River Basin, Jamaica. *Applied Geography* **11,** 143–56.

McGregor D, Simon D, Thompson DA (2002) Peri-urban Natural Resources Management at the Watershed Level, Kumasi, Ghana. Final Technical Report on Grant R7330 to DFID, December. (CD available from authors on request.)

McGregor D, Simon D, Thompson D, Quashie-Sam J, Edusah S, Nsiah-Gyabaah K (2006) A co-management approach to sustainable watershed utilization: peri-urban Kumasi, Ghana. In McGregor D, Simon D, Thompson D (eds) *The Peri-Urban Interface: Approaches to Sustainable Natural and Human Resource Use*, 287–309. Earthscan, London.

McGregor D, Thompson D, Simon D (2000) Water quality and management in peri-urban Kumasi, Ghana. Case Study 16, *Land-Water Linkages in Rural Watersheds*: Electronic Workshop. FAO, Rome.

McGregor D, Thompson D, Simon D, Kotei NO, Poku KO (2001) The influence of Kumasi on peri-urban water quality: a problem for community health and floodplain agriculture? In G. Cornish (ed) *Informal Peri-Urban Irrigated Agriculture: Opportunities and Constraints*, 65–76. HR Wallingford, Wallingford.

Mensah E, Amoah P, Drechsel P, Abaidoo RC (2001) Environmental concerns of urban and peri-urban agriculture: case studies from Accra and Kumasi. In Drechsel P, Kunze D (eds) *Waste Composting for Urban and Peri-urban Agriculture: Closing the Rural-Urban Nutrient Cycle in Sub-Saharan Africa*, 55–68. CABI Publishing, IWMI and FAO, Wallingford, Colombo and Rome respectively.

Nsiah-Gyabaah K, Adam M (2001) Kumasi: farming systems and farming inputs in and around Kumasi. In Drechsel P, Kunze D (eds) *Waste Composting for Urban and Peri-urban Agriculture: Closing the Rural-Urban Nutrient Cycle in Sub-Saharan Africa*, 96–111. CABI Publishing, IWMI and FAO, Wallingford, Colombo and Rome respectively.

Obiri-Danso K, Adjei B, Stanley KN, Jones K (2009) Microbiological quality and metal levels in wells and boreholes water in some peri-urban communities in Kumasi, Ghana. *African Journal of Science and Technology* **31** (1)**,** 59–66.

Obuobie E, Keraita B, Danso G, Amoah P, Cofie OO, Raschid-Sally L, Drechsel P (2006) *Irrigated Urban Vegetable Production in Ghana: Characteristics, Benefits and Risks*. IWMI, RUAF and CPFW, Accra.

Onibokun AG (ed) (1999) *Managing the Monster: Urban Waste and Governance in Africa*. International Development Research Centre, Ottawa.

Owusu K, Waylen P (2009) Trends in spatio-temporal variability in annual rainfall in Ghana (1951–2000). *Weather* **64** (5)**,** 115–20.

Sarfo-Mensah P, Adam M (1998) PRA analysis of land use changes in peri-urban Kumasi, Ghana. In Drechsel P, Gyiele L (eds) *On-farm Research on Sustainable Land Management in Sub-Saharan Africa: Approaches, Experiences and Lessons*, 115–27. IBSRAM Proceedings 19, IBSRAM, Bangkok.

Simon D, McGregor D, Nsiah-Gyabaah K (2004) The changing urban-rural interface of African cities: definitional issues and an application to Kumasi, Ghana. *Environment and Urbanization* **16** (2)**,** 235–47.

Simon D, McGregor D, Nsiah-Gyabaah K, Thompson D (2003) Poverty elimination, North-South research collaboration, and the politics of participatory development. *Development in Practice* **13** (1)**,** 40–56.

Simon D, Nsiah-Gyabaah K, Warburton H, Adu-Gyamfi V, McGregor D (2001) *The Changing Urban-Rural Interface of African Cities: Conceptual Issues and an Application to Kumasi, Ghana*. CEDAR Kumasi Paper 1. CEDAR, Royal Holloway, University of London and IRNR, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.

Tacoli C (ed) (2006) *Rural-Urban Linkages*. Earthscan, London.

van Veenhuizen R (ed) (2006) *Cities Farming for the Future: Urban Agriculture for Green and Productive Cities*. RUAF Foundation, IDRC and IIRR, Leusden.

Viljoen A, Howe J (2005) Cuba: laboratory for urban agriculture. In Viljoen A (ed) (2005) *Continuous Productive Urban Landscapes: Designing Urban Agriculture For Sustainable Cities*, 146–91. Architectural Press, Oxford.

Westcot DW (1997) *Quality Control of Wastewater for Irrigated Crop Production*. FAO Water Report no. 10. FAO, Rome.

World Health Organisation (WHO) (1989) *Reuse of Effluents: Methods of Wastewater Treatment and Health Safeguards*. WHO, Geneva.

World Health Organisation (WHO) (1993) *Guidelines for Drinking-Water Quality. Volume 1. Recommendations*. WHO, Paris.

World Health Organisation (WHO) (2006) *Guidelines for the Safe Use of Wastewater in Agriculture, Excreta and Gray Water: Wastewater Use in Agriculture, Volume 2*. WHO, Geneva.

Wright J (2009) *Sustainable Agriculture and Food Secuity in an Era of Oil Scarcity: Lessons from Cuba*. Earthscan, London.