DEPARTMENT FOR INTERNATIONAL DEVELOPMENT

STRATEGY FOR RESEARCH ON RENEWABLE NATURAL RESOURCES

NATURAL RESOURCES SYSTEMS PROGRAMME

FINAL TECHNICAL REPORT

DIFD Project Number

R7099

Project Title

Improved Utilisation of Urban Waste by Near-Urban Farmers in the Hubli-Dharwad city-region

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NRSP Production System

Peri-Urban Interface

Date

December 1999

EXECUTIVE SUMMARY

The main aim of this research was to explore how the collection, disposal and treatment of urban waste can better meet the needs of farmers, particularly small farmers, in the peri-urban areas of Hubli-Dharwad. The research looked at the present and past use of composts, including urban waste, by near-urban farmers and used on-farm trials to pilot test the use of sorted and treated municipal solid waste (MSM.

Within Hubli-Dharwad, MSW has been purchased from the two dumpsites, one in Hubli and the other in Dharwad, for many years. The waste is now purchased from the dumpsites by tractor loads. Until 1997, decomposing MSW was sold from the Dharwad dumpsite via an annual auction system managed by the Hubli-Dharwad Municipal Corporation (HDMC), selling waste by the pit load. The auction system stopped because of the lack of staff at the dumpsite to prepare pits for auction and to manage the auction process.

The research was conducted at a time when the private sector is entering into waste treatment in Hubli-Dharwad, through a contract with HDMC. The use of MSW by the private sector potentially conflicts with the purchasing of MSW by local farmers, as both seek the same decomposing waste. At present, there is sufficient MSW for both groups of people. In the future, decisions will have to be made regarding access to MSW and pricing policy.

The research involved a number of activities, including the observation of farmers' activities, to generate a better understanding of soil fertility strategies, and on-farm trials using sorted and treated MSW The research generated much information about the use of urban waste by near-urban farmers, feeding into a number of strategies and policy recommendations. The main conclusions from the research include:

- An integrated approach to urban waste management, currently absent, is needed to improve the use of urban waste. Such an approach should recognise the roles of livestock keepers and farmers, incorporate approaches to segregate waste materials, manage the waste in an environmentally sustainable way and consider effective ways to market waste.
- Declining quality of MSW was the most often cited reason by farmers for not, or abandoning, using it. Segregation of waste materials is a key issue, but is a very difficult problem to solve in a cost-effective manner. The involvement of a range of stakeholders is needed, as is perseverance in raising awareness.
- There is a range of options that could be considered to maintain access to MSW by near-urban farmers. These include subsidising composts produced by the private sector; producing a range of composts at different prices and maintaining access for both farmers and the private sector.

- Marketing the waste does not appear to be the most important issue in Hubli-Dharwad. The main problem is to improve the quality of the MSW (principally by removing contaminants).
- Transport of MSW from the point of collection or sale, to the farm, was also identified as a significant constraint for small farmers wishing to utilise this resource.

The research concluded that MSW plays a useful role as a soil amendment, but problems with quality and access have to be addressed if the use of urban waste by near-urban farmers is to be encouraged.

ACKNOWLEDGEMENTS

This publication is an output from a 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. The project, *Improved Utilisation of Urban Waste by Near-Urban Farmers in the Hubli-Dharwad city-region*, is funded under the Natural Resources Systems Programme, Peri-Urban Interface, project number R7099.

Thanks are due to the many people who have assisted in getting this research underway. These include Mr Vastrad, the Commissioner of Hubli-Dharwad, officers of the Hubli-Dharwad Municipal Corporation, Prakash Bhat of Bharatiya Agro-Industries Foundation (BAIF) and the Indian Development Service (Dharwad). Special thanks are owed to the participating farmers in Mugad, Navalur and Maragadi for their co-operation and involvement in the on-farm trials.

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ABBREVIATIONS

BAIF	Bharatiya Agro-Industries Foundation
DS	Distillery sludge
EAWAG	Swiss Federal Institute for Environmental Science and Technology
EPAT	Environmental Protection and Technology, the Netherlands
FPR	Farmer Participatory Research
HDMC	Hubli-Dharwad Municipal Corporation
ICAR	Indian Council on Agricultural Research
IDD	International Development Department
IDS	Indian Development Service
MSW	Municipal solid waste
NGO	Non-governmental organisation
NRSP	Natural Resources Systems Programme
NS	Nightsoil
PUI	Peri-urban interface
RNR	Renewable Natural Resource
SANDEC	Department for Water and Sanitation in Developing Countries of EAWAG
SWM	Solid waste management
UAS	University of Agricultural Sciences

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1. BACKGROUND AND PROJECT PURPOSE

1.1 Aims of the research

The main aim of this research was to explore how the collection, disposal and treatment of urban waste can better meet the needs of farmers, particularly small farmers, in the peri-urban areas of Hubli-Dharwad. The research looked at the present and past use of composts, including urban waste, by farmers in four villages and used on-farm trials to pilot test the use of sorted and treated municipal solid waste (MSW). Small farmers are generally considered to be those with landholdings under five acres (two hectares), but are not necessarily poor, as they may have other sources of income or lease land from other farmers. However, small farmers are more likely to be poorer than other farmers and are less likely to own a tractor, one key factor in explaining which farmers buy MSW from the dumpsites. They have, therefore, generally purchased less MSW than larger farmers.

Urban organic wastes are used productively in many Southern countries and include much MSW, collected from households, street bins and street sweepings by the municipal corporation, or private companies contracted by the corporation, vegetable market waste, wastewater and livestock manure. Within Hubli-Dharwad, MSW has been purchased from the two dumpsites, one in Hubli and the other in Dharwad, for many years. The waste is now purchased from the dumpsites by tractor loads. Until 1997, decomposing MSW was sold from the Dharwad dumpsite via an annual auction system managed by the Hubli-Dharwad Municipal Corporation (HDMC), selling waste by the pit load. The auction system stopped because of the lack of staff at the dumpsite to prepare pits for auction and to manage the auction process. Photograph 1 shows a pit at the dumpsite in Dharwad.

Photograph 1 A pit at Dharwad dumpsite

The sale and use of MSW is, however, reducing as the waste is increasingly contaminated by non-compostable waste, particularly plastics. Other factors which have affected the ability of HDMC to sell the waste, and the farmers' willingness to buy the waste, include:

- shortages of labour at the dumpsites, making pit preparation difficult;
- shortages of labour for farmers to hire to dig up the waste pits, sort the waste and spread it onto the fields. This is due to competing employment opportunities, and higher wage levels, in the urban areas; and,
- farmers who do not own tractors are less willing to hire vehicles to purchase MSW when the quality is so low.

There are, however, some farmers who continue to purchase MSW. These farmers are relatively wealthy, have their own tractors and are able to hire labour to transport and sometimes sort the waste. Small and marginal farmers make less use of this potentially useful resource, though some do hire tractors to collect waste. The price of untreated and unsorted MSW (i.e. nothing has been done to the collected MSW) is quite low, Rs.25-30[1] for a tractor load (equal to between one and a half to two tonnes). However, only about 40% of this is usable, as glass, plastics, etc. will be taken out and left alongside fields. Photograph 2 shows a pile of MSW purchased from Dharwad dumpsite ready to be spread onto fields.

Photograph 2 Farmer with MSW purchased from Dharwad dumpsite

The problems that exist with purchasing MSW must be viewed within the context of an inadequate waste collection system, where hospital waste was, until recently, collected together with household and commercial waste, and where municipal bins are often overflowing, with pigs and cows gathered to consume waste materials. The situation is improving. As described in Chapter 3, the Commissioner of HDMC has initiated many activities to improve the collection and disposal of solid waste in Hubli-Dharwad. There remains,

[1] The exchange rate is around Rs.70:£1.

however, a need to explore ways to improve the quality of waste purchased by farmers, whilst encouraging access to small, poorer, farmers.

The situation in Hubli-Dharwad is similar to other urban centres in India, such as Hyderabad, where the use of MSW has declined due to injuries to draught animals and the unwillingness of farm labourers to work in fields with pieces of inorganic waste materials in the soil (Furedy, 1999). However, there is not a great deal of literature on the use of urban waste by near-urban farmers. Whilst there is some technical literature on composting MSW, there are few references to traditional systems of using urban organic wastes. Discussions of urban solid waste management systems also neglect the sale of organic waste. Although the operation of informal markets for urban inorganic wastes, such as glass and plastics, in the solid waste management[2] of cities in Southern countries is widely reported (see, for example, Beall 1997; Furedy, 1992; School of Public Policy *et al.*, 1996), markets associated with organic wastes are not. As the generation and sale of organic waste in urban areas is not widely recognised, farmers and livestock keepers are not considered to be stakeholders in urban solid waste management. The growing literature on urban agriculture may, however, raise awareness of the sale and use of urban organic wastes as such wastes form an important input to urban and peri-urban agricultural systems.

This project, therefore, sought to contribute greater understanding and knowledge of the use of urban waste, particularly MSW, by near-urban farmers and to develop strategies to respond to the declining use of MSW. The strategies described in Chapter 3 draw on the research in Hubli-Dharwad whilst being aware of experiences in other parts of India and in other Southern countries.

1.2 Project Purpose

The project sought to address the research issues by generating greater understanding of the stakeholders involved, particularly of the preferences of farmers regarding the use of MSW as a soil amendment. Information was gathered through participatory techniques such as matrix scoring of soil amendments, as well as through key informant interviews and observation of farmers' activities. The project also sought to generate a deeper understanding of the changes that have taken place regarding the management and use of MSW.

Using the information generated, on-farm trials were carried out to test sorted and composted MSW with a number of organic additions. Further details of these trials are given in Chapter 2. From these activities, a number of policy options and recommendations have been derived, as set out in Chapter 3. These focus on potential ways forward to support the use of MSW as a soil

[2] Solid waste management (SWM) encompasses the collection, treatment and disposal of municipal solid waste (MSW). MSW includes wastes collected by, or for, the Corporation from households, street sweepings, commercial properties and markets.

amendment and, in particular, to keep MSW available at an affordable price for local farmers, whilst improving quality.

The research addresses Output 2 of Purpose 3 of the original Peri-Urban Interface (PUI) Production System logical framework:

> *Technologies and management strategies to increase production of commodities in peri-urban areas using solid and liquid wastes as fertiliser, soil ameliorant or feed developed and promoted.*

It was the intention that the research, however, would also feed into the other outputs of the purpose. Purpose 3 and the associated outputs from the original PUI logical framework are shown in Table 1.1.

Table 1.1 Purpose 3 with associated outputs of the original PUI logical framework

Purpose 3: Productive potential increased by greater use of "waste" materials and recycling of resources.
Outputs: 1. Cost-effective techniques for recycling/processing organic waste for use as a fertiliser, soil ameliorants or feed developed and promoted. 2. Technologies and management strategies to increase production of commodities in peri-urban areas using solid and liquid wastes as fertiliser, soil ameliorant or feed developed and promoted. 3. Environmentally acceptable methods of waste processing and disposal in peri-urban and rural environments developed and promoted.

The waste management system in the city, therefore, was explored in relation to the use of MSW by farmers, reflecting the concern of the PUI programme with environmentally acceptable methods of waste processing and disposal.

In the revised logical framework, the project mainly feeds into Output 3:

> *Improved resource management strategies which increase the production of food and commodities in peri-urban areas developed.*

The second objectively verifiable indicator for this output calls for

> *…new approaches which increase the use of solid and liquid wastes in commodity production validated in two city regions*

to be in place by 2002. This research is a precursor to such activity as it highlights issues in the use of solid waste in Hubli-Dharwad, with relevance to many other urban centres in Southern countries.

The research in Hubli-Dharwad has confirmed that urban wastes form an important input to, and output from, urban and peri-urban agriculture. Many farmers interviewed during the research stressed their preference for organic matter above artificial fertilisers, due to the longer-term residual effects of organic composts.

The goal of the revised PUI research programme is to improve the livelihoods of poor people through sustainably enhanced production and productivity in renewable natural resource (RNR) systems. The use of organic amendments to soil should contribute to productivity improvements. There are, however, issues, explored in the project, that need to be addressed to improve poorer farmers access to MSW. The policy options and recommendations discussed in Chapter 3 are made in the light of the desire to ensure that MSW remains affordable and, perhaps, becomes more affordable for small, poorer, farmers.

1.3 Demand for the research

The research project was initiated after studies on the availability and use of organic waste undertaken for the project 'Baseline Study and Introductory Workshop for the Hubli-Dharwad City-Region, Karnataka, India' (R6825), revealed the need for further research into how organic waste, generated in urban and peri-urban areas, can be better utilised by peri-urban farmers to help improve productivity.

The studies highlighted the declining purchase of MSW and the lack of information about farmers' preferences and views about MSW. The participants at the stakeholders' workshop in July 1997 identified the use of urban waste by farmers as a useful research area.

The project also reflects the priorities set out in the original logical framework of the PUI system (see Table 1.1) and some of the gaps highlighted in the review of the literature on the use of urban waste by Allison and Harris (1996), a study commissioned under the NRSP PUI programme (project number R6446). The final report from the study highlighted the need for the selected case study city regions of the programme to establish baseline data on:

- the current use of urban organic wastes; and,
- the local availability, supply and cost of organic waste materials and their practical application in the chosen communities.

The report also noted the need for further research into the demand for using urban wastes as a soil amendment and exploring ways of developing small-scale and on-farm processing of wastes. This research has established a considerable amount of information about the use of urban wastes, particularly MSW, in the Hubli-Dharwad city-region and, in addition to recommendations on ways forward within the city-region, further research directions are discussed in Chapter 4.

1.4 Approach of the research

The research drew on a wide range of methods to elicit information and to build up a picture of the use of MSW in Hubli-Dharwad. These include reviewing literature, conducting key informant interviews, a small scale household survey, observing farmers' practices, composting trials and on-farm trials of several treatments of sorted MSW.

The research approach changed from that set out in the project memorandum in one main area; the design and timing of the on-farm trials. The reasons for the changes in the on-farm trials were the desire to make the research more participatory than originally envisaged, and so, spend time developing an understanding of, and rapport with, farmers in several villages, and the lack of adequate amounts of readily available MSW and other composts in a treated form. This led to spending one kharif (rainy) season[3] observing farmers' activities and learning more about their soil fertility strategies, postponing the on-farm trials, which were subsequently designed and conducted with farmers' inputs and assistance, to the following kharif season in 1999. This resulted in only one season of trials, but assisted in making the research more farmer-led than originally envisaged and gave farmers the opportunity to feed into the planning process and to comment on the composts produced in trial pits by the research project. The logical framework was subsequently revised and agreed after the submission of the Inception Report in May 1998 and can be found in Appendix A.

Two initiatives from the HDMC also led to the need to revise the originally conceived approach and scope of the research. These were the tendering for private sector companies to compete for waste disposal and treatment services and a trial source separation scheme, carried out at a community level by local NGOs and HDMC. To date, one private sector company, Hubli Biotechnologies, has been leased one acre of land at the Hubli dumpsite to develop a trial scheme to produce high quality compost and is soon expected to receive a further 12 acres. MSW is sorted and manures (poultry manure and cow dung) are added to increase the nutrient quality of the MSW. The company has access to decomposing waste at the site and sells the resulting compost for around Rs.2600 per tonne. Access by both the private sector and farmers to the dumpsite waste potentially conflicts, as they both seek the same waste. The local farmers, however, particularly small farmers, may not be able to afford the higher priced, value-added, compost. These initiatives are discussed further in Chapter 3.

Due to these initiatives, segregation trials were not conducted separately within this project, as set out in the logical framework. The composting trials did involve manual segregation of waste, but no schemes were piloted in the project. The research did, however, generate further information that could be used to assist in designing new approaches, as discussed in Chapter 3, and remained in touch with developments in the trial source separation schemes.

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[3] There are two main growing seasons: *kharif*, the rainy season (May to September) and *rabi,* the dry season (October to February).

1.5 Previous research on use of urban waste

The Inception Report (School of Public Policy *et al.*, 1998a) reviewed a number of areas of literature, including composting and the use of urban waste as a soil amendment and the role of the informal sector in solid waste management. The conclusions from the review of literature included the following points:

- There are few documented sources of information concerning the sale of urban waste, despite the fact that it is likely that the practice is widespread. This may be related to the often informal nature of the sales and to the urban-rural nature of the practice, escaping interest from either urban or rural specialists.
- Source separation of waste materials appears to be a key factor in producing good quality compost. However, it is often difficult to develop effective and efficient source separation schemes. Public education is a key factor in developing such schemes. Source separation schemes are generally carried out at a household level in India, where organic and inorganic portions of waste are collected separately. Organic wastes are often composted (generally using vermicomposting[4]) and the product is sold to local gardeners and farmers (see Beall, 1997; Furedy, 1996).
- There has been little research conducted on the risks, particularly health risks, associated with the use of waste materials as soil amendments.
- Many of the centralised composting plants built in the 1970s and 1980s have closed down due to high production costs, inappropriate technology, inadequate maintenance and poor marketing (Selvam, 1993 and Furedy and Whitney, 1997).
- Constraints to the use of urban waste as a soil amendment include quality problems, costs (land, labour and transportation), the need for further processing (generally composting) and toxicity (Allison and Harris, 1996:22-25).
- There has been little research conducted on the fertilising value of MSW in Southern countries.

One area of literature where there is increasing reference to the use of urban waste in agricultural activities is the literature on urban agriculture. Smit and Nasr (1992:141) define urban agriculture as "food and fuel grown within the daily rhythm of the city or town, produced directly for the market and frequently processed and marketed by the farmers or their close associates". They suggest that urban agriculture is "a large and growing industry" which contributes to more sustainable resource use through using "urban waste water and urban solid waste as inputs" (1992:142).

Previous research has, therefore, been limited in the area of the use of urban waste as a soil amendment. The research in Hubli-Dharwad does, however, support the findings from the limited sources on the use of urban waste. These include the tradition of farmers using urban waste, the existence of a range of constraints to the use of urban waste as a soil amendment (as noted by Allison and Harris, 1996) and the desire of farmers to use organic matter

[4] Vermicomposting involves the use of worms to speed up the composting process.

as a soil amendment, in preference to artificial fertilisers. The experience in Hubli-Dharwad in developing a trial source separation scheme at household level also confirmed the difficulty in doing this in terms of gaining adequate commitment to make an impact on solid waste management at a city level. The belief that it is the role of the municipal corporation to manage solid waste often prevents households from becoming involved in such schemes.

The literature on urban waste, though limited, was, therefore, used to inform the direction and content of the research, to ensure that the research built on existing knowledge, contributes further knowledge about the use of urban waste and makes policy recommendations that reflect experience in other Southern cities, as well as having relevance to other Southern cities.

2. RESEARCH ACTIVITIES

2.1 Introduction

This chapter sets out the details of the research activities carried out during the project. Details of the research activities are also contained in the Inception and Phase 1 reports, which are referred to as appropriate in this chapter. Further details are also provided in appendices, as noted in the sections of this chapter.

Phase 1 of the research project refers to the period January to September 1998. The activities during this period included:

- Stakeholder analysis.
- Selection of two villages and farmers for the observation period.
- Observation of farmers' activities during the *kharif* season.
- Soil sampling of the fields belonging to participating farmers.
- Participatory exercises in two villages.
- Composting trials.

Phase 1 concluded with a two-day workshop in September 1998. This was attended by farmers, officials from HDMC (including the Commissioner), academics and representatives from government bodies and NGOs. The workshop facilitated disseminated of the research and helped to design the research activities for Phase 2. The workshop was held at SDM College, where the composting trials were being conducted and the participants were able to view the compost pits and comment on the quality of the composts. The preferences of the farmers expressed at the workshop were instrumental in deciding which composts to produce for the on-farm trials. A list of participants and the programme for the workshop can be found in the Proceedings of the Workshop (School of Public Policy, *et al.*, 1998b).

Phase 2 of the research involved the following activities:

- Generation of composts for the on-farm trials.
- The selection of two further villages and farmers to participate in the on-farm trials.
- Further collection of data on stakeholders and waste management issues in Hubli-Dharwad.
- Regular visits to farmers during the kharif season.
- Analysis of samples of soils, plants, composts and decomposing waste at the dumpsites.

Phase 2 also concluded with a workshop. This was held for only one day due to the limited availability of farmers and other stakeholders. One farmer from each of the participating villages provided feedback on their impressions of the research and the composts. A list of participants and the programme for the workshop can be found in the Proceedings of the Final Workshop (School of Public Policy, *et al.*, 1999b), as well as the presentations given.

2.2 Stakeholder analysis

Stakeholder analysis was undertaken through the use of key informant interviews with municipal officers, private sector companies (those involved in waste collection and treatment and recycling), waste pickers, NGOs, livestock keepers and farmers. Details of the roles of different stakeholders are provided in Chapter 3, particularly Section 3.5. A small-scale household survey was conducted to elicit views about waste management issues and recycling in the urban areas. A copy of the questionnaire used in the household survey can be found in Appendix B of the Phase 1 report (School of Public Policy *et al.*, 1999a).

The purpose of the stakeholder analysis was to identify the roles of, and interactions between, different stakeholders involved in the use of urban waste. The information generated by the stakeholder analysis has been used in the development of a number of recommendations set out in Chapter 3. The analysis explored the potential role of local NGOs in systems to encourage the use of urban waste and the options for segregating, managing and marketing urban waste.

2.3 Selection of villages and farmers

Two villages were selected for farmer observation during Phase 1, Mugad and Navalur, and an additional two villages were selected in Phase 2 to participate in the on-farm trials, Maradagi and Navalur. Working with only two villages, rather than four, during the first phase gave time for the research team to build experience in the approach and build relations with farmers. Criteria for the selection of villages included soil types, a variety of cropping patterns and differing localities in relation to Hubli and Dharwad. The team sought similar and differing criteria in the selection of villages to facilitate comparison and lessons for other locations. Some of the main characteristics of the villages are shown in Table 2.1. Map 1 shows the location of the four villages in relation to Dharwad and Hubli.

Mugad was sited on a different soil type (alfisols, or 'red' soils) to the other villages, which had predominantly vertisol (black) soils of varying degrees of depth. Farming systems differ quite markedly between alfisol and vertisol soils. Rice is confined almost entirely to alfisols. Mean long-term annual rainfall in Mugad is 998 mm, which is adequate for drilled, rainfed paddy rice. This is grown in rotation with *kharif* season pulses, often greengram.

On vertisols, characteristic *rabi* crops are chilli, onion and potato, rotated with *kharif* season wheat and safflower intercrops, sorghum and chickpea, all of which mature on residual moisture. In Halyal, chilli is a major cash crop. This is grown as an intercrop with local landraces of cotton. Rainfall figures for the three villages located on vertisols are not available, but rainfall declines significantly in the easterly direction. Thus UAS Dharwad, 9 km east of Mugad, receives 801 mm, and Halyal and Maradagi are reported to receive less than UAS. Therefore, the high water holding capacity of high clay content soils such as vertisols is important in such semi-arid areas.

Table 2.1 Village and participating farmer characteristics

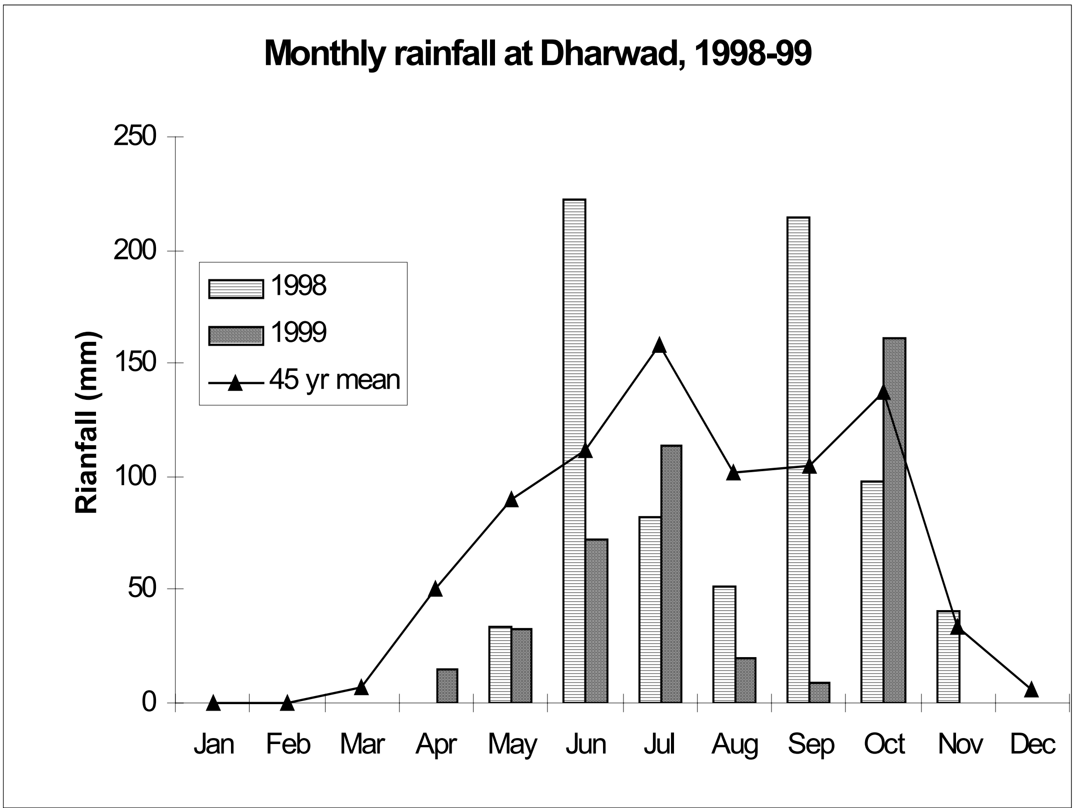
Village and location	Soil type	Formal education (years)	No. in family	Area farmed (ha)	Main cropping system	Head of cattle per farm	Soil amendments
Mugad: 12km west of Dharwad	Alfisol	1.0 (0 – 5)	5.4 (3 – 8)	1.9 (0.8 – 3.6) owned	Rabi: rice Kharif: grams	3.4 (2 - 5)	Pit compost @ 3.8 (1.9–5.0) t/ha/y DAP @ 62 (0–188) kg/ha/y Sometimes urea top dressing
Navalur: 8km east of Dharwad	Vertisol (deep)	5.4 (0 – 10)	10.2 (4– 25)	3.0 (1.6 – 5.7) owned 3.9 (1.6 – 6.5) leased, all collaborating farmers	Rabi: potato, cotton Kharif: grams, sorghum	3.8 (0 – 8) One owns tractor	One uses MSW @ 140 t/ha/y Pit compost @ 4.1 (2.6–6.0) t/ha/y DAP @ 22 (20 – 30) kg/ha/y Two use tank silt @ 20 t/ha/y
Maradagi: 16km northeast of Dharwad	Vertisol (shallow to medium)	3.4 (0 – 10)	5.2 (4 – 6)	1.4 (0.2 – 1.6) owned 5.3 leased, one farmer only	Rabi: green gram, groundnut, chilli, onion Kharif: sorghum, chickpea, wheat, safflower	2.2 (0 – 4) One farmer hires bullocks	Pit compost @ 5.8 (4.4 – 7.9) t/ha/y DAP or NPK @ 50 (0 – 63) kg/ha/y
Halyal: 5km southeast of Halyal	Vertisol (deep)	4.0 (0 – 7)	8.8 (3- 19)	1.5 (0.6 – 3.3) owned. 6.7 (6 – 7.4) leased, two farmers only	Rabi: chilli & cotton, groundnut, onion Kharif: sorghum, wheat & safflower.	3.6 (1- 7) Some farmers hire bullocks	Pit compost @ 4.5 t/ha/y DAP @ 197 (0 – 250) kg/ha/y on chilli intercrop Chilli haulm compost (rate not ascertained)

Explanatory notes: Means are followed by ranges (in parenthesis), as this conveys more information about farmers' practices than standard errors.
Pit compost is applied at start of season, but in a one to three year rotation; rates quoted in table are mean application rates averaged over the rotation cycle.
Chemical fertilizers are those applied to *kharif* crops only. Much lower doses are applied to *rabi* crops.

Table 2.1 also records the number of years of formal schooling experienced by each farmer, which varied widely, but on average was by far the least in Mugad (only one farmer having had any formal education) and most in Navalur, where only one farmer had not been to school. Farm sizes were similar in Mugad, Maradagi and Halyal, whilst those at Navalur were on average about twice the area of those in the other villages. In addition, leasing extra land from non-farming landowners was the norm in Navalur, whilst this occurred to a lesser extent among collaborating farmers in Maradagi and Halyal, and not at all in Mugad. Head of cattle refers to buffaloes, cows and bullocks. Buffaloes are kept for milk, whilst bullocks are used for draught power.

Figure 2.1 shows the rainfall levels in 1998-1999, against a 45-year mean value.

Figure 2.1 Rainfall trends in Dharwad



Farmers also reported that in recent years the onset of the monsoon has been erratic in timing, as has rain fall within the wet season. In the Baseline Study, when analysed at a resolution of monthly totals, no trends were detectable (Universities of Birmingham, *et al*., 1998). Analysis of weekly or even daily rainfall is probably required to determine if the reported increase in short term variation has any basis in fact.

Farmers in three of the villages had purchased MSW in the past. No farmers from Mugad had purchased MSW, which is some distance from the dumpsite in Dharwad. Box 2.1 briefly reports comments on the use of MSW in the three villages.

Box 2.1 Use of MSW in three of the villages

Navalur
Farmers in Navalur have been using urban waste for many years. As Navalur is close to Dharwad, waste pickers go to the fields and take plastic not sorted from the waste before spreading. Some farmers from Navalur, with their own vehicles, have collected waste directly from houses and roads in Dhrwad, before it becomes too contaminated. This is then composted in the village.

The farmers have not fully compensated for the reduction in use of urban waste by using more chemical fertilizers or other composts. The farmers felt that the soil has now become too adjusted to chemical fertilizers, making the soil hard. However, when mixed with urban waste, they felt that fertility improves, the soil becomes softer and moisture is retained.

Maradagi
Farmers in Maradagi have purchased waste from Dharwad dumpsite, but would buy more if the quality improved. If it was sorted, and subsequently more expensive, they would still be interested in buying the waste. Only around 3 or 4 farmers have hired vehicles to purchase urban waste, at a cost of Rs.250 per trip. For those with their own vehicles, it costs Rs.75-100 per trip.

Halyal
Many of the farmers have purchased MSW from Hubli dumpsite. Farmers there expressed concern about the private sector taking waste from Hubli dumpsite and sought reassurance from the Commissioner, Mr Vastrad, that access to the waste for farmers would continue.

The identification of farmers was undertaken largely through the participatory exercises, described in Section 2.4, which were arranged in conjunction with the Agricultural Assistants and contacts in the villages. In Mugad, the identification of potential farmers was assisted by an employee of an NGO, Indian Development Services (IDS), who works in the village. He was able to introduce team members to poor farmers.

In other villages, identifying poor farmers was less easy. Colleagues in the professional sector led us to their own farmer contacts, who were often smaller scale farmers but with significant off-farm income, or to those farmers with standing in the local community. NGOs based in Hubli-Dharwad working in villages tend to work in more distant rural areas. It was therefore impossible to make contacts via NGOs in the three villages. Identifying poorer farmers takes more time than finding wealthier farmers. They are more likely to undertake a number of income-generating activities (such as off-farm work, either as farm labourers or work in the urban areas), and are less able to employ labourers, therefore undertaking all the farm work themselves with help from household members.

The research team did find small farmers to work with the project, however, by calling for meetings that everyone was encouraged to attend and by pressing for small farmers to become involved in the research. This can be seen from Table 2.1, as indicated by the size of the areas farmed.

2.4 Participatory exercises

Matrix scoring and social mapping exercises were conducted in the four villages chosen for the research. The purpose of the matrix scoring was to collect information from men and women on the

- types of soil ameliorants used and preferences with respect to farmer-determined criteria;
- experiences of using urban waste;
- factors constraining the purchase of more urban waste; and,
- social taboos concerning different waste types, which may vary between different communities.

Guidance notes written for the matrix scoring are shown in Appendix B. The findings of the matrix scoring in Mugad and Navalur are discussed in the Inception Report. The findings of all four villages are also discussed in Section 3.4 of Chapter 3 of this report.

Social mapping was conducted in each village to show the layout of the village and to provide a basis for discussing the characteristics of each village, contributing to the context of the farmers' livelihood strategies and cropping patterns. Many people contributed to the mapping process, making corrections and involving different groups within the village. Maps were generally drawn on the ground and copied onto paper. The maps are shown in Appendix C.

2.5 Observation of farmers' activities

During initial visits, the research team learned that small-scale farmers around Hubli-Dharwad already have extensive composting experience, and are presently composting nearly all suitable materials in their village. Accordingly, the team decided that more valuable information could be gained by monitoring farmers' own techniques in managing soil fertility and their informal experiments in the use of composts and fertilizers rather than beginning on-farm trials designed with inadequate local knowledge. The information gained during this period fed into the design of the on-farm trials. The observation took place in only two villages as a learning experience. A further two villages joined in to the on-farm trials to provide a greater spread of different farming conditions.

Guidance on visits to farmers that was used in the research is given Appendix D. The research assistants employed by the project through the University of

Agricultural Sciences were the main contacts with the farmers, though other members of the team visited the farmers on a number of occasions. The information generated during the observation period was used to inform the design of the on-farm trials and to generate further information about the use of organic composts. This information, as well as results from the chemical analyses and on-farm trials, is used in Section 3.4 in the discussion of soil fertility management strategies.

2.6 Chemical analyses of soil, plants, composts and decomposing wastes

Chemical analysis of soil, plants (harvested from two kharif seasons), farmers' composts, the composts generated by this project (both on a pilot basis and for the on-farm trials) and decomposing wastes from the two dumpsites were tested for nutrient contents. The results are discussed in Chapter 3. A sampling programme for the research in Phase 2 is set out in Appendix E.

Analysis of soil samples was also carried out by the University of Wales, Bangor, to determine levels of micro-nutrients.

2.7 The generation of MSW-based compost

The generation of MSW-based compost for the on-farm trials was preceded by small-scale composting trials. These were conducted at SDM College using municipal solid waste, with a number of treatments. The trial enabled the researchers at SDM College to familiarise themselves with composting and generated useful information regarding logistics and technical considerations in developing further trials. The results of the trials also helped in making decisions regarding the types of composts to be produced for the on-farm trials. The Phase 1 report provides details of the composting trials conducted between May and September 1998.

Farmers attending the workshop at the end of Phase 1 of the project in September 1998 commented on the composts. These comments, along with observations of the trials, raised the following points:

- Sorted MSW has a high proportion of non-compostable material, mainly consisting of soil.
- MSW without any organic additives has low organic matter (19.8%).
- Adding organic amendments to MSW increased organic matter and nitrogen content, increasing its manurial value.
- When farmers examined the eight treatments, on the basis of texture and colour, they expressed a preference for MSW + 25% distillery sludge and MSW + 5% cow dung.
- Farmers also expressed interest in compost from vermicomposting pits developed from the trial source separation scheme, visited during the workshop in September 1998.

Accordingly, treatments selected for the trial production stage were based around these preferences. It was not possible, however, to obtain cow dung in sufficient quantities (urban dairies already having their own clients for dung), so nightsoil was used instead. Indeed, when interviewed, many farmers had stated that the quality of MSW had declined since the practice of adding night soil to it at Dharwad dumpsite had stopped.

Treatments selected were:
1. Sorted MSW
2. Sorted MSW + 25% distillery sludge + *Azospirillum* + *Bacillus polymyxa*
3. Sorted MSW + 50 kg cow dung + vermiculture
4. Sorted MSW + night soil + *Azospirillum* + *Bacillus polymyxa.*

Rather than use MSW of uncertain age from the municipal dump, MSW was procured from several sites in Dharwad city over a period of 15 days in January 1999. This was then manually sorted into compostable and non-compostable fractions. Four pits were dug, measuring 3 x 3m x 0.6m deep. At an application rate of 10t/ha (a typical figure for compost applications on farmers' fields) for 20 farmers, 2t of each type of compost would be needed. To allow for wastage and handling, 2.5t of each type were produced.

The pits were filled at the beginning of February. To treatment 1 (MSW), no further additions were made. To treatment 2, 625kg of sludge from the SLN Distillery at nearby Garag was added on 3 February. To treatment 3, 50kg of cow dung was added as layers at the base and at 30cm depth to facilitate proper multiplication of worms. 200 worms (*Eudrila ugina*) were added on 1 March. 750kg of night soil (delivered by tanker, pumped from septic tanks) was added to treatment 4 on 10 February. This was allowed to dry on the surface of the pit for two days before being incorporated. To treatments 2 and 4, nitrogen fixing *Azospirillum* and P solubilizing *Bacillus polymyxa* were added to enhance the decomposition process, at 1kg of culture per 1t of MSW, on 1 March. The differing dates of adding amendments was unavoidable due to supply constraints. In the event it probably had little effect, as changes in nutrient status had stabilized by the time the pits were emptied. Treatments 2, 3 and 4 were watered to maintain moisture content of approximately 50%, to enable decomposition to proceed. Treatment 1 was not watered to simulate conditions in the municipal dump in the dry season. Photograph 3 shows the composts pits at SDM College.

Photograph 3 The composting pits at SDM College

Every two weeks, pits were sampled to determine the progress of decomposition. Temperature was recorded at 30 cm. Five samples were taken per pit, from the centre and towards each of the four corners, at a depth of 30 cm. Samples for each pit were bulked; thus no errors could be calculated. The samples were oven dried and moisture content calculated. Nitrogen (N) and carbon (C) contents were analysed, and the carbon to nitrogen ratios (C:N) derived. These ratios reveal how the decomposition is progressing, as the ratio decreases, the carbon content is decreasing relative to nitrogen. The quantity of the matter decreases and, as a consequence, the amount of nitrogen available in the total amount of material increases.

The four treatments had different N contents. N content was used to determine the quantity of compost to be applied to each plot, as discussed in Section 2.8. The compost was then bagged and delivered to farmers on 20 May 1999. Emptying of pits commenced on 16 May. The compost was spread on level ground to reduce its moisture content and halt decomposition. Photograph 4 shows a farmer spreading one of the composts onto the trial area of a field. It was then sieved through a 2.5 x 2.5cm mesh to remove remaining non-compostable items that had escaped manual sorting. This further improved the quality of the compost.

Photograph 4 Farmer spreading one of the composts for the trials

2.8 On-farm trials

On-farm trials were conducted in *kharif* (wet) season 1999, following observations of farmers' soil fertility management practices and discussions with farmers in 1998. Five farmers from each of four villages collaborated in the on-farm programme. Crops used for the trials were the main *kharif* season monocrops grown by the farmers; rice *(Oryza* sativa) in Mugad, potato *(Solanum* tuberosum) in Navalur, greengram (*Phaseolus mungo*) in Maradagi and groundnut (*Arachis hypogea*) in Halyal. In Halyal, most of the soil amendments are applied to the chilli (*Capsicum annuum*) and cotton (*Gossypium herbaceum*) intercropping system, but as this is relay cropped, cotton being planted one or two months later than the chilli, yields would have not been obtained before the end of the project.

After delivery of the compost on 20 May, plots were marked out with pegs in one field of each farmer. There were five adjacent plots per farm, thus farms within each village formed the replicates. Treatments applied were:

1. Sorted MSW (125kg/100m^2)
2. Sorted MSW + 25% distillery sludge + *Azospirillum* + *Bacillus polymyxa* (70kg/100m^2)
3. Sorted MSW + 50 kg cow dung + vermiculture (80kg/100m^2)
4. Sorted MSW + night soil + *Azospirillum* + *Bacillus polymyxa* (80kg/100m^2)
5. Farmer's own practice.

Plots were randomised within each field. At the usual time for compost incorporation, non-labeled but numbered bags of MSW compost were assigned to each plot (research assistants knew which treatments were allocated to which plot, but farmers did not). Farmers were permitted to apply their usual dressings of inorganic fertilizers, so long as applications were the same for all plots. Additionally, in the farmer's practice control, farmers applied their usual levels of compost. It is recognized that the effect of permitting farmers to apply possibly different rates of chemical fertilizer to each other would increase variability in response. However, this would have the effect of increasing only the error term of the between farm source of variation (that is, unless there was an interaction between farm and treatment).

Before application of composts, soil was sampled down to 15cm for every plot. Farmers then cultivated their land and fertilized it, in their normal manner, except that cultivations had to run across plots to avoid mixing of MSW composts between plots. Crops were sown on different dates, depending on when reliable rains arrived in each village. Research assistants were present when compost application and sowing took place. It should be mentioned that logistically, this was a difficult experiment to manage. Farmers were not sufficiently aware of research procedures to be able to manage allocation of treatments themselves, but villages were widely spaced and communications with the research assistants on likely sowing rates was poor.

During the growing season, repeat visits were made to each farm to check upon progress and to elicit views from farmers. At the end of the season, crops were harvested and weighed on a plot basis. Apart from samples retained for chemical analysis, crops were returned to the farmers. Soil samples were also taken from each plot following harvest.

Notebooks were given to each farmer to record details about farming activities and to record labour inputs, from the household and external. The number of men and women hired to work on each farm was recorded against relevant activities, with the wage rate received. Labour budgets were therefore derived for each farm, as discussed in Chapter 3.

The research endeavoured to be as participatory as possible, drawing on farmer participatory research (FPR), as discussed in School of Public Policy *et al.* (1998a). The on-farm trials were, however, researcher-designed and laid out, though farmers were involved in deciding the field in which the trials would take place. The short time of the research project prevented further involvement of the farmers in the design of the trials. The farmers monitored the trial area by recording observations and participated in the workshops of the research project.

2.9 Research approach

The research therefore drew on a range of research methods and was inter-disciplinary, drawing on farming systems, crop science, social science research methods and engineering disciplines. The range of methods used enabled triangulation (cross-checking) of research findings and enabled the research to address the social, economic and technical aspects of using MSW as a soil amendment.

3. OUTPUTS

3.1 Introduction

This chapter sets out the findings from the research in terms of the strategies set out in the logical framework. The recommendations for strategies are drawn from the research project and from the wider literature, to ensure that recommendations are realistic and build on experience elsewhere. The strategies are interconnected and dependent on each other. They address the need to segregate waste materials, make optimal use of the range of organic wastes produced in the urban areas, manage the waste effectively and market the waste in as an efficient and effective way possible. The strategies are set within the context of a changing environment within Hubli-Dharwad, as a number of new initiatives are underway to improve solid waste management in the city. The recommendations should, however, be of relevance to other South Asian cities, and perhaps elsewhere, and should be seen in this context.

3.2 Changes in SWM in Hubli-Dharwad

There were a number of changes in the management of solid waste in Hubli-Dharwad during the life of the project, and many more changes are expected, though these may depend on the length of time the current Commissioner stays in post and on his successor. The Commissioner of HDMC is very interested in waste issues and has undertaken a number of new initiatives. He is very open to new ideas and has actively supported this research project, as discussed in Chapter 4.

Some of these initiatives have been described in previous reports. The Inception Report described the trial source separation scheme initiated in Hubli-Dharwad by the HDMC and local NGOs. The idea was to support residential areas in setting up committees to organise the collection of separated waste by a casual worker. Organic waste would be vermicomposted and inorganic materials taken to the nearest corporation bin. It has not been as successful as hoped, though a few residential areas in

Dharwad are continuing to collect waste separately and vermicompost the organic materials. This is particularly supported by an NGO called Shoda.

Tendering for private sector involvement in waste treatment was also described in the Inception Report. Hubli Biotechnologies, the company that won the tender, is expected to be leased 12 acres of land at the Hubli dumpsite to produce high quality compost from the MSW. The Phase 1 report also noted private sector involvement in waste collection, especially from market areas. This has expanded during the life of the project to more areas.

The HDMC has also recently begun door-to-door collection of waste from a number of commercial and residential areas and now collects hospital waste separately from MSW. The Corporation hopes to eventually encourage the use of separate bins to decrease the contamination of organic waste. Whilst pursuing this aim, however, the Corporation is also concerned about safety issues and hopes to hire tipper trucks to reduce manual handling of waste. The Commissioner is also exploring the possibility of banning certain types of plastics in order to reduce the contamination of MSW and to reduce litter problems in the city. Plastic bags would probably be the first casualty, which would also solve one of the problems facing owners of roaming cows and buffaloes – the ingestion of plastic bags when the animals eat rubbish. In addition to these initiatives, the Corporation is seeking new locations outside the city for new dumpsites, or, hopefully, sanitary landfill sites, as, in Dharwad in particular, residential areas have sprung up around the dumpsite as the city has grown. These initiatives are discussed further in the following sections.

The Commissioner has, therefore, demonstrated initiative and willingness to improve the solid waste management of Hubli-Dharwad. The Corporation has worked with NGOs and the private sector, and the Commissioner has attended a number of workshops on solid waste in India. He is, however, also aware of farmers' desire to access MSW and of their concerns about the contamination of the waste. Concern has been raised by farmers about the increasing role of the private sector in composting MSW and of the high price charged for the product. The price of Rs2000-Rs2600 per tonne is considerably more than they are presently paying. The product is, of course, much cleaner than unsorted MSW and has been enriched with manures.

The Commissioner is looking into the possibility of offering 50 per cent discount for local farmers wanting to purchase the compost produced by Hubli Biotechnologies. This would require permission from State Government and also a set of criteria for deciding which farmers would qualify for such a discount. These criteria could include:

- Farmers from villages that have traditionally purchased waste from the dumpsites (see Map 2 later in this chapter for the locations of some of these villages).
- Poor farmers could be identified by village accountants, particularly since the recent introduction of 'green cards'. These have been distributed in the last couple of years to low-income households in rural areas. Criteria

assessed include income, land holding and other livelihood activities carried out by the household.
- A quota system could be used, such as a discount on the first few tonnes.

Whatever system is considered, there are a number of concerns about the use of subsidies.

- A ceiling may have to be set on the amount of waste subsidised to keep costs to the HDMC down.
- It is not easy to identify poor farmers. There could be instances of inappropriate distribution of green cards, for example. Farmers with small land holdings may lease land from other farmers.
- Once a subsidy is introduced, it would be difficult to withdraw it.

The various options for maintaining access to the MSW by near-urban farmers is explored in greater detail in the following sections. It is, however, noted that this access is supported by the Commissioner of the HDMC.

Whilst there have been changes in the SWM of Hubli-Dharwad, a number of issues remain as constraints to further progress in improving the use of MSW by near-urban farmers. These include:

- The increasing pressure on HDMC to make solid waste collection and disposal more environmentally safe.
- HDMC has inadequate financial resources and is unable to recruit more personnel.
- Can community source separation schemes be operated on a large-enough scale to make a significant difference to soil fertility and waste management issues?
- The potentially conflicting demand for MSW from local farmers and private sector contractor.

These issues are addressed through the following strategies.

3.3 Strategy for the segregation of waste

Segregation of municipal solid waste into organic and inorganic materials is critical to the generation of good quality compost. ‘Separation at source’, generally at household level, is recognised as the most effective way of achieving good quality and safe compost. However, literature on source separation schemes highlights many examples of source separation schemes that have failed and the small-scale of such schemes means that there are limited impacts on solid waste management at a city-level (Beall, 1997; Furedy, 1996).

Neighbourhood composting schemes have been initiated across India and involve households putting organic and inorganic waste materials into different containers for collection. Area committees formed by residents organise collection by people employed by the scheme, funded by fees paid by each household, sometimes assisted by NGOs and municipal corporations. Such schemes have largely been developed in response to the inadequate provision of waste collection services by municipal authorities, but have also resulted from efforts to support waste pickers (Beall, 1997; Furedy, 1996; IDD, 1998; Snell, 1999).

In Bangalore, for example, a number of NGOs support neighbourhood schemes, where waste pickers are employed to collect waste door-to-door, sell or dispose of the inorganic wastes, and put the organic wastes in local vermicomposting pits. Such schemes are not easy to maintain. Household involvement may be sporadic, as many people believe that it is the municipal corporation's responsibility to collect waste and do not want to make additional payments. Beall (1997:955) also suggests that, in South Asia, 'wet', organic, waste "is considered polluting and a job for others born to such work", which creates another constraint to the separation of waste materials 'at source'.

The trial source separation scheme initiated in Hubli-Dharwad has met with limited success, due to two main factors: the difficulty of employing people to collect the waste on a regular basis and the lack of willingness of households to pay an additional charge to their municipal tax, seeing it as the responsibility of the Corporation to collect waste.

There is a range of casual work opportunities in Hubli-Dharwad and some people are used to seeking work opportunistically, that is, if a better job came along (even for a day), they would leave the waste work for it. It is difficult to employ waste pickers in Hubli-Dharwad to do such work as they prefer to remain in control of their working hours and areas of work. Reasons for this may include flexible working hours and areas, other responsibilities or employment and the ability to earn more through collecting and selling waste from other areas of the city. From research in Bangalore, Huysman (1994:159) suggests that women who work as waste pickers prefer to be assured of a daily income and like to be able to divide their time between their domestic responsibilities and earning money. Waste picking on an informal basis enables them to earn money every day they are able to work and, to an extent, fit their work in with their other activities.

In addition to the trial source separation schemes, separation of waste materials in Hubli-Dharwad is also undertaken by the private sector waste treatment contractor and farmers. Hubli Biotechnologies employs staff to separate waste manually at the Hubli dumpsite as part of the process of generating compost to sell on a commercial basis. Some separation of MSW is carried out by farmers, or by labourers employed by them, once MSW is purchased and taken to farms.

Separation of waste materials is critical to the success of composting urban waste and ways forward have to be found to separate waste. Separating at source can be expensive if done on a large scale owing to the need for separate collection times or vehicles. Some manual or mechanical separation would still need to be carried out as not all households would put their waste out separately. The issue of the separation of waste materials, however, cannot be discussed outside considerations of the management of waste across the city. The aim of integrated waste management is discussed in Section 3.5.

As noted in Section 3.2, HDMC has recently introduced door-to-door collection of waste materials and hopes to provide bins to encourage the separation of waste materials. The Corporation has also recently started to collect hospital waste separately from MSW, to ensure that farmers buying MSW from the dumpsites are not put at additional risk. The problem of how to deal with hospital waste is being addressed jointly by the HDMC and the Karnataka Institute of Medical Science, Hubli. The aim of keeping inorganic and organic wastes separate is, therefore, being pursued, but it is unlikely that HDMC will be able to separate waste at the dumpsites themselves. This is due to lack of access to capital to purchase mechanical equipment and the constraints placed on the Corporation by State Government on employing new staff. One possible way forward would be for private sector involvement in the separation of waste materials, without producing compost. The advantages would include:

- The private sector would be able to access capital to finance mechanical equipment.
- The sorted MSW would be available at a lower cost than the added-value product the private sector is currently producing in Hubli.
- As there would be fewer contaminants in the MSW, it would be more attractive to near-urban farmers, even small farmers, who have in the past hired tractors between a group of farmers to purchase MSW. Sorted MSW could even be mixed with the farmers own pit compost to improve the nutrient quality of the compost.

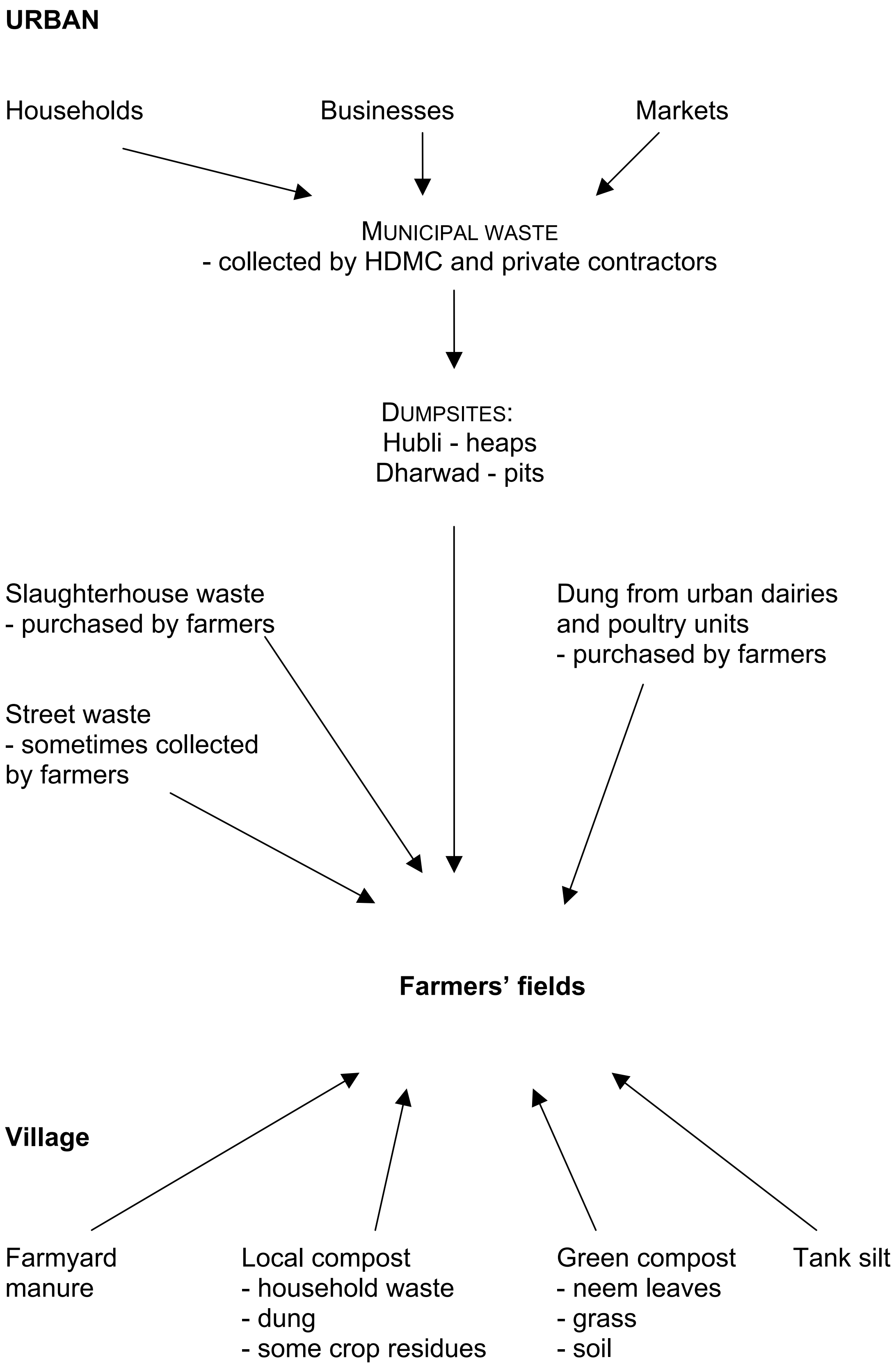
Farmers in the villages studied have stressed their preference for organic fertilisers over chemical fertilisers. They have also claimed that they would purchase more compost if it were available. Productivity in the peri-urban area must depend to some extent on the fertility and structure of the soils. Increasing access to less contaminated MSW could be a part of strategy to increase soil fertility and maintain soil structure and moisture.

3.4 Strategy for optimizing the use of urban wastes in sample communities

This section discusses farmers' preferences for soil amendments and the results from the composting processes and on-farm trials. These are used to explore how the use of urban wastes could be optimized in the villages, particularly through the use of MSW-based composts.

Figure 3.1 shows the range of urban wastes used by farmers, as well as organic materials gathered at village level. Farmers in some villages use sewage waste that flows, untreated, into streams leaving Hubli and Dharwad. The research focused on the use of MSW rather than on livestock manure because there were obvious researchable constraints to increasing the use of MSW and because it was believed that the informal markets for livestock manure worked well. It was also believed that there is no surplus manure available from the urban areas, though this is not the case for pig manure as the pigs roam freely and little of the manure is collected for use (see University of Birmingham *et al.*, 1998 for further information on pigs in Hubli-Dharwad). Some information on livestock manures was gathered, however.

FIGURE 3.1 SOURCES OF ORGANIC SOLID WASTE



3.4.1 Farmers' preferences for soil amendments

During visits to the four villages, matrix scoring was undertaken to compare the characteristics of a range of organic soil amendments used by farmers. Each group selected the range of soil amendments and criteria against which to score them. The results of the exercises conducted in the four villages are consolidated in Table 3.1.

Table 3.1 shows that farmers' preferred option for soil fertility maintenance was pit compost, even though this was the most expensive to produce and buy. Pit compost is produced from manure, household organic wastes and agriculture residues. Mean application rates in each season were quite similar between the four villages, although there was considerably more variability between individual farmers. Many farmers who either did not own livestock or who could not produce sufficient pit compost were prepared to buy it at Rs.300 to 350 per tractor load (1.5 t). Most, but not all, farmers used chemical fertilizers. In Mugad, Navalur and Maradagi, these were at low rates (DAP = 12% N and 52% P_20_5). Typical analysis of NPK fertilizers used was 10:20:20. At Halyal, on chilli-cotton intercrops, high rates of DAP were used (except by one farmers, who applied no fertilizers). The gross return on sale of chilli in 1999 was Rs70,000 (£1,000)/ha, and application of chemical fertilizer was a cost effective option.

Table 3.1 also shows that MSW ranks in a fairly average position regarding retention of soil moisture, maintaining soil fertility and achieving good yields. It ranks poorly in terms of weed infestation. This confirms the view that if there were more pit compost available, for example, this would be used rather than MSW. Chemical fertilizers, however, ranked lower than MSW in several instances, reflecting farmers' preferences for organic matter even from MSW before choosing to use chemical fertilizers.

The reality is, of course, that farmers generally use a combination of soil amendments. They do not rely on one source but make use of as many sources as possible, reflecting availability and different properties of different types of soil amendments, as well as the purchasing power of the farmer.

Table 3.1 Matrix ranking of farmers' views of soil amendments

Characteristics	Category of soil amendment					
	Pit compost	Chemical fertilizer	Tank silt	Sheep penning	Poultry manure	Municipal Solid Waste
Cost (Rs/ha)	6,250	1,150 – 3,750	2,500 – 5,000	750 – 1,250	1,250 – 3,750	2,500 – 6,000
Cost (rank)	5	2	4.5 (4 – 5)	2	n.r.	5
Crop yield in: Good rainfall	5	4.5 (4 – 5)	4.25 (4 –5)	4.75 (4 –5)	5	3.7 (3 – 5)
Poor rainfall	5	2 (1 – 3)	4 (2 – 5)	3 (2 – 4)	1	3.3 (2 – 5)
Weed infestation	3.5 (2 –5)	3.75 (2 –5)	3 (2 – 5)	5	5	5
Moisture holding	5	1	4.5 (4 – 5)	2.5 (1 – 3)	1	3 (1 – 4)
Medium term soil fertility	5	1	3.75 (2 –5)	4.25 (3 –5)	2.5 (1 – 4)	3.3 (3 – 4)

n.r.: not recorded   Figures in brackets are range of rankings given

3.4.2 Availability of livestock manure

Livestock manure is generally used in pit compost. As well as using manure from their own cattle and buffaloes, farmers purchase manure from landless households and from urban areas. Livestock manure generated in the urban areas includes poultry, pig, sheep and goat manure, and cattle and buffalo dung. There are well-established, though informal, markets for cow and buffalo dung, used to enrich soil or as fuel for cooking. Farmers wanting dung visit localities within the city to look for supplies and, over time, establish contacts. Tractor loads of dung are sold for Rs.300-400, providing additional sources of organic fertilizer and contributing to the return of nutrients to the soil.

The role of manure produced in urban areas in peri-urban agriculture is significant, as organic matter for soil management is always in short supply. The competing demands of agricultural waste for use as a source of fuel and as a soil improver, and increasing mechanisation, reducing the need for draught livestock, has led to a decline in the availability of organic matter produced in more rural areas.

There are a number of problems with keeping livestock in urban centres, including obtaining sufficient fodder, access to grazing land and water (both for drinking and washing buffaloes and cows) and storing waste for sale. The difficulties experienced by urban authorities include roaming and herded animals contributing to traffic chaos, dung and fodder in storm drains, complaints about smell and concerns about health hazards, particularly resulting from pigs left to roam, who are suspected of carrying some diseases (e.g.Japanese encephalitis).

These informal markets for livestock manure appear well-established, but may be threatened by possible moves to evict livestock from urban centres with a population over 500,000 (The Hon. Supreme Court of India, 1998). This option has arisen due to concern about the hazards resulting from livestock in cities and could lead to urban dairies being forced to move to the outskirts of cities. This would most likely lead to the closure of small dairies, as households would not want to move away from other income sources, and to the opening of bigger, more commercial, dairies. How this would affect the availability of manure for farmers it is difficult to say. However, many of the large dairies that presently exist in Hubli-Dharwad use manure on their own farms which grow fodder for the buffalo and cows.

3.4.3 Results from the analysis of MSW-based composts

The decomposition of the MSW-based composts generated for the on-farm trials were monitored in terms of carbon to nitrogen content, moisture and temperature. These factors indicate how decomposition is progressing and enable comparisons between the composts.

The initial moisture content ranged from 28 to 32%, and this increased as the pits were watered. MSW also increased in moisture content, presumably due to rainfall. Moisture content in the MSW pit was slightly lower than in the other three pits.

Figure 3.2 Change in moisture content during composting process

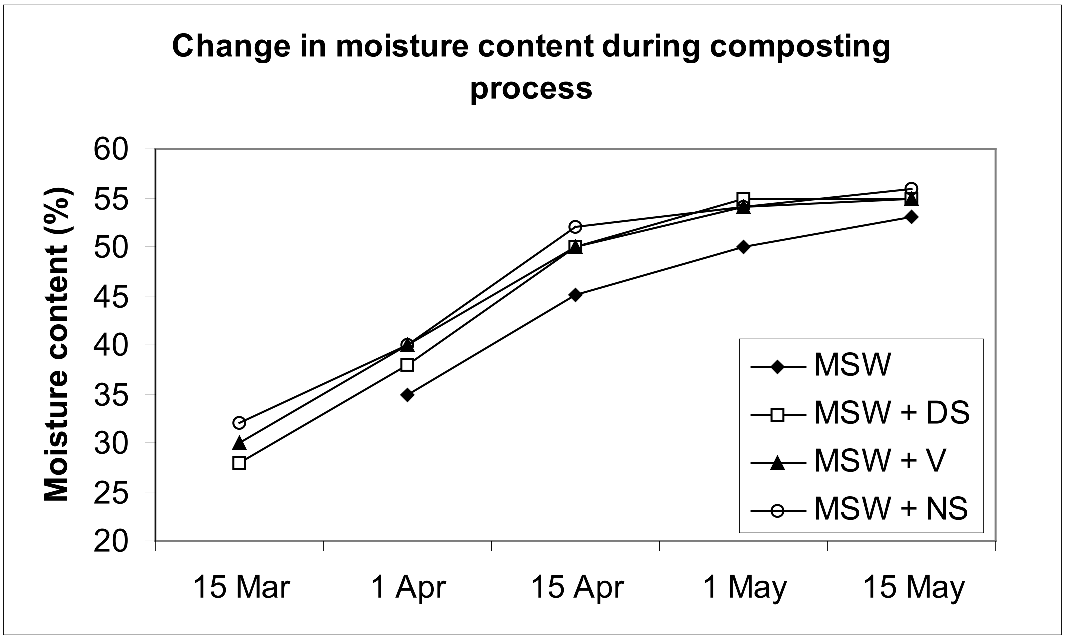
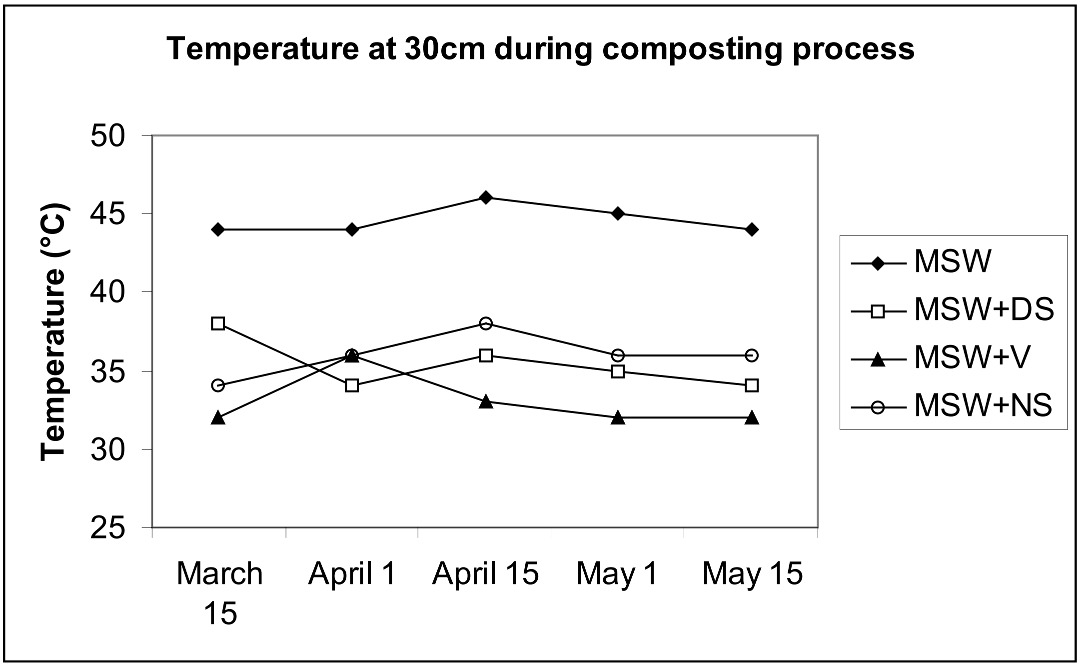
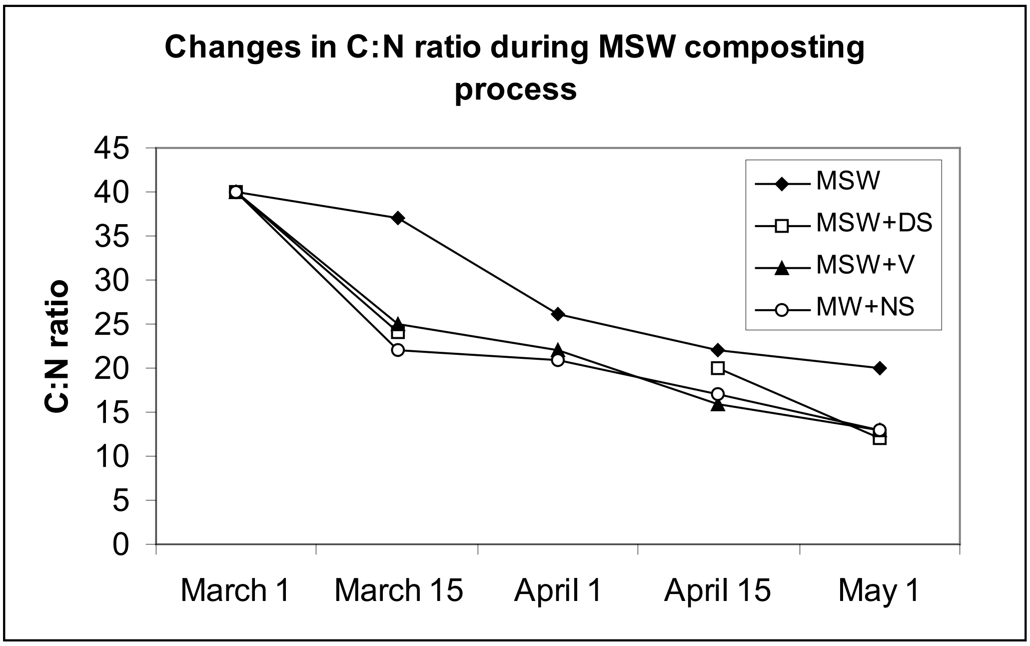


Figure 3.3 Temperature during composting process



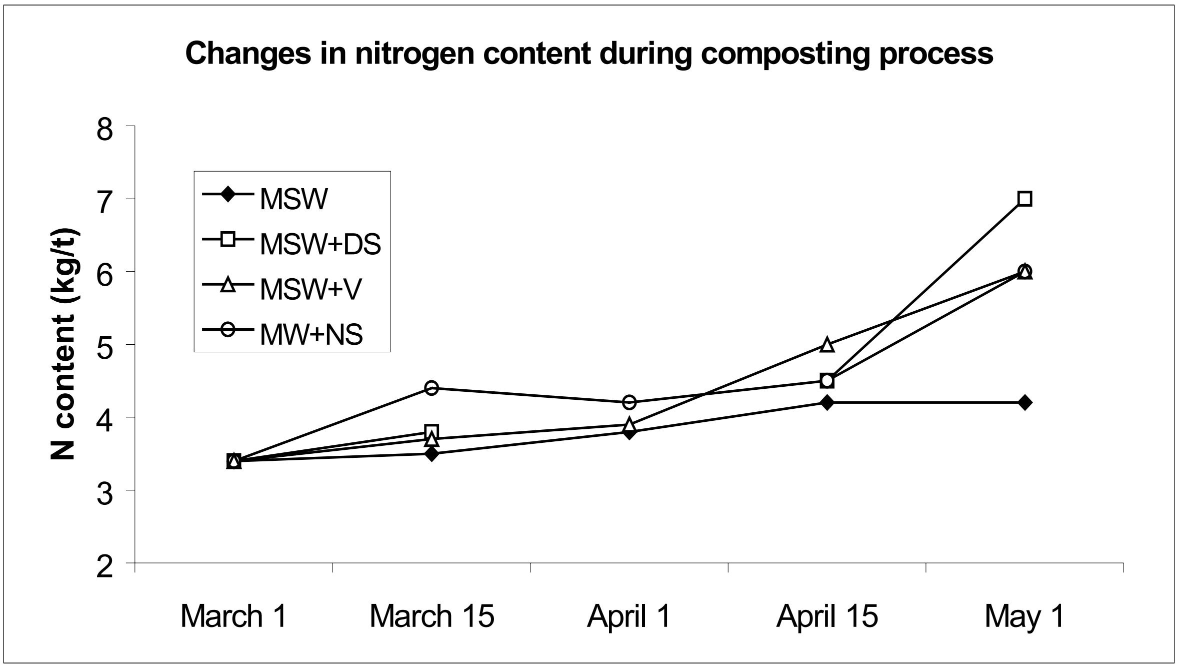
The decomposition process did not generate much heat, the temperature for the three pits with MSW + amendments ranging around 34° to 36°C, although MSW with vermiculture was between 2° and 5°C lower than the other two pits. Much higher temperatures were recorded in the MSW only pit, ranging between 44° and 46°C. This was possibly because the lower moisture content permitted less evaporative cooling.

Figure 3.4 Changes in C:N ratio during decomposition



As decomposition proceeded, the C:N ratio rapidly decreased from an initial value of 40 as micro-organisms respired carbon in the MSW. This value is indicative of poor quality compost, the ideal ratio being 10:1. By 1 May, the C:N ratio in the three MSW + amendment treatments had fallen to 12 to 13, whilst MSW alone decreased to only 20. Thus, the addition of amendments improved the quality of compost compared to MSW alone.

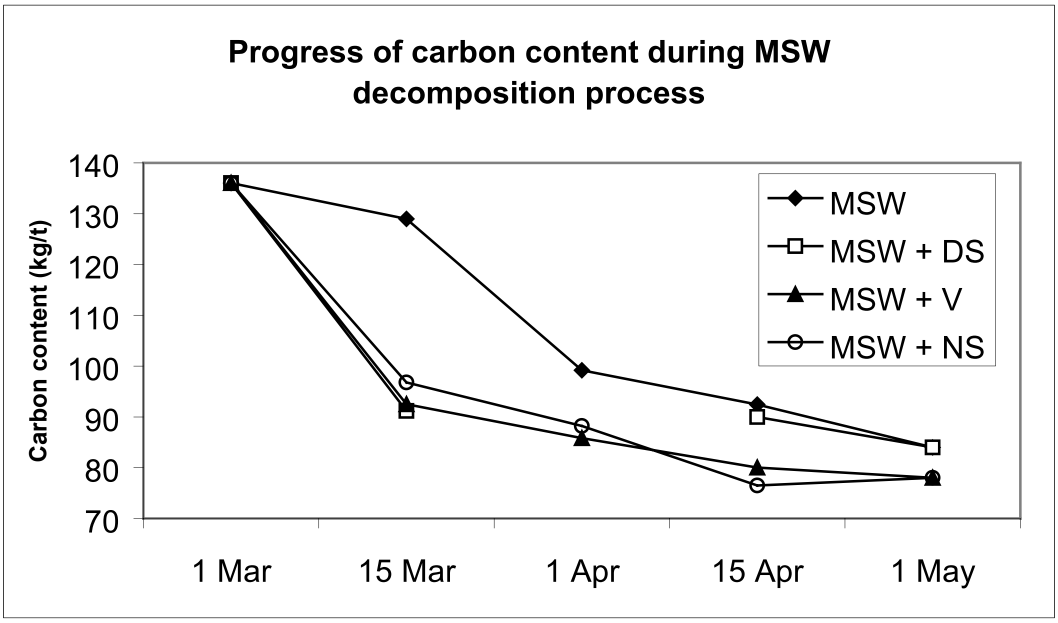
Figure 3.5 Changes in nitrogen content during decomposition



As carbon was respired, nitrogen remained, so its content increased. This was most marked in MSW + distillery waste, whilst there was only a slow increase in MSW alone. The final N content was used as the factor determining the quantity of MSW-based compost applied to each plot.

Figure 3.6 shows that in most treatments, nearly half the carbon present was respired. This process was initially slowest in the MSW treatment, although microbial respiratory activity increased sharply between 15 March and 1 April, so that by the end of the composting process, its carbon content was the same as MSW + distillery sludge, and only slightly above those of MSW + vermiculture and MSW + night soil.

Figure 3.6 Changes in carbon content during decomposition



It can be concluded from the composting trials that the addition of amendments improved the quality, but also that the decomposition process significantly improved the quality of MSW alone.

At the end of the composting process, samples of compost from each pit were analysed. The results are presented in Table 3.2, in comparison with standard pit compost (textbook typical values).

Table 3.2 Results from the analysis of the composts

Parameter	MSW – derived composts				Typical pit compost[1]
	MSW	**MSW + DS**	**MSW + V**	**MSW + NS**	
pH	8.0	7.3	7.7	7.6	7.2
EC (dS/m)	1.53	2.80	1.10	1.18	0.22
% N	0.42	0.70	0.60	0.60	1.00
% P	0.34	0.35	0.59	0.56	0.50
% K	0.95	0.97	1.10	1.07	0.80
% Ca	3.00	4.40	2.70	3.20	0.18
% Mg	0.80	0.80	1.80	1.30	0.15
% S	0.15	0.19	0.26	0.30	0.23
Cu (ppm)	2.60	2.50	2.10	2.90	2.80
Mn (ppm)	25.8	16.7	16.1	12.0	69.0
Fe (ppm)	25.3	18.4	21.4	21.7	35.0
Zn (ppm)	5.50	5.10	5.60	5.20	25.0

[1] Source: Tandon (1993)

Compared to pit compost, the MSW – derived composts were generally lower in N, Mn^{2+} and Zn^{2+}, but higher in Ca^{2+}. Electrical conductivity (EC) was also noticeably higher, particularly in MSW + 25% distillery sludge. Distillery effluent wastewater has an EC of 45.3 to 46.0 dS/m (Tandon, 1993), with the bulk of the ionic species being Na^+, K^+, Ca^{2+}, HCO_3^- and Cl^-. Addition to MSW at a rate of 25% clearly diluted these ions, as did adding water and leaching due to through flow of rainfall. Of the ions mentioned above, only Ca^{2+} and K^+ were analysed. Levels of K^+ were not noticeably higher (but it is a very soluble ion), but Ca^{2+} was. However, EC of these levels would be unlikely to have a significant effect upon soils, particularly if MSW – derived composts were incorporated.

In terms of content of major nutrients, values of N, P and K were lower than those quoted for USA derived urban compost at 1.7, 1.6 and 2.5 %, respectively (National Research Council, 1996). During the analysis of the MSW – derived compost, it was noted that there was a high proportion of soil (presumably from road sweepings). In the vermicomposting process, the proportion of worm casts was much lower (although not quantified) than when organic waste is vermi-composted. Typical nutrient contents for vermicompost are 0.5 – 1.5% (N), 0.1 - 0.3% (available P), 0.15 – 0.56% (available K), 0.23 – 0.48% (Ca and Mg), 2.0 – 9.5 ppm (Fe and Cu), 5.7 – 11.5 ppm (Zn) and 128 – 548 ppm (S) (Kale, no date). Despite the low proportion of workmcasts, although N content was at the lower end of the scale, major nutrient content of the MSW – derived composts was comparable to vermicompost.

During the on-farm trials, farmers applied other soil amendments to plot five ('farmer's own practice'). Table 3.3 shows the farmers soil ameliorant practices during the on-farm trials. It is apparent that rates of application of many of the soil amendments, particularly inorganic fertilizer in Navalur, are higher than values presented in Table 2.1. It could be that applications vary considerably between seasons, according to each farmer's circumstances. Alternatively, the discrepancy could have arisen because farmers were responding to a specific question about a practice at a particular time, rather than being asked for an opinion about their general practice, as occurred during semi-structured interviews before the season.

Table 3.3 Farmers' soil amelioration practices during on-farm trials

Village	Inorganic fertilizer at sowing	Inorganic fertilizer top dressing	Organics application before sowing
Mugad	31 (0-50) kg/ha DAP	35 (0 – 51) kg/ha urea. One farmer also applied 25 kg/ha 17:17:127 NPK.	3.5 (0 – 6.2) t/ha pit compost
Halyal	125 kg/ha DAP	None	7.5 t/ha pit compost
Navalur	224 (185 – 250) kg/ha DAP	137 (125 – 185) kg/ha DAP	Two farmers applied 8.7 (7.5 – 10) t/ha MSW. Two applied 7.5t/ha pit compost. One farmer applied nothing.
Maradagi	125 kg/ha DAP	None	Three applied 6.7 (5 – 7.5) t/ha pit compost. Two applied nothing.

Notes: Values are means with ranges in parenthesis.
Inorganic fertilizers were applied to all five treatments, as per normal farmer practice.
Organic amendments were applied to treatment 5 only, at the same rate as to the rest of the field outside the plots.

Table 3.4 provides the results from the analysis of farmers' pit composts. In general, the pit composts are higher in N content than the MSW-derived composts, but lower than a 'typical' pit compost. Similar to the MSW-derived composts, they are higher than 'typical' pit composts in levels of total K. Level of total P were similar in farmers' pit compost, MSW - derived composts and the text book 'typical' pit compost.

Table 3.4 Analysis of collaborating farmers' pit compost, samples April – May 1999

Village	Total N (%)	Total P (%)	Total K (%)
Mugad	0.93 (0.510-01.26)	0.44 (0.35 – 0.52)	1.03 (1.0 – 1.07)
Navalur	0.71 (0.50 – 0.98)	0.41 (0.21 – 0.59)	0.97 (0.87 – 1.1)
Maradagi	0.83 (0.72 – 0.99)	0.50 (0.35 – 0.58)	1.01 (09.5 – 1.1)
Halyal	0.76 (0.70 – 0.84)	0.45 (0.29 – 0.56)	1.02 (0.91 – 1.07)

The analysis of the MSW-derived composts reveals mixed findings in terms of nutrient levels. No one compost stands out as being the most suitable compost, as this will vary with soil conditions and crops grown.

3.4.4 Results from the on-farm trials

Crop yields

The crop yields from the plots are given in Table 3.5. Different crops were grown in each village, as agreed beforehand with the farmers, according to their normal farming system. Thus, comparisons of yields between villages would be meaningless. In all cases there were significant differences in yields between farmers, indicating variability due to each farmer's circumstances, such as soil fertility, local variations in rainfall, husbandry.

Table 3.5 Yields of crops in 1999 on-farm field trials

	Navalur (5)	Mugad (5)	Maradagi (4)	Halyal (2)
	Potato	**Rice**	**Greengram**	**Groundnut**
Treatment	**t/ha (fresh)**	**t/ha (paddy)**	**kg/ha (seed)**	**t/ha (in shell)**
Sorted MSW	23.0 bc	4.04	485	1.52
MSW + DS	20.6 a	3.60	407	1.48
MSW + V	20.9 a	4.21	497	1.56
MSW + NS	23.5 c	3.80	536	1.73
Farm practice	22.6 b	4.30	427	1.55
s.e.m.	0.333	1.01	60.0	0.106
P (treatment effect)	<0.00	0.572	0.251	0.244
P (farmers)	<0.00	<0.00	<0.00	0.004

Notes:
Numbers in parenthesis after village names indicate numbers of farmers collaborating.
s.e.m. = standard error of means
Navalur data followed by similar letters indicate those means not significantly different (separated by Least Significant Difference).
P = level of probability in F test.

As can be seen from Table 3.4, yield results have not been collected for all of the farmers. This is because:

- In Halyal, the groundnut crop failed for one of the farmers due to late rain.
- One farmer in Halyal, on hearing that the project would be supplying composts, grew chilli/cotton, despite agreeing to participate on the basis that he would be growing groundnut.
- Another farmer in Halyal grew long-duration spreading groundnut, which would be harvested much later.
- In Maradagi, one farmer decided to plant onion rather than greengram.

These changes and problems are inevitable when there is some degree of participation in the research. It is interesting to note that the changes took place in villages that did not participate in the observation period in the previous *kharif* season, perhaps reflecting the benefits of spending time building relations.

Concerning treatment effects, only at Navalur were these statistically significant. It should be borne in mind that effects of organic amendments often do not show in up the season of application, particularly if there has been a history of application of organic amendments. Although in three locations treatment effects did not reach significant levels, there were consistent effects of ranking. MSW+distillery sludge consistently resulted in the lowest yields, whilst MSW+nightsoil was ranked highest in all locations except Mugad. This supports farmers' views that MSW has declined in quality since the addition of nightsoil was stopped by the Municipal Corporation. In Mugad, the farmers' own practice resulted in the highest rice yields, and in other villages it was as effective as some of the MSW treatments. Sorted MSW, but without other amendments, was also as effective as most other treatments. These results suggest that sorted MSW is as effective a soil amendments as farmers' own practices, and that if any additions are made, night soil would probably be the most effective. The reason for the poor performance of MSW+distillery sludge is not known, but it may have been related to its high electrical conductivity.

Relationships between nutrient uptake and crop yields

This section discusses the relationships between nutrient uptake and crop yields from the on-farm trials. The results are presented for Navalur and Maradagi, as there were only two crops in Halyal, making analysis difficult, and the crop yield data from Mugad is not yet available. The analysis does provide some support for nightsoil being added to MSW, or MSW being vermicomposted. This is particularly the case for greengram, grown in Maradagi during the on-farm trials. Repeat experiments would further strengthen the findings.

Navalur

At Navalur, the indicator crop used was potato. Content of N, P and K of the soil before and after the season, and of potato tubers, was analysed. The strongest relationships were between potato yield and mineral nutrients taken up. In the case of N, a quadratic regression (Figure 3.7) explained 87% of the variation in tuber yield. All the terms in the regression (constant, linear and quadratic) were highly significant. Significant linear relationships were found between potato yield and P and K uptakes. However, as there were no significant relationships between potato yield and %N, %P and %K contents, it is not possible to say which is cause and which is effect. What these analyses do indicate is that availability of N, P and K were not likely to have been factors limiting yield in 1999. Rainfall was good and yields higher than the norm, but nevertheless potato has a high water requirement, and this was probably the limiting factor. This would indicate that the main advantage of applying MSW and pit compost would be to increase infiltration of rain and the proportion of soil water which was available to the crop. Figures 3.7 to 3.9 illustrate these relationships.

Figure 3.7 Nitrogen uptake and potato yield

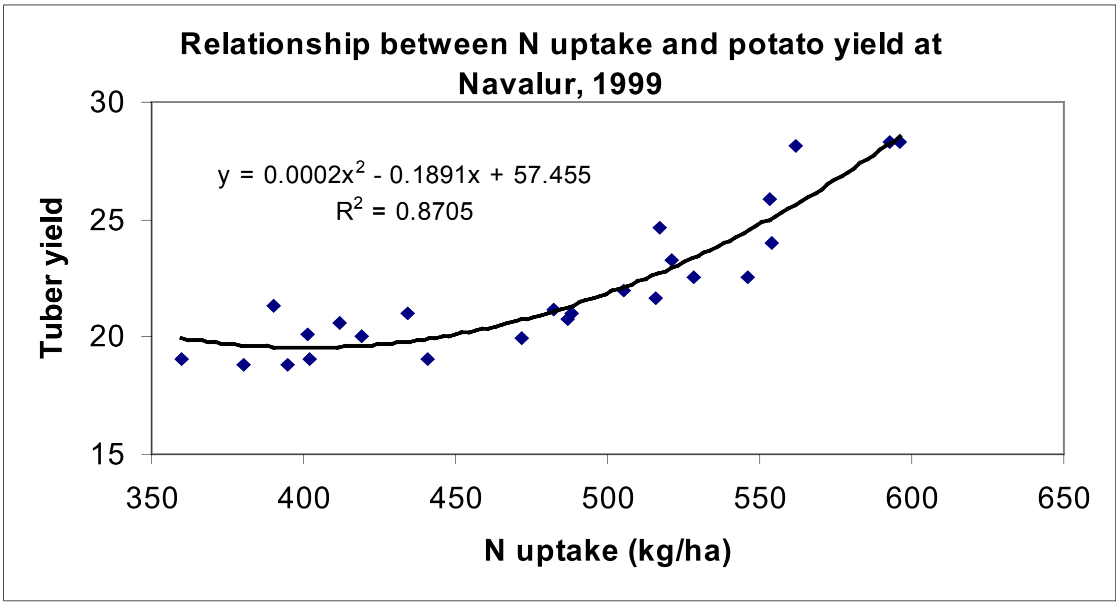


Figure 3.8 Potassium uptake and potato yield

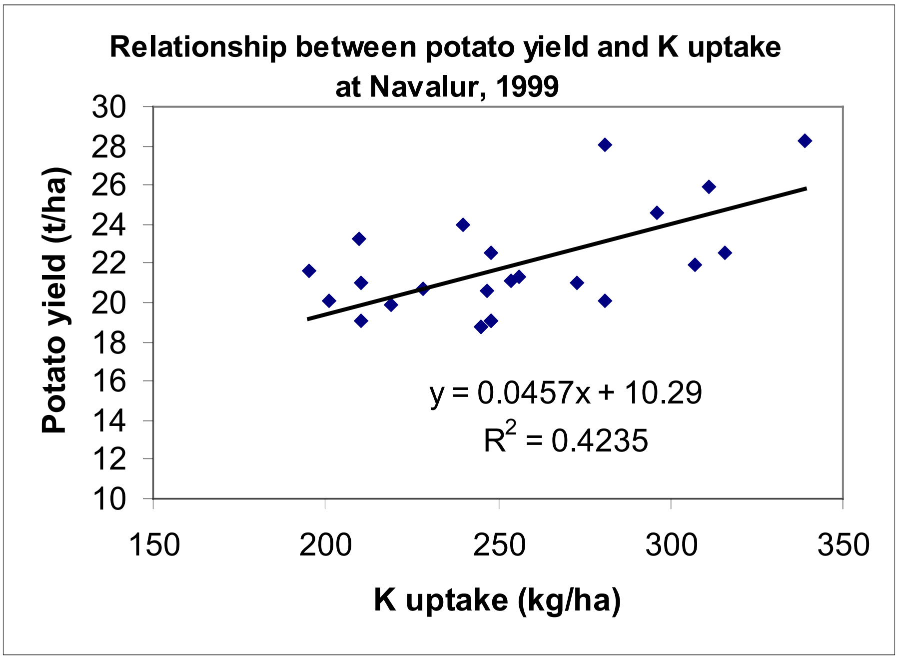
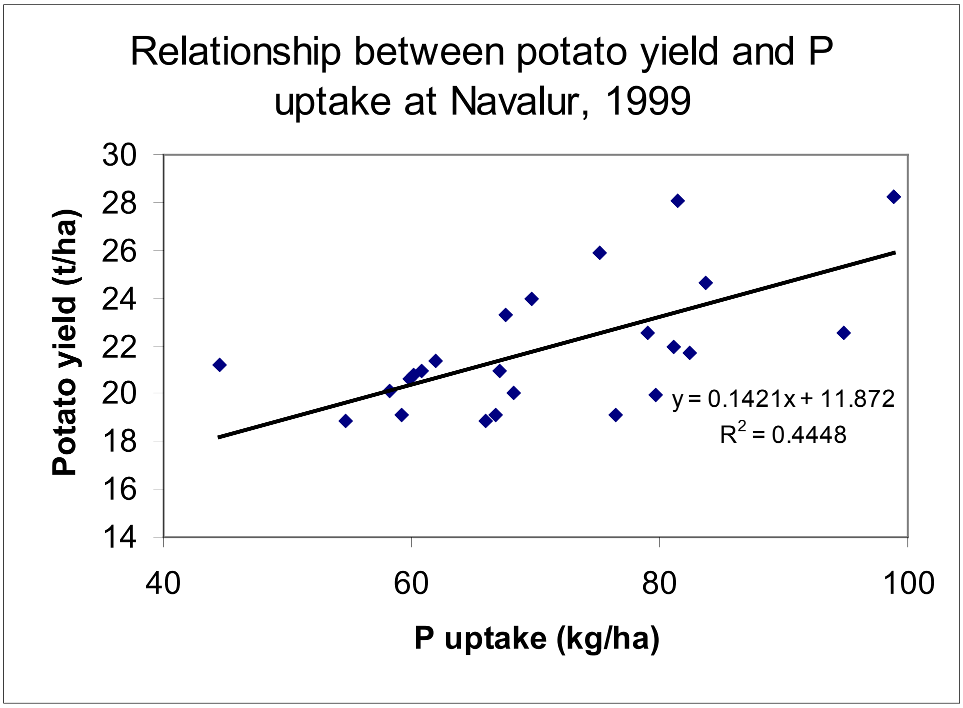


Figure 3.9 Phosphorus uptake and potato yield



Maradagi

Although the effects of compost treatments upon yield of green gram were not significant in Maradagi, there were significant effects upon quantity of P and K taken up by the crop seed. There were also significant effects of treatment upon %N, %P and %K content of green gram seeds, as shown in Table 3.6.

Table 3.6 Effect of MSW derived composts upon seed yield of green gram and nutrient uptake in Maradagi on-farm trials

Treatment	Green gram seed yield (kg/ha)	N uptake (kg/ha)	P uptake (kg/ha)	K uptake (kg/ha)	%N	%P	%K
MSW	485	17.5	1.34	4.81	3.60	0.28	1.02
MSW + DS	407	14.9	1.38	4.16	3.64	0.34	1.05
MSW + V	497	18.7	1.82	5.53	3.78	0.36	1.12
MSW + NS	534	20.2	1.99	7.53	3.78	0.36	1.23
Farmers' practice	427	15.8	1.11	4.01	3.68	0.26	0.95
Level of P	0.251	0.154	0.004	0.019	0.013	<0.00	0.004

In terms of uptake of P and K, and %N, %P and %K, there is evidence of a clear positive effect of MSW + vermiculture and MSW + night soil, although in the event these were not reflected in crop yields. Nonetheless, these results are indicators that sorted MSW either vermicomposted or with nigh soil added increase the nutrient status of crops. The lack of an effect upon crop yield may have been a function of rain fall, although there are no records to support this hypothesis.

As was found in Navalur, were positive correlations between crop yield and nutrient uptake (Figures 3.10 to 3.12). In particular, the linear relationship between yield and N uptake was almost perfect, which is not surprising, given that green gram is a grain legume and its seeds are N accumulators. There was some evidence from the significant quadratic regression that at higher yields, there was some limitation to the uptake of K. However, relationships between crop yield and %N, %P and %K were weak. This indicated that, as for Navalur, it terms of crop yield and uptake of nutrients, it was difficult to uncouple cause and effect.

Figure 3.10 Phosphorus uptake and green gram yields

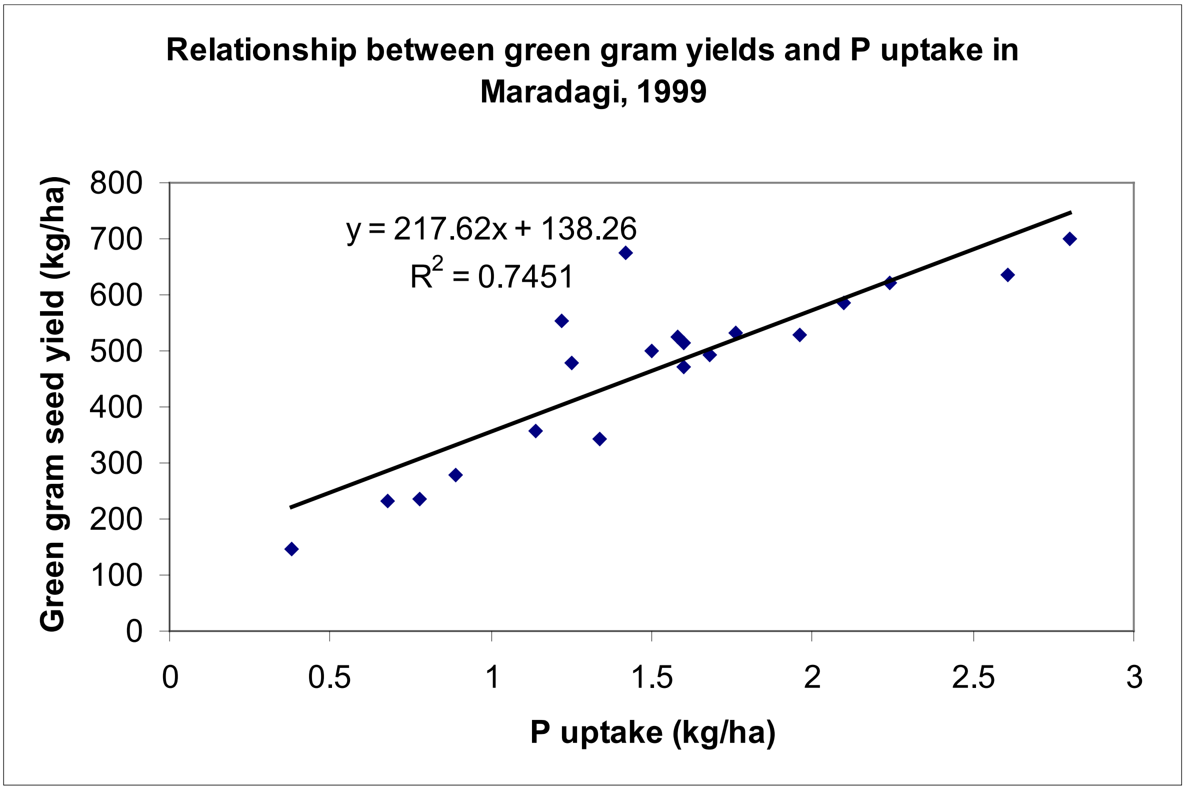


Figure 3.11 Nitrogen uptake and green gram yield

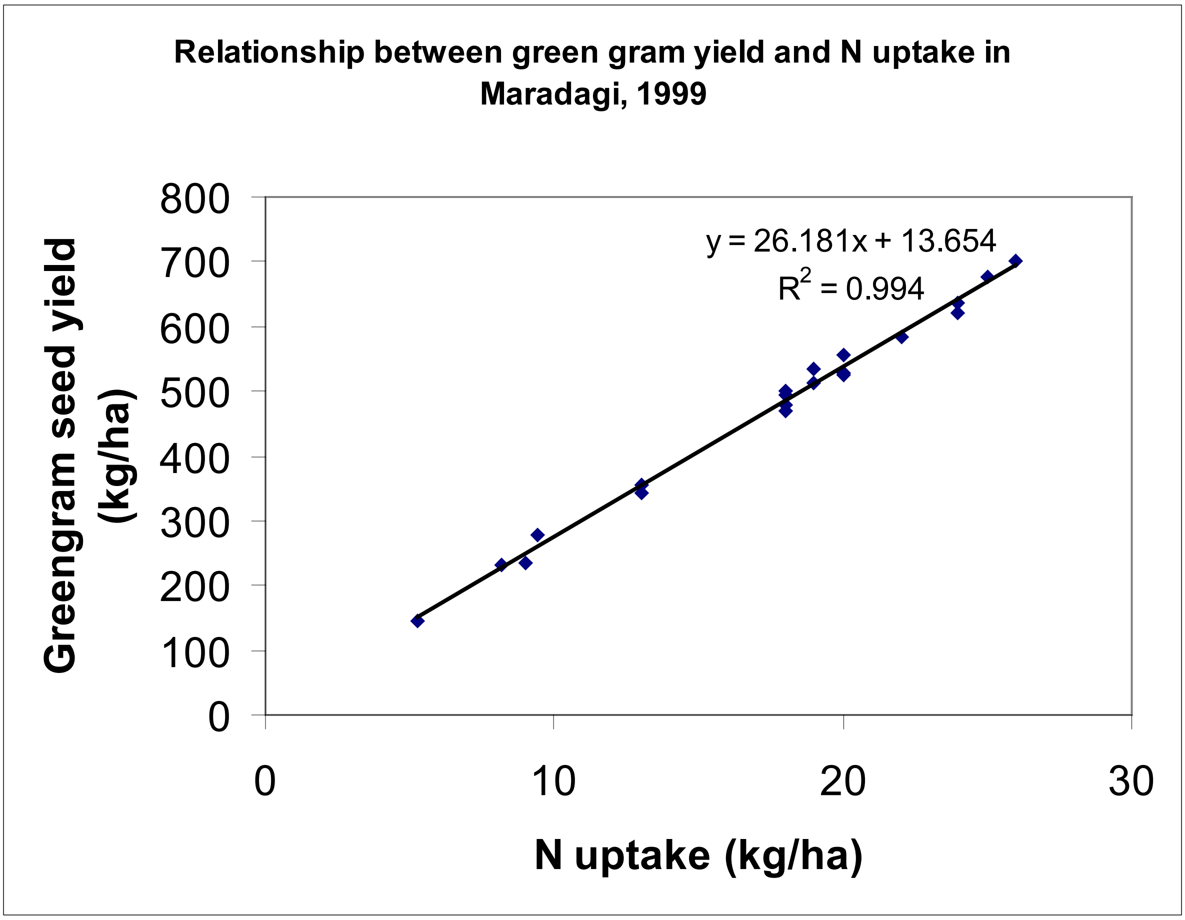
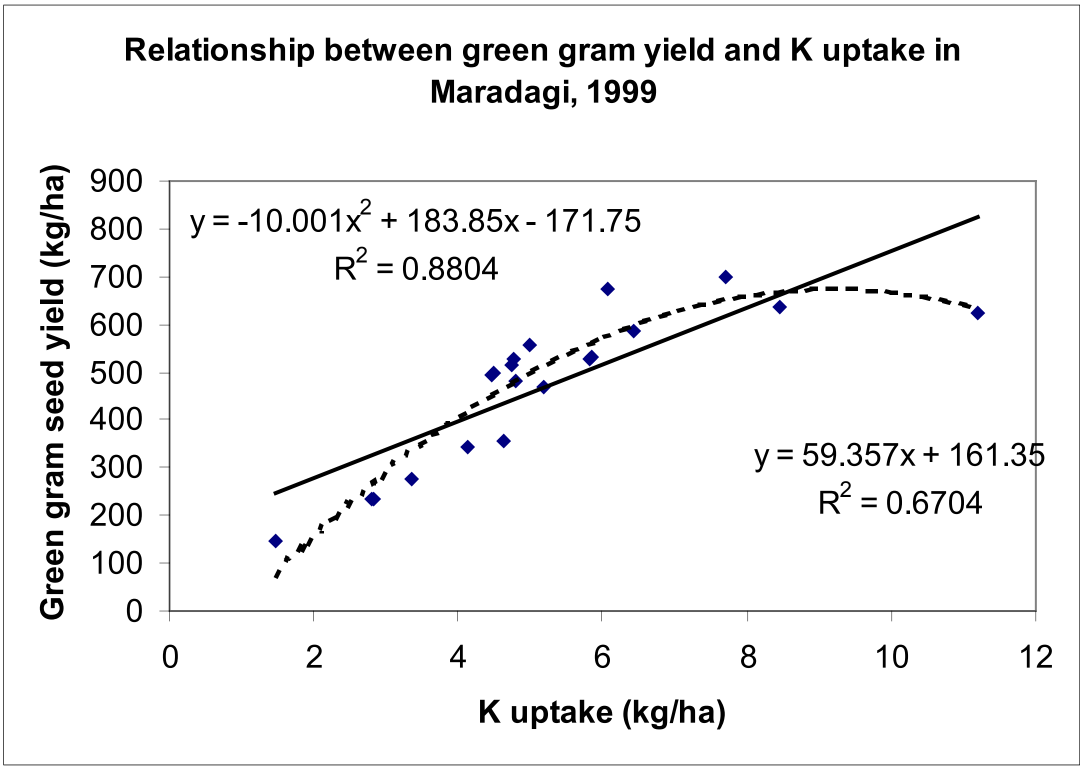


Figure 3.12 Potassium uptake and green gram yield



3.4.5 Labour employed

Tables 3.7 to 3.10 show an analysis of labour employed on the farms participating in the on-farm trials. Potato crops are most labour intensive, followed by paddy. This reflects the particular activities associated with potato crops and the price obtained for the crop that allows farmers to employ external labour. Women are mainly involved in weeding and harvesting and earn less per day than men. Women earn between Rs.20-30 a day, compared to between Rs.20 to Rs.50 for men. Wages differ according to the type of activity and those that women are involved in tend to attract a lower wage.

Table 3.7 Employment and wages per acre for paddy, *Kharif*-99, Mugad

Name of the farmers	Land holdings
1. Kallappa Unakal	1.6 ha.
2. Basappa Annapanavar	2.0 ha.
3. Basappa Kumbar	0.8 ha.
4. Durgappa Mamatannavar	1.6 ha.
5. Nagappa Garag	1.0 ha.

Agricultural operations	Month	Men	Wages	Women	Wages	Family Labour				Total	Wages
						Men	Wages	Women	Wages	Labour	
Ploughing	May	3	60	-	-	1	20	-	-	4	80
Clod crushing	May	3	60	-	-	1	20	-	-	4	80
Levelling the land	May	2	40	-	-	1	20	-	-	3	60
Cultivater	June	1	20	-	-	1	20	-	-	2	40
Sowing	June	2	40	-	-	1	20	1	20	4	80
Application of pit compost	June	1	20	-	-	1	20	-	-	2	40
Harrowing	June	5	120	-	-	1	20	-	-	6	140
Laveller	July	1	20	-	-	1	20	-	-	2	40
Maintaining Water stand	July	2	50	-	-	1	25	-	-	3	75
Fertilizer application	July	-	-	8	200	-	-	1	25	9	225
Weeding	August	-	-	8	200	-	-	1	25	9	225
Weeding just before harvesting	August	-	-	4	100	-	-	1	25	5	125
TOTAL		20	430	20	500	9	185	4	95	53	1210

Total labour engaged per acre = 53 Total wages paid: Rs 1210

Men = Rs 20/day Total number of men engaged per acre = 29 Total wages paid: Rs 615

Weeding = Rs 25/day Total number of women engaged per acre = 24 Total wages paid: Rs 595

Table 3.8 Employment and wages per acre for potato, *Kharif*-99, Navalur

Name of the farmers Land holdings
1. Vittal More 2.8 ha.
2. Alam Savanur 2.8 ha.
3. Vaman Rao Shinde 1.2 ha.
4. Mallikarjuna Jagadale 4.8 ha.
5. Basappa Aralappanavar 0.8 ha.

Agricultural operations	Month	Men	Wages	Women	Wages	Family Labour				Total Labour	Wages
						Men	Wages	Women	Wages		
Transportation & application of pit compost	May	14	700	-	-	1	50	-	-	15	750
Ploughing	June	3	150	-	-	1	50	-	-	4	200
Harvesting	June	2	100	-	-	1	50	-	-	3	150
Sowing/Dibbling	July	10	500	-	-	1	50	-	-	11	550
Earthing up	August	4	200	-	-	1	50	-	-	5	250
Fertilizer application	Sept.	2	100	-	-	1	50	-	-	3	150
Weeding	Oct.	1	50	5	150	1	50	-	-	7	250
Harvesting	Oct.	10	500	5	150	1	50	-	-	16	700
TOTAL		46	2300	10	300	8	400	-	-	64	3000

Total Labour engaged per acre - 64- Total wages paid: Rs 3000
Men = Rs 50/day- Total Men labour engaged per acre = 54 Total wages paid: Rs 2700
Women = Rs 25/day Total Women labour engaged per acre = 10 Total wages paid: Rs 300

Table 3.9 Employment and wages per acre for greengram, *Kharif*-99, Maradagi

Name of the farmers	Land holdings
1. N.G.Hiremath	3.1 acre
2. Mallappa Mulimani	4.0 acre
3. Pakrusab Gudi	4.0 acre
4. Mallappa Kampli	0.5 acre
5. Nagappa Bellary	5.5 acre

Agricultural operations	Month	Men	Wages	Women	Wages	Family Labour				Total Labour	Wages
						Men	Wages	Women	Wages		
Ploughing	May	-	-	-	-	1	35	-	-	1	35
Harvesting	May	-	-	-	-	1	35	-	-	1	35
Land cleaning	May	-	-	-	-	1	35	-	-	1	35
Sowing	June	1	35	1	25	1	35	-	-	3	95
Weeding	July	2	70	2	50	1	35	-	-	5	155
Inter cultivation	July	-	-	-	-	1	35	-	-	1	35
Picking of green gram	August	1	35	4	100	1	35	2	50	8	220
TOTAL		4	140	7	175	7	245	2	50	20	610

Total labour engaged per acre = 20 Total wages paid: Rs 610
Men = 35 Rs./day Total number of men engaged per acre = 11 Total wages paid: Rs 385
Women = 25 Rs./day Total number of women engaged per acre = 09 Total wages paid: Rs 225

Table 3.10 Employment and wages per acre for groundnut, *Kharif*-99, Halyal

Name of the farmers	Land holdings
1. Shivappa Naikar	0.6 ha.
2. Mallikarjun Sattammanavar	3.3 ha.
3. Iswaragouda Kerimani	1.1 ha.
4. Somanagouda Naganagouda	0.8 ha.
5. Shankargouda Hiregouda	1.6 ha.

Agricultural operations	Month	Men	Wages	Women	Wages	Family Labour				Total Labour	Wages
						Men	Wages	Women	Wages		
Ploughing and Harrowing	June	4	100	-	-	1	25	-	25	5	125
Stubble collection & Weeding	June	4	100	2	40	2	50	1.20	70	9	110
Field broadcasting of FYM	June	4	100	-	-	1	25	-	25	5	125
Sowing and covering	June	4	100	-	-	2	50	1.20	70	7	170
Intercultivation and weeding	August	12	300	-	-	2	50	1.20	70	15	370
TOTAL		28	700	2	40	8	200	3.60	260	41	9000

Total labour engaged per acre = 41 (1000 Rs./-)
Men = 25 Rs./day Total number of men engaged per acre = 36 Total wages paid = 900 Rs./-
Women = 20 Rs./day Total number of women engaged per acre = 5 Total wages paid = 100 Rs./-

3.4.6 Availability and preferences for soil amendments

A number of conclusions can be drawn from the exploration of the availability of urban wastes, farmers' preferences for soil amendments, the results of the analysis of composts and the crop yield results. These include:

- Many farmers prefer organic soil amendments to artificial fertilisers as their residual effects last longer and they are better for soil structure and moisture retention.
- There is a concern about the availability of manures due to mechanisation of farm activities, and the resulting decline in the number of draught animals, and to the potential closure of urban dairies.
- The range of sources and uses of urban organic wastes illustrates the importance of understanding urban-rural interactions, both for policy-making to support agriculture and waste management in urban areas.
- The analysis of the MSW-derived composts did not point to any one compost as the best. The results are mixed in terms of nutrient levels.
- The MSW-nightsoil compost appeared to perform well in the trials, supporting the claims that when nightsoil was mixed with MSW, it was a better soil amendment than MSW alone. There is no immediate explanation for the better performance of the MSW-nightsoil compost that can be derived from the nutrient analysis.
- Vermicomposted MSW also produced good results compared to MSW alone.

In order to optimize the use of urban wastes in the villages studied, access to urban organic wastes should continue. In addition to considering subsidies (see Section 3.1), HDMC could consider:

1. Continuing to allow access to MSW for local farmers, whilst allowing access to MSW for the private sector.

This would have the benefit of enabling farmers to access untreated MSW at low cost, whilst enabling the private sector to sell high quality and cost products, but potential problems include:

- Acceptance by the private sector.
- Future availability of an adequate amount of decomposing MSW.
- The existence of price differentials.
- Would not solve the quality problems of MSW for local farmers.

2. Persuading the private sector or NGOs to get involved in separating and distributing waste, perhaps on a relatively small-scale ('decentralised composting') and produce composts of different content and quality (therefore at different costs).

This option should result in a larger, more local market, thereby supporting local farmers and food supplies for Hubli-Dharwad and HDMC could charge more for separated waste. Additions could be added to the separated waste, but another option that could be explored is farmers adding MSW to pit compost. Different types of composts at different prices may increase the cost of production, but would also ensure that less nutrient intensive composts are available for farmers unable to afford more expensive inputs.

There are potential problems with this option, including:

- The capacity and funding of local NGOs.
- The present effectiveness of waste collection in Hubli-Dharwad is questionable.

The options for adding nightsoil to MSW could also be considered. Indeed, at the final workshop, the Commissioner expressed his willingness to make nightsoil available to farmers. There are, of course, health concerns arising from the use of nightsoil that would have to be taken into account. Efficient and effective composting should ensure that using nightsoil with MSW is safe, but monitoring should take place. Whatever decisions are made regarding the use of organic wastes, they are, however, intricately linked to the management of waste within the urban area.

3.5 Managing waste

The composting trials conducted at SDM College indicated the land and labour demands required for larger scale operations. Appendix F provides details on the costs involved in generating the compost for the on-farm trials. The trials used pits to compost waste, which had the advantage of not using too much land and is a method used by most farmers in the area. Disadvantages include the difficulty of turning the compost, which implies that the waste would take longer to decompose than if a more aerobic system waste used. Alternative methods of composting MSW, such as windrow, could be also explored by HDMC and private sector contractors.

As noted at the beginning of this chapter, however, an integrated approach to solid waste management is required, rather than adopting a piecemeal approach to each problem related to solid waste. In summary, the current issues in managing solid waste in Hubli-Dharwad are:

- Inadequate collection of solid waste, based on the use of municipal bins, located alongside roads. Rubbish overspills onto pavements and roads, partly because people are reluctant to actually place rubbish in the bin as cows and pigs, in particular, feed in the bins. The result is unsightly, unhygienic and difficult to manage.
- Insufficient numbers of staff and vehicles to organise efficient collection.
- Dumpsites not managed in an environmentally sensitive manner and too close to residential areas. The dumpsite in Dharwad is now surrounded by residential areas, due to the expansion of the city, increasing the need for new locations to be found.
- Different types of waste are not collected separately. Until recently this included hospital waste, which made the use of MSW as compost more difficult and dangerous.

As noted in Section 3.2, HDMC is undertaking a range of initiatives to address some of these shortcomings. Through these initiatives, HDMC, along with NGOs, is raising awareness of solid waste issues within the city. It will take time to develop a more integrated approach, but it is critical to continue to raise awareness, and by doing so, raise willingness to co-operate in new systems and perhaps even willingness to pay more tax to improve the collection and disposal systems.

In addition to looking at solid waste management, policy areas such as the level of local taxes, especially property tax, and the distribution of finance between municipal activities could be explored. Could more money be raised locally to improve solid waste management? A systems approach should review waste as a resource and adopt a systematic rather than piecemeal approach to waste management.

Developing an integrated system requires recognition of the range of stakeholders involved in, and affected by, solid waste management in the city. Figure 3.13 illustrates the range of stakeholders involved. The Phase 1 Report (School of Public Policy *et al.*, 1999) provides further information on some of the stakeholders. It is critical, however, that as many stakeholders as possible are involved in decision-making. This should facilitate greater understanding of the roles of each stakeholder in solid waste. It is particularly important that urban livestock keepers and near-urban farmers are recognised as stakeholders in urban solid waste management, if markets for waste are to be fully understood and developed.

It is recognised, however, that different stakeholders have differing degrees of access to decision-makers and differing levels of knowledge and resources. Waste pickers, for example, are at the bottom of the 'hierarchy' of solid waste actors and would certainly have less access to decision-makers and less power than private sector contractors. This will, inevitably, be reflected in decision-making processes, but there are mechanisms available to facilitate the inputs of all types of stakeholders, with the use of intermediaries, such as NGOs, being one way forward. In addition, such consultation and involvement takes time, as well as money, and a balance should be struck so that decisions, and progress, are made. Figure 3.14 outlines how a decision-making process for integrated waste management could proceed.

Figure 3.13 Flow of urban waste between stakeholders

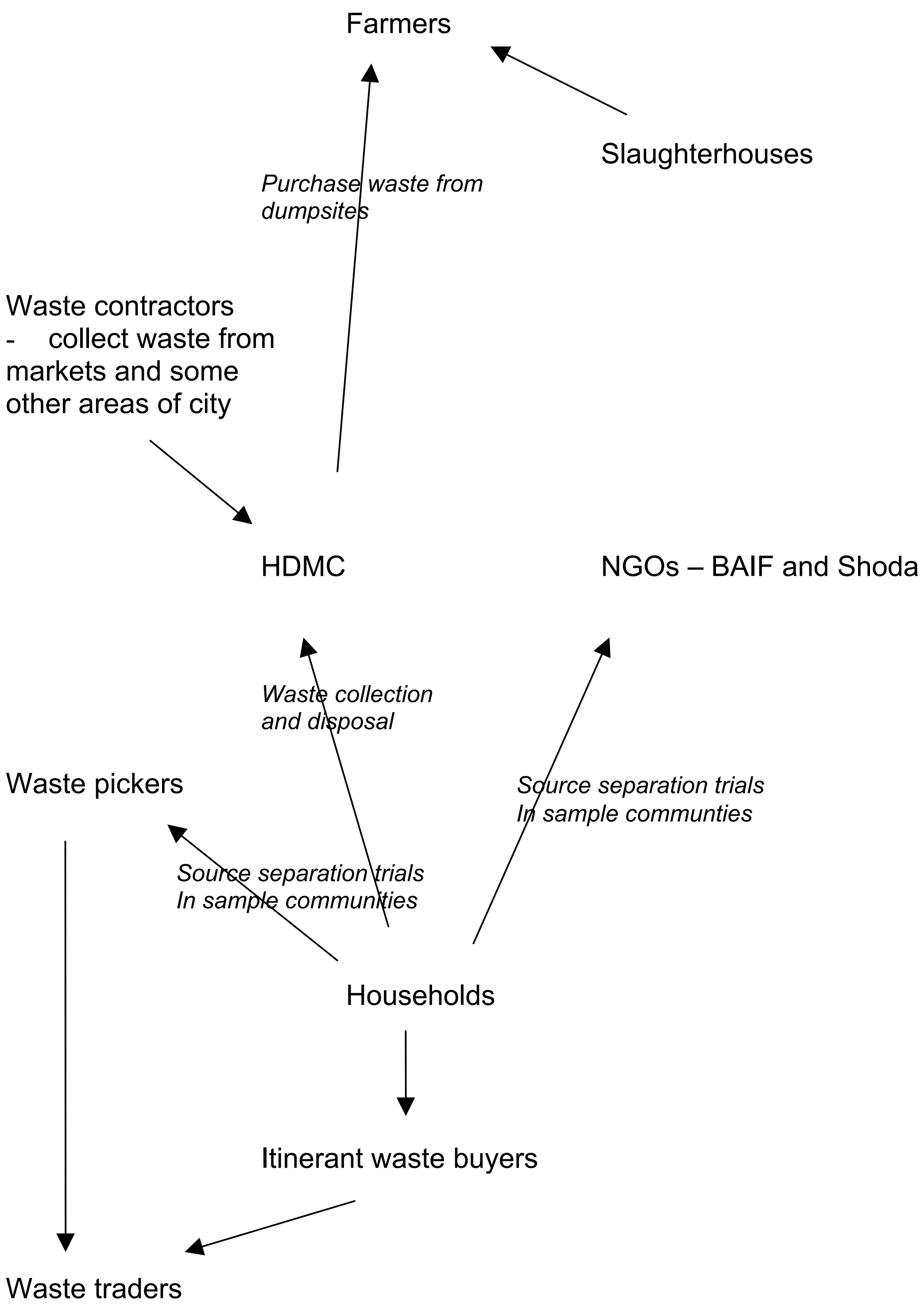
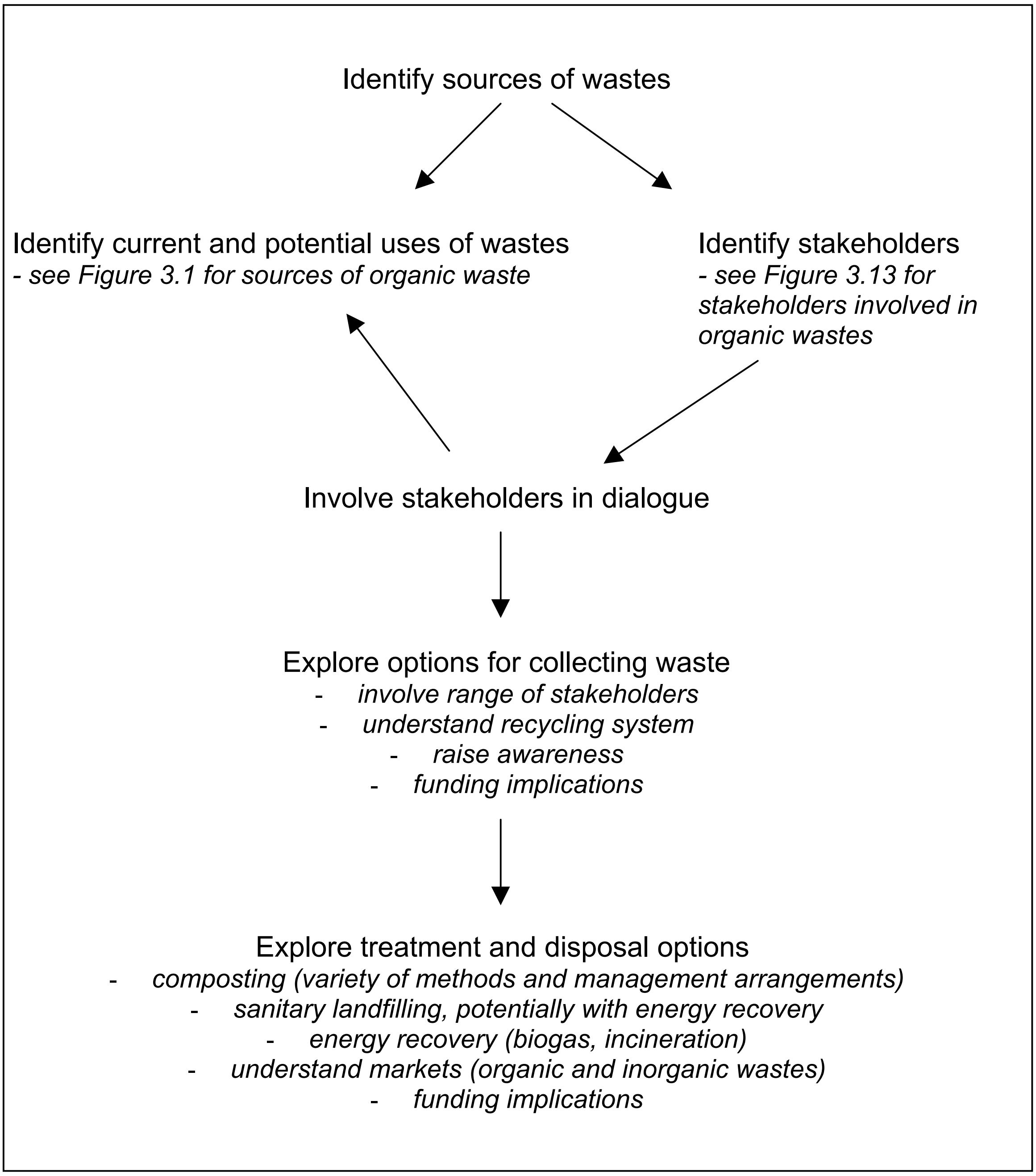


Figure 3.14 Decision-making for integrated waste management



In conclusion, the research indicated that alternative systems for managing waste would include:

- Processes to incorporate involvement of as many stakeholders as possible in planning and decision-making, whilst recognising the constraints of time and the need for decisions to be made.
- The development of an integrated approach to solid waste management which starts from the base of exploring the types of wastes generated in the city, and how much, leading into an understanding of present uses of organic wastes and how these can be supported.
- An integrated approach to solid waste management would usefully consider the role of wastewater in soil fertility management and look for complementarities in terms of management and access in the future.
- Raising people's awareness and willingness to co-operate in new initiatives will take time and perseverance.

3.6 Marketing strategies

As noted previously, MSW was sold in the past through an auction system at Dharwad dumpsite, owing to the existence of pits. No auctions have been held since 1997 due to the lack of staff to prepare the pits. MSW is now sold from both Dharwad and Hubli dumpsites by the tractor load (around one and a half tonnes), presently sold at Rs.30 per load. A detailed description of the auction system can be found in the Final Technical Report of the Baseline Study (University of Birmingham, *et al.*, 1998).

Map 2 shows the location of some of the villages where farmers have purchased MSW. Records of purchases are not complete, and have not been kept at all at Hubli dumpsite, but it is readily apparent that the farmers purchasing MSW come from villages to the east of Hubli-Dharwad. This information came from records kept for waste sold at Dharwad dumpsite and from interviewing farmers. This pattern can be explained by a number of factors, including:

- Soil type – vertisol (black cotton) soils are found in the east and alfisol (red) soils in the west. The high montmorillonite clay content of the vertisol soils results in reduced workability when wet and can be improved by the addition of MSW as it is generally found on flat land, making access by tractors easier. Alfisols have lower clay content in surface horizons and have less need for amendments to improve workability.
- Related to soil type are the types of crops grown. Villages where crops are grown on a more commercial basis are more likely to purchase MSW. Apart from mango (grown on alfisols around Hubli-Dharwad), the majority of cash crops are grown on vertisols (cotton, potato, onion, chilli). MSW is not used on mango.
- Accessibility of the dumpsites from the villages.

The main advantages of the auction system for selling waste included the high income raised for HDMC and the pits being sold at the same time, reducing the administrative demands on HDMC from the sale of MSW. The price of the pits varied between Rs.480 (the lowest bid price between 1986 and 1996) and Rs.2110 for a pit in 1992 that contained slaughterhouse waste. Each pit has a capacity for 10-15 tractor loads, that is, between 15 and 22.5 tonnes. At present prices, a pit would cost between Rs.450 and Rs.900, though the price may be higher for pits containing slaughterhouse waste. Now that farmers can approach HDMC individually to purchase MSW, they can do so at a time most convenient to themselves, and can purchase less than one pit at Dharwad dumpsite.

As noted in the Inception Report, there are few examples in the literature of the sale of urban waste to near-urban farmers and no reference has been found to the use of auction systems. News of the willingness of HDMC to sell MSW outside the auction system from Dharwad dumpsite was advertised and has spread through word of mouth.

Any changes in marketing are likely to come about from changes in the management and treatment of MSW. The private sector contractor sells the compost produced through Rallis India to other states in India and to other parts of Karnataka. As the practice of purchasing MSW is historical in the Hubli-Dharwad city region, increasing the sale of MSW is dependent more on improving the quality of the MSW, particularly by decreasing the amount of contaminants, than on changing marketing systems. However, knowing more about farmers preferences for MSW as a soil amendment will help in decision-making for treating and pricing waste-based composts.

3.7 Conclusion

The research has highlighted many issues for consideration and has identified a number of ways forward to support the use of urban organic wastes by near-urban farmers. Critically, an integrated approach to urban waste management is needed, that recognises the roles of livestock keepers and farmers, would incorporate approaches to separate waste materials, manage the waste in an environmentally sustainable way and would consider effective ways to market waste.

Other conclusions arising from the research include:

- Separation of waste materials is a very difficult area to solve in a cost-effective manner. The involvement of a range of stakeholders is needed, as is perseverance in raising awareness.
- There are a range of options to maintain access to MSW by near-urban farmers, including subsidising composts produced by the private sector, producing a range of composts (including one with no additives), providing a range of composts at different prices and maintaining access to both farmers and private sector.

- Adding nightsoil to MSW could be a good way to increase the nutrient content of MSW and crop yields. Further health issues and management issues would have to be explored.
- Marketing the waste does not appear to be the most important issue in Hubli-Dharwad. The main problem is to improve the quality of the MSW (principally by removing contaminants).

The aim of developing an integrated approach should therefore be to maintain access to MSW by near-urban farmers, whilst improving quality, the collection service in urban areas and the environmental standards of disposal. It is a challenging agenda; one facing local governments in many countries. Involving stakeholders and raising awareness has to be a key part of the way forward.

4. Contribution of outputs

4.1 Contribution towards DFID's developmental goals

DFID developmental goals are now led by the key objective of poverty reduction. In Chapter 1 of this report, it was noted that this project commenced prior to the development of the revised logical framework of the Peri-Urban Interface (PUI) programme.

The goal of the revised PUI research programme is to improve the livelihoods of poor people through sustainably enhanced production and productivity in renewable natural resource (RNR) systems. The use of organic wastes certainly contributes to more sustainable agriculture by improving soil structure. This research has generated a significant amount of information on farmers' preferences concerning soil amendments and on the constraints and opportunities presented by the use of urban waste as a soil amendment. However, the research has not fully solved the issue of access to MSW by poor farmers. This is because:

- They may farm in more marginal areas, where access by tractors to fields is difficult.
- They have not purchased as much MSW in the past, due to the cost of hiring tractors and labour to sort waste.
- Farmers with small areas of land and limited alternative livelihood options tend not to grow cash crops, and the project found a strong link between application of MSW and growing cash crops. Whether this has always been the case was not ascertained.

From the research, it appears that the willingness of small farmers to invest in accessing MSW may increase if the waste was sorted, and perhaps enriched, though this may be too expensive. There is also the possibility of subsidising enriched MSW by the Corporation to make it more accessible for low-income farmers. These possible options were discussed in Chapter 3, which concluded that

- Private sector or non-governmental organisations could become involved in separating waste rather than, or as well as, composting. This would relieve the Corporation of the problem of segregating waste whilst providing a better product (separated waste).
- Once separation of waste has been improved, composting could take place on a smaller scale than envisaged, or could be carried out by farmers themselves, perhaps mixing the MSW with pit compost.
- A range of composts could be produced to reflect the purchasing power of different farmers and different requirements.

In view of the range of activities HDMC is pursuing (see Section 3.2), there may be more scope for achieving segregation of waste. This is critical to achieving good quality compost.

The research also contributed to capacity building within the participating institutes of the research team in India. The research made use of some participatory research techniques and emphasized the role of the farmer in the on-farm trials. These were new approaches for the research team. The research was also interdisciplinary and required consideration of social and economic information, as well as drawing on skills and knowledge from agronomy, soil science and engineering. Over the course of the two years, the team gained a lot of research experience and worked well together.

4.2 Dissemination and promotion pathways

Mechanisms to disseminate research findings and to develop promotion pathways have been initiated throughout the project. Both the Inception and Phase 1 reports recorded the activities undertaken in this respect. Activities undertaken throughout the project include:

- Meetings between team members and the Commissioner of HDMC and other HDMC staff. HDMC is responsible for solid waste management in the urban area and, as discussed in Section 3.1, the Commissioner has demonstrated commitment to improving the management of solid waste within the city.
- Meetings with other institutional stakeholders, such as the Joint Director of Agriculture in Dharwad and local NGOs involved in waste activities (including the trial source separation scheme and working in villages to promote vermicomposting).
- Dissemination of reports to a range of stakeholders, including HDMC and local NGOs, but also to organisations working on waste issues in other parts of India and in other countries. These include Wastewise in Bangalore (working with waste pickers and communities in source separation schemes), WASTE and EPAT (Environmental Protection and Technology) in the Netherlands, and the Department for Water and Sanitation in Developing Countries (SANDEC) of the Swiss Federal Institute for Environmental Science and Technology (EAWAG) in Switzerland. Reports were also sent to the Indian Council on Agricultural Research (ICAR) in Delhi, which is working in peri-urban areas of Delhi.
- A range of articles have appeared in practitioner and NGO-type journals, including *Biocycle*, *International Agricultural Development* and *Landmark*. These journals will be approached with short articles outlining the key findings of the research to follow up the original articles.
- A summary of the objectives of the research was posted on the website of the International Development Department (IDD), University of Birmingham, and on the Cities Feeding People website, run by the International Development Research Centre in Canada.

The Commissioner of HDMC, Mr Vastrad, expressed interest in this research from the outset and has supported the project through allowing the team to collect MSW from Dharwad. As well as receiving published reports from, and having meetings with, the research team, a visit report was written for the Commissioner after the visit by the UK team in March 1999. One point raised in this report was the concern of farmers over the existence of hospital waste, such as syringes, in MSW. This contributed to the Commissioner acting swiftly to start collecting hospital waste separately from MSW from September 1999.

The Commissioner has undertaken many initiatives in the area of waste management in Hubli-Dharwad and has attended several meetings on the issue. These include a workshop arranged by the Government of India to disseminate the interim findings of the Supreme Court on solid waste management and a roadshow organised by the World Bank in Bangalore. The Commissioner is keen to support local farmers use of MSW.

Indeed, the two workshops organised by the research team have been attended by farmers and staff of HDMC, including the Commissioner. These provided a neutral forum for dialogue between the two parties and have contributed to farmers learning more about MSW and the Commissioner and other HDMC staff learning more about farmers' preferences.

The research team met with many farmers in the four villages and have had dialogue with farmers beyond those involved in the on-farm trials. This has raised awareness about the issues surrounding the use of MSW as a soil amendment. The on-farm trials also raised interest in how much better sorted MSW is than unsorted, which may lead to greater interest in using MSW and to greater pressure put on HDMC to act.

In terms of wider dissemination, the journal articles, published in *Biocycle*, *International Agricultural Development* and *Landmark*, and electronic dissemination led to interest in the research expressed by a number of organisations. This led to email exchanges on research projects and to exchanges of reports.

The experience of the project leader gained from the research was instrumental in being commissioned to write a paper on urban agriculture in Hubli-Dharwad for ETC in The Netherlands. Although this was a broader study of urban agriculture, the work built on the research project and demonstrated the scope for further work in the city.

In terms of future dissemination, a final report will be sent to stakeholders in Hubli-Dharwad and to organisations that have expressed interest in the research. Summaries of the findings of the research will be posted on the IDD website and passed to ID21. Other potential means of dissemination via websites will be explored. The research team will also submit articles to academic journals in both the UK and in India.

4.3 Further action and research to promote the findings

The research has generated knowledge and information that can be taken forward in Hubli-Dharwad and in other South Asian cities. Indeed, although information has been gathered about the use of MSW by near-urban farmers in the Hubli-Dharwad city-region, there remains little information about practices in other parts of South Asia that could usefully lead to policy developments. This could be rectified through further research, but also through a conference on the use of urban waste, perhaps in relation to urban agriculture.

The results from the on-farm trials would benefit from further validation through repeat experiments, particularly on the MSW-nightsoil compost and the vermicomposted MSW.

In terms of the new logical framework, further research could be supported to explore the potential of small-scale composting schemes and on-farm processing, whilst taking into consideration the time and resource constraints of small farmers. This research project has acknowledged production issues that face the poor and has worked with small farmers where possible. Further information, however, on the nature and scale of poverty within the peri-urban interface of Hubli-Dharwad and on the types of livelihood strategies of the poor would ensure that future research on waste issues directly addresses their production constraints.

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Appendix A Logical Framework

NARRATIVE SUMMARY	OBJECTIVELY VERIFIABLE INDICATORS (OVI)	MEANS OF VERIFICATION (MOV)	IMPORTANT ASSUMPTIONS
GOAL: Productive potential increased by greater use of "waste" materials and recycling of resources.			
PURPOSE: Technologies and management strategies to increase production of commodities in peri-urban areas using solid and liquid waste as a fertiliser, soil ameliorant or feed developed and promoted			
OUTPUTS: 1. Strategy for improved segregation of urban waste developed to improve quality of waste for utilisation.	1. Pilot systems up and running by December 1998.	1. Progress and final reports. Reports to relevant parties, e.g. HDMC.	1. That strategies are taken up and contribute to increased production of commodities in peri-urban areas.
2. Development of a strategy for optimizing the use of municipal waste, livestock manure and, potentially, nightsoil, as soil ameliorants in sample communities.	2. Observation of farmers' soil management activities, commencing May 1998. Field trials on the use of urban waste, commencing April 1999. Measures of improvement explored e.g. farmer satisfaction, improvement in organic matter content of soils.	2. Phase 1 report, September 1998. Final report Final report	2. Findings have relevance to other city-regions of South Asia.
3. Alternative systems for managing the waste explored.	3. Composting trials commence on pilot basis, May 1998 Further trials by December 1998.	3. Phase 1 report, September 1998. Final report.	
4. Recommendations for improving the marketing of the municipal waste.	4. Recommendations made by May 1999.	4. Final report and reports submitted to HDMC and relevant NGOs and CBOs.	
5. Dissemination products e.g. booklets, radio programmes.		5. Wide and appropriate distribution of findings.	
ACTIVITIES: 0. Development of dissemination and uptake pathways.	BUDGET: Staff £47155	0. Inception and final reports.	

PHASE 1: January to September 1998	Overheads £14202 Travel £16375		
1. Literature review: soil fertility, waste segregation and auction systems, and nutrient quality of manure.	Miscellaneous £5150 SUBTOTAL: £82882	1. Inception report (May 1998) and Phase 1 report (September 1998)	1. Relevant work accessible and applicable.
2. Options for segregating waste explored through key informant interviews, surveys, participatory exercises and composting trials.	Plus VAT £14505 TOTAL: £97387	2. Phase 1 report (September 1998)	2. Options lead to strategy development.
3. Selection of sample communities according to size of holdings, income level and other poverty indicators.		3. Phase 1 report (September 1998)	3. Sample communities reflect population.
4. Observation of farmers' soil management activities during kharif season 1998.		4. Phase 1 report (September 1998)	4. Soil fertility issues correctly understood.
5. Analysis of soil fertility issues in sample villages in the peri-urban interface.		5. Phase 1 report (September 1998)	
6. Mini-workshop to review Phase 1 and plan Phase 2.		6. Report on workshop outcomes.	5. Findings from Phase I of research enable decisions to be made.
PHASE 2: September 1998 to September 1999			
7. Initiate trials for segregating the municipal waste, co-composting and on-farm application.		7. Inception report for Phase 2 (March 1999).	6. Costs of segregation of waste do not exceed market value of segregated and composted materials.
8. Development and testing of improved integrated management approaches for urban wastes and their use in farm level nutrient management strategies.		8. Final report.	7. On-farm trials produce conclusive results.

Appendix B Guidelines on matrix scoring

Taken from Appendix D of the Inception Report.

Matrix scoring helps us to:
- understand the criteria that different people use when choosing between different alternatives;
- explore the trade-offs made during the process of choosing;
- highlight the criteria that are high (best) and low (worst) for any particular item.

Think about two aspects before you do this in the field:
- How are you going to help illiterate people do it?
- How are you going to record all the information that they give you through the debate?

This is one of the biggest problems with those who have little PRA experience - very few people really note down all the detail of discussions.

What to do:
1. Ask the informants to list all the soil amendments which they know of; prompt them with examples, and add ones which they may not be using but which you want to know their attitudes to.
2. Find out the criteria for each soil amendment, with open questions such as
   - 'What is good about it?'
   - 'What is bad about it?'
   - 'What problems do you have with this one?'.

   Avoid prompting them - find out what they consider to be important.
3. List all the criteria, and turn the negative criteria into positive ones, so that a high score is always good. For example if one criterion is 'smell', and a compost 'smells bad', turn this criterion into 'smells good' so that the other composts score highly, and the bad one scores low. The same applies to 'cost'. A low score means that are unhappy with the cost (i.e. it is expensive), while a high score means they are happy with the cost (i.e. it is cheap). Ask questions to make sure that the farmers understand the scoring system.
4. Draw up a matrix with the criteria across the top and the different soil amendments down the side.
5. Ask the informants how well each criterion is fulfilled by each soil amendment. You can ask them to use beans, stones or other objects to make piles in the boxes. Score on a scale of 1 to 5, 1 meaning they are least happy or satisfied, and 5 meaning they are most happy or satisfied with that soil amendment. If they leave any boxes empty, ask them why. If it is due to no experience of that soil amendment, record it in your note book.
6. You will need to ask open questions and probe, just as in semi-structured interviewing. You can help the discussion by asking, for each criterion, 'which one is best?', 'which is next best', 'which is worst', etc.
7. Copy the matrix into your note book, and at the end of each person's turn, write down the total number of stones or beans in each box. Clear the matrix and start again with the next farmer.
8. Even more information can be gained by interviewing the matrix: ask the respondents why they have chosen to put many, or few stones, in the boxes. If there are differences between people or groups, ask them why.

The opinions of men and women may be different, so conduct this exercise with two separate groups. It is not a good idea to add up all the scores on the matrix, because it implies an equal weighting for each criterion.

You could add more detail to the analysis, by asking the respondents to rank the various criteria before doing the scoring. This gives you some idea of which scores are most significant.

Matrix scoring can be a lengthy procedure, so choose a time of day when people have enough leisure time to do the exercise.

After one of these group activities, ask if any small or marginal farmers would be willing to take part in a monitoring exercise until the end of the kharif season. Arrange a time to see each one in the field.

Appendix C Social maps of the four villages

Appendix D Guidelines on visits to farmers

Taken from Appendix D of the Inception Report.

Visits to individual farmers in the field
At the first visit, ask if the farmer understands what the project is about, in case they misunderstood during the first meetings. Before moving to the field, ascertain some general information about their farm:

- Area of land farmed
- How many work on the farm?
- How many work off-farm?
- What kind of soils do you have here?
- Are they good soils?
- How do you tell whether the soil is good or bad (to find out the farmer's method of assessment)?
- What problems do you experience with the soils?
- What do you do about these problems?
- Where do you obtain soil amendments?
- What prevents you from using more?
- Do you have access to transportation (tractor/trailor)? Do you own one or have you hired or borrowed one in the past? How much does hiring one cost? What would you hire one for?
- How do you tell if your crop is going to be good or bad?
- At what stage (how soon) can you tell this?
- Will you do anything about problems with the crop?
- What?

At this point, ask the farmer to draw a resource flow diagram (on paper, or on the ground if the farmer is ill at ease with paper, using symbols such as leaves or stones). Researchers should explain that they would like to understand better how the farmer manages resources available to him or her, and that it would be helpful if we could see this visually.

- Do not draw the diagram yourself.
- Ask questions during the process to take attention away from the farmer's drawing skills.

Move to the field. Ask the farmer to draw the farm. Record this in your notebook, asking the following questions:

- What will the farmer grow in each field this kharif season?
- Is the soil good or bad in each field?
- Will he/she try to improve it?
- How?
- When?

Decide which fields to ask the farmer to monitor. Choose ones with similar crops, if possible (see point above), but at different stages in the fertilising/manuring cycle (e.g. fields which had compost one, two and three seasons ago). This sort of decision will have to be made on the spot, but try to prepare yourself for it by ascertaining what the farmer grows in advance. Ask if the farmer is willing to let you take a soil sample from each field that will be studied. Take samples in the ordinary manner, and label bags clearly. Also put a sub-sample in the plastic tubes left for the purpose. Label clearly with date, farmer's name and field name or number. These will be collected during the next visit by a member of the UK part of the team, for further analysis in Bangor.

Thank the farmer for his/her time, explaining that future visits will be much shorter. Arrange a time for the next visit.

Further visits

One visit before crop sowing is adequate. After sowing, visit each farmer on a once a fortnight cycle, if this is appropriate and convenient. Where possible and applicable, talk to men and women separately. They often have different views. Ask:

- What have they done since your last visit?
- Have they encountered any problems?
- Have they been able to do anything about the problem?
- How is the crop progressing (for each field)?
- How do they judge the soil/crop? Ask them to demonstrate.

Try to keep each visit brief. After each visit, thank them for their time, and arrange the next visit.

Appendix E Sampling programme (February – November 1999)

1) SDM compost pits (Feb - May)	
Original sample	= 1
4 pits x 6 times	= 24
Subtotal	= 25 compost
2) Before season (May)	
Baseline sample x 4 villages	
x 5 farmers	= 20 soil
3) Start of season (May - June)	
Sample farmers' soil ameliorants	
applied by farmers: 4 villages	
x 5 farms (pit compost or MSW)	= 20 compost
4) Mid-season (August - September)	
Mugad + Navalur samples from	
last kharif season site x 5	= 10 plant
All four villages x 5 farms	
x 4 plots + 1 control	= 100 plant
4) After season (November)	
Sample all plots from where	
crop samples were taken	= 110 soil
Total sampling =	45 compost 110 plant 130 soil

Appendix F Economics of compost preparation

For on-farm trials, it was estimated that about 10 tonnes of sorted MSW was needed, taking into consideration about 60% of non-degradable matter in MSW, so it was decided that about 25 tons of waste would be collected.

Eighteen truckloads of waste were collected over a period of 15 days which, when sorted, resulted in about 10 tonnes of waste. The economics of this trial are presented in Table F.1.

Table F.1 Costs associated with preparing compost for on-farm trials

Activity	**Cost**
Freight charges for transportation of waste at Rs500 per trip	9000
Freight charges for transportation of distillery waste	500
Freight charges for transportation of nightsoil (2 trips)	800
Labour costs for sorting waste (4 for 15 days @ Rs.75)	4500
Labour costs for filling pits (2 days per pit, 4 people @ Rs.75)	600
Labour costs for mixing (2 people per pit for 2 days @ Rs.75)	600
Labour costs for unloading distillery waste (2 x Rs.100)	200
Labour costs for unloading nightsoil (2 x Rs.200)	400
Removal of non-degradable waste @ 2 people per day for 15 days	2250
TOTAL:	**19450**

To prepare 10 tonnes of composted waste, it took 27 tonnes of waste, 15 days to collect the waste and cost approximately Rs.20,000. This works out at Rs.2000 per tonne, which is very expensive compared to unsorted waste. The high costs are due to freight charges and labour costs. Such an activity done on a larger scale would reduce costs by having a more systematic system of waste collection, sorting and disposal.

Response to reviewers' comments

1st February 2000

Reviewer 1

Point 10: *What is the likelihood of uptake by target institutions and beneficiaries?*

There was close contact with some of the key actors, but work on the details and the further examination of options would help to improve the uptake. This is especially true if the poor are to benefit.

Point 13: *What additional action would you propose to support implementation of the findings?*

The further investigation of options which might benefit the poor.

Further investigation of the options could be conducted through pilot projects to develop mechanisms that will improve the access to MSW by small, poorer, farmers. Such mechanisms, however, would benefit from NGO involvement and there is not a strong NGO presence in the peri-urban areas. The potential for such pilot projects could be explored at a stakeholder workshop and a practical approach developed which addressed the constraints to the use of MSW by poorer farmers.

Reviewer 2

Point 4: *Where significant modifications have been made to Outputs or Activities in the course of the research, were these justified?*
Why were spatial variability and rates of compost addition not investigated?

It was evident after the Inception visit that farmers did not allow for spatial variability in fields when applying composts or fertilizer. Thus, the whole experimental design was changed. Rates of compost addition would have necessitated large on-farm trials, which would have been be too complex for a more participatory approach to on-farm trials. It was felt to be more worthwhile to invest any complexity in the research by examining several different composts instead. It was also felt that if the original design was followed, less relevant results would have been obtained as it would not have reflected farmers' practice.

Point 5: *Is the presentation and analysis of the results accurate and are the conclusions valid?*
In section 3.4.4 does %N, %P, %K in the various tables relate to plant, soil or compost?

The figures and analysis discussed in this section were derived from plant samples.

Point 6: *Has adequate attention been given to social science, environmental and bio-metric issues?*
It is stated pg. 14 that identification of farmers to be involved in on-farm experimentation was through the 'participatory' exercises. It is not clear how this was done.

Participatory exercises were conducted in each village, comprising of matrix ranking of soil amendments and mapping of the village. During, and immediately after, these sessions, small farmers were approached by team members through contacts in the village and asked to participate in the research. These contacts were village accountants, NGO staff (in one village) or Chair of the Panchayat.

Point 9: *Are the proposed means of promotion and implementation of Outputs satisfactory?*
The strategy for dissemination via web sites should be elaborated.

Summaries of the research will be posted on the website of the International Development Department (University of Birmingham), the City Farmer website and on the ID21 database. Other avenues for internet dissemination will be explored.

Point 11: *Are there other ways in which the research has or might contribute to meeting development needs (e.g. institutional development, training, technology transfer etc.)?*
The process of engaging stakeholders, if elaborated/documented may contribute to development.

The process of engaging stakeholders has not been separately documented outside the three reports of the research project. These reports have stated who contacts were made with, and why, and how contacts were maintained, such as through the dissemination of reports (the Inception and Phase 1 reports), meetings and invitations to the workshops. These activities ensured that stakeholders were encouraged to contribute to the development of the research at many stages.

I am not clear if there is innovation in the composting methods tested. If there is, then related dissemination materials would be useful.

There was no innovation in terms of composting methods. The method used was adapted from local practice.

Additional comments:

I found the FTR report interesting. The project attempted to implement an interdisciplinary research approach that considered the utilisation of urban waste in agriculture. It seems to provide a useful insight to the management of urban waste at Hubli Dharwad and claims to have a broader relevance. These generic themes (and the justification of why they are generic) do not seem to have been drawn out in the FTR.

Section 1.5 of the FTR summarised the findings from the literature review contained in the Inception Report (1998). The literature review highlighted several issues from research and experience elsewhere. These issues were used to inform the design of the research to ensure that the findings have relevance to other city-regions, particularly those in South Asia. In Chapter 3, several of the outputs related the experience in Hubli-Dharwad to other city-regions. There is no doubt that the problems associated with separating waste and producing a good quality, affordable, compost are problems facing many city regions. The strategies discussed in Chapter 3, therefore, have relevance to other city-regions.

It seems that the involvement of Hubli Biotechnologies may significantly affect the dynamics of this system. Whilst this was recognised in the FTR I am surprised that that representatives were not engaged as a key stakeholder / target institution.

The involvement of Hubli-Biotechnologies emerged as the research progressed. The company is owned by Mr Kubsad, who was invited to both workshops, but was only able to attend the Phase 1 workshop. Members of the research team also met with him on several occasions to discuss the issues relating to the use of urban waste with him (such as contamination of MSW, collection systems and marketing). A copy of a paper to be written from the FTR will be sent to him.

I was a little surprise that, given experience of most villages in composting, the project supplied composted materials to participating farmers rather than seeking to involve farmers in this activity.

The logistical complexities in getting 20 farmers across 4 villages to prepare 4 types of amended MSW to a consistent standard would have been beyond the ability of the team to manage. Even if it were done centrally for each village, 4 sites would have been hard to manage (particularly in terms of delivering nightsoil and distillery sludge to each village and sorting the MSW).

Village level production of new composts would increase the level of participation and ownership, but there would be a trade off with quality of data due to variability. Section 4.3 acknowledges that on-farm processing could be explored as a potential solution to some of the constraints to centralised composting. However, labour and transport constraints would have to be overcome.

The purpose of supplying MSW-treated composts was to explore the logistics and benefits of adding additional organics to MSW.

Description of the field methodologies is somewhat limited. For instance we are told that soil samples were collected to 15 cm. We are not told how, nor whether single sample or composite was taken etc.

Details of the soil sampling approach used were given in the Phase 1 report, particularly Appendix F. Composite samples were taken.

Farmers reported hardness as a consequence of using chemical fertilisers and that organic matter was being incorporated to ameliorate this. Given this observation I am surprised that soil physical measurements were not made. Indeed is a C, N or nutrient concentration of much value without also knowing bulk density?

This limitation becomes apparent where the team are left speculating that factors related to water availability and its interaction with soil physical properties determined the outcome of the field trial.

The simplest instrument to use in these circumstances is a penetrometer. Unfortunately, the Department of Soil Science of the University of Agricultural Sciences, Dharwad, does not have one.

The bulk density (specific gravity of undisturbed soil) is a hard value to obtain (undisturbed soil is needed and the soil must not be compressed during sampling). A value of $1.3 g/cm^3$ is often assumed. Although the value would have been useful, particularly for comparing the alfisol and vertisol soils, it would have had to be from below 20 cm. All the soil samples were taken above that depth.

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