# 4 WASTEWATER IRRIGATION: HUBLI-DHARWAD, INDIA

*Andrew Bradford[1], Robert Brook[2] and Chandra Hunshal[3]*

[1]Department of Geography, Royal Holloway, University of London, UK (A.M.Bradford@rhul.ac.uk)
[2]School of Agricultural and Forest Sciences, University of Wales, Bangor, UK
[3]Agronomy Department, University of Agricultural Sciences, Dharwad, India.

## Summary

Within the twin city of Hubli-Dharwad approximately 60 million l of wastewater is generated every day: this flows, untreated, from sewers and wastewater *nallas* (open drains) into the natural watercourses that flow into the city's hinterland (Hunshal *et al.* 1997). In the semi-arid climate, where the summer temperatures exceed 35 degrees centigrade and the monsoon rains are erratic and unreliable, the wastewater is an extremely valuable resource for urban and peri-urban farmers and many extract it from the *nallas* and underground sewer pipes to irrigate their crops. This is considerably cheaper than constructing a borehole, which makes the practice more accessible and attractive to farmers with fewer financial resources. The wastewater also provides an irrigation source during the dry season, which enables farmers to sell their produce for three to five times the *kharif* (monsoon) season prices (Hunshal *et al.* 1997), while its high nutrient load increases crop yields and also reduces the need for costly fertilizer inputs.

While this farming practice alleviates poverty for many urban and peri-urban farmers, it simultaneously places them, the consumers of their products and the environment at risk. The farmers have repeated close contact with the untreated wastewater, which is a major source of pathogens, and the high levels of anaemia found amongst them can be attributed to water-borne parasitic diseases and worm infestation. The wastewater also contains potentially injurious bio-medical waste (including disposable needles and syringes), which after tilling operations becomes half buried in the soils creating hazardous conditions for farmers that work in the fields. Unregulated and continuous irrigation with wastewater also leads to environmental problems such as salinisation, phytotoxicity (plant poisoning) and soil structure deterioration (soil clogging), which in India is commonly referred to as 'sewage sickness'.

Further examination of wastewater irrigation practices reveals a range of associated problems that threaten to outweigh the benefits. In particular, the improved crop yields are offset against a problematic increase in the incidence of pests, which are then controlled by the habitual blanket spraying of organo-phosphate pesticides. In addition to the pest problem, the high nutrient content of wastewater greatly increases the incidence of weeds. Weed control accounts for the high labour inputs that are associated with wastewater irrigated farming, as the main method of weeding is hand tillage. Within the household, women carry out these tasks; likewise when farm labourers are hired they are more likely to be women due to their cheaper labour costs. As well as perpetuating their positions as the poorest social group, this practice repeatedly exposes the women to the hazards of wastewater: pathogens and organophosphate pesticides.

The situation in Hubli-Dharwad highlights the failures of political policies rather than those of farming practices. The Ministry of Agriculture does not provide agricultural extension services to urban and peri-urban farmers and the Hubli-Dharwad Municipal Corporation fails in their legal requirement to treat the discharged wastewater and they are unlikely to implement such a programme in the near future on the grounds of cost. In this context farmers using wastewater should be encouraged and supported to adopt safer and more sustainable farming practices. This requires long-term support through participatory approaches, such as the use of farmer field schools, which empower farmers through education and training in sustainable agricultural practices, in addition, the benefits of this approach could be enhanced through public health education.

## 4.1 Introduction

In May 2001, a six-week study of wastewater-irrigated agriculture in the peri-urban areas of Hubli-Dharwad was undertaken (Bradford, 2002). The principle aim of this short study was to address some of Brook and Dávila's (2000) research recommendations by conducting a preliminary survey addressing the scope for integrated pest management (IPM) in the wastewater irrigated crop production systems that are located in the peri-urban areas of Hubli-Dharwad. The information gained from the study has now been used in the planning of IPM interventions for marginalised farmers on DFID Project No. R8084 'Enhancing livelihoods of the poor around Hubli-Dharwad'. During this study, additional information was gathered on the use of wastewater for agricultural irrigation. This not only provided greater understanding of the wide variations in cropping practices, but also highlighted several potential interventions that could mitigate the health and environmental risks associated with wastewater irrigation while contributing to poverty reduction.

#### *4.1.1 Hubli-Dharwad*

Hubli-Dharwad, in southwest India, is the second largest urban agglomeration in Karnataka after Bangalore, the state capital. The twin city was formed in 1962, when Hubli and Dharwad were brought together under the Hubli-Dharwad Municipal Corporation. Today, the bustling university city is a pivotal transport hub and home to 800,000 people. Hubli, the larger of the two is a regional centre for commerce, trade and industry, while Dharwad, located twenty-two kilometres away is the administrative centre and host to several prestigious educational institutions. The city has a rapidly expanding information technology sector alongside well-established commerce and service sectors, but despite this the traditional practice of agriculture in and around the city remains strong and continues to play an important social and economic role.

The climate of Hubli-Dharwad is semi-arid and the rainfall across the peri-urban area varies, exceeding 1000 mm to the west of Dharwad and less than 700 mm to the east; the mean annual rainfall is 740 mm (Brook and Dávila, 2000). In 1993, the percentage share of households connected to water, sewerage, electricity and telephone, were 38%, 37%, 74% and 8% respectively (Brook and Dávila, 2000). Households that are not connected to the piped water mains are dependent on either communal water taps or privately owned boreholes. Within the twin city approximately 60 million l of wastewater is generated per day: this flows, untreated, via sewers and wastewater *nallas* (open drains) into natural watercourses that flow into the hinterlands (Hunshal *et al.* 1997). In Dharwad, the main wastewater *nalla* flows to Madihal, once an outlying village but now incorporated as a suburb due to the expansion of the city. From Madihal the *nalla* generally flows east passing on peripheries of Govankoppa, Gongadikoppa and Maradagi villages. In Hubli, the main wastewater *nalla* flows to Bidnal, which is also now incorporated as a suburb. From Bidnal the *nalla* generally flows south passing on the village peripheries of Gabbur, Budarsingi and Katnur. In both Dharwad and Hubli smaller pockets of wastewater irrigation can also be observed in other areas of the city, however, the main areas of wastewater-irrigated agriculture are to be found along the two main *nallas*.

### 4.2 Methodology

A farming systems survey was conducted in May 2001 using semi-structured interviews and participatory rural appraisal (PRA) techniques. The first phase consisted of an orientation and familiarisation survey of the farming systems located along the main Dharwad and Hubli wastewater *nallas.* This provided an opportunity to make initial contact with the farmers thereby introducing the research project and identifying some of their main concerns, issues and constraints, in addition, the geographical extent to which wastewater is used for irrigation was also gauged. The results of the preliminary survey were used to select the peri-urban villages that would be targeted during the main survey; consideration was given to ensuring that a wide geographical area was covered in an attempt to identify spatial patterns and trends.

The second phase consisted of the main survey and incorporated semi-structured interviews; cropping calendars and on-farm transect walks. During the main survey a total of 25 farmers were interviewed, consisting primarily of smallholders with plot sizes below one hectare. In the peri-urban areas of Hubli-Dharwad, land ownership and occupations are the principle criteria used by the villages to describe characteristics of the poor (Brook, 2002). Indeed, many of the villagers themselves classify smallholders with plot sizes below two hectares as 'poor', while the landless – often employed as agricultural labourers – are classified as the 'very poor' (Hillyer *et al.* 2002). The interviews were supported with cropping calendars and transect walks with the farmers through the areas that were irrigated with wastewater; most of the interviews took place in the farmers' fields.

### 4.3 Wastewater irrigated agriculture

#### *4.3.1 Main cropping patterns*

Along the main Dharwad and Hubli wastewater *nallas* three distinct cropping systems are apparent: vegetable production; field crops with vegetables; and agroforestry. The spatial variation of the cropping systems results from a combination of factors which include labour availability, farm size, market access, village conformity and soil types, with the overriding aspect being the availability of wastewater itself. In the city and suburbs, where the wastewater supply is guaranteed, intensive vegetable production occurs. In locations where the supply is erratic and unreliable field crops and agroforestry predominate (see Table 1).

**Table 1 Spatial variation of wastewater irrigated cropping systems**

| Main nalla | Village | Distance (km) | Cropping system |
|---|---|---|---|
| | Madihal | 2.0 | Vegetable production |
| Dharwad | Govankoppa | 5.4 | Field crops & vegetables |
| | Gongadikoppa | 9.2 | Field crops & vegetables |
| | Maradagi | 11.85 | Field crops & vegetables |
| | Bidnal | 2.5 | Vegetable production |
| Hubli | Gabbur | 8.9 | Field crops & vegetables |
| | Budarsingi | 10.7 | Agroforestry |
| | Katnur | 13.5 | Agroforestry |

Note: Distance = length of the wastewater *nalla* from city source to village including any meander

### *4.3.2 Irrigation methods*

Regardless of the cropping systems used, the wastewater irrigation method utilized along the Dharwad and Hubli wastewater *nallas* remains the same; consisting of an overland flow and furrow irrigation system using centrifugal pumps powered by either diesel motor or grid electricity. The irrigation pump and diesel motor together constitute the highest investment cost; therefore they are often housed in small brick buildings adjacent to the wastewater *nallas* for security and protection against the elements. Wastewater is lifted from the *nallas* by means of the pump and delivered under pressure to the highest field elevation; the distance from the wastewater off-take to the actual outlet may reach up to 500 m. From the outlet point the wastewater flows under gravity along the furrows irrigating the crops. The opening and closing of the furrows is a precisely timed operation to ensure soils are not left waterlogged and ridges are not inundated. However, the use of ridge and furrow irrigation rather than flood irrigation does not reduce the risk of crop contamination or reduce farmer exposure to wastewater. The results of an exploratory crop test at the University of Agricultural Sciences, Dharwad, showed that crop samples taken from a ridge were still bacterially contaminated by the wastewater flowing in the furrow (Alagawadi, 2001; Bradford, 2002).

Furthermore, farmer exposure to wastewater was increased as farmers stand in the flowing wastewater in the furrow rather than damaging the ridges during transplanting and weeding operations, thus increasing their contact and exposure to untreated wastewater. Indeed, in a study carried out by Hunshal and Sindhe (1997) on the effects of wastewater on the health of 40 farmers from Madihal and Gabbur villages, anaemia was identified as the "commonest finding and was related to nutritional deficiency and to worm infestation". Despite this study being inconclusive due to the small sample size and the lack of a control it did highlight some of the health implications of wastewater irrigation. The frequency of irrigation is dependent on the crop type, soil type and rainfall amount, with irrigation increasing in the dry season and during erratic rainfall conditions. During the dry season, vegetable crops are irrigated every two days and tree crops are irrigated every ten days. The only other water sources are shallow wells and these are used for drinking purposes only.

Despite using a common irrigation method, one aspect, which remains heterogeneous, is that of wastewater filtration. Most farmers have adopted some method of filtering the wastewater as it is pumped from the *nalla*. The filtration serves two purposes: it prevents debris entering the pump thereby reducing wear and tear and it prevents the fouling of soils with any debris and solid wastes present in the wastewater. The various forms of filtration include: improvised gauze filters round the inlet pipe; positioning of the inlet pipe inside pierced plastic barrels that act as large sieves and the use of sieve baskets woven from natural fibres. The gauze filter prevents debris larger than 10 mm from entering the inlet pipe, while the plastic barrel sieve only prevents debris larger than 20 mm; regardless of the filtration, used suspended solids and sediments enter the inlet pipe. If the filters become blocked they are simply rinsed with wastewater in the *nalla*, however, the steady flow of the *nalla* generally prevents debris from accumulating. In Maradagi village, one farmer has constructed a settling tank, which also serves as a wastewater storage tank, to ensure a sufficient irrigation supply when the wastewater flow is low. If the wastewater is not filtered, any solid waste flowing in the wastewater that can pass through the inlet is pumped onto the fields. As the wastewater infiltrates into the soil the solids remain on the surface, clogging the topsoil with plastics and other debris. After tilling operations, such waste becomes half buried resulting in potentially hazardous conditions for the farmers that are working in the fields.

#### *4.3.3 Discussion of main cropping systems*

##### *4.3.3.1 Vegetable production*

A distinct feature of the intensive vegetable production systems is the continuous all year production of vegetables and the absence of a fallow. The proximity to the urban areas – i.e. the source of wastewater – ensures a reliable irrigation supply during the dry season (February – May). These production systems are predominantly found at Madihal in Dharwad and at Bidanal on the outskirts of Hubli. The ease of access to local urban markets and high urban demand ensure a secure market for vegetable produce, particularly during the dry season when vegetable market prices increase three to five fold. The intensive vegetable production systems require considerably higher labour inputs than field crop and agroforestry-based systems. Household members normally meet these labour inputs but during peak periods additional farm labourers may be hired.

Further examination of wastewater irrigation practices reveals a range of associated problems that threaten to outweigh the benefits. In addition to the health hazards already discussed, the improved crop yields are also offset by a problematic increase in the incidence of weeds and pests. The increased incidence of pests associated with wastewater irrigated vegetable production systems results from a combination of factors. Pests are habitually controlled by blanket spraying with organophosphate pesticides; however, the hot and semi-arid climate provides opportunistic breeding conditions by quickening the reproduction cycle, which then enables pests to build pesticide resistance faster. The planting of vegetable crops in monoculture blocks also facilitates their proliferation, while the continuous cycle of crop production during the dry season when land is normally barren, ensures that insect populations can thrive when they would typically encounter a seasonal decline. Furthermore, Alagawadi (2001) has raised a further concern and has suggested that boring pests (e.g. *Helicoverpa armigera*) that invade crop fruits (e.g. aubergine) on wastewater irrigated fields are likely to increase bacterial contamination of the crop by providing additional entry routes.

Due to the lack of an effective control, the prolific multiplication of pests such as the *Plutella xylostella* and *Helicoverpa armigera* has resulted in complete crop failures and high economic losses; consequently, farmers in some areas have stopped growing what were once highly profitable crops, such as cabbage[1]. *Plutella xylostella* affects aubergine and most *Brassica* species, while *Helicoverpa armigera* affects most vegetable crops. During interviews, farmers on both wastewater *nallas* identified *Helicoverpa armigera* as a major pest currently affecting aubergine, chilli, okra, onion and tomato crops. However, despite the failure of organophosphate pesticides to provide effective crop protection, many farmers increase the frequency of pesticide application – with some farmers spraying twice weekly – and many also mix pesticides, creating potentially hazardous combinations. These practices are advocated by pesticide dealers who remain the chief source of agricultural advice for farmers. The net result is an increased risk of crop contamination and of farmers' exposure to pesticide poisoning. In India, farmers are well aware of the immediate toxic nature of organophosphate pesticides: the 1984 Bhopal disaster and the oft-reported cases of farmers committing suicide through pesticide consumption serve as vivid reminders. Conversely, there is less general awareness of the accumulative effect of organophosphate pesticide poisoning, which often manifests itself in the gradual failure of the immune system, making it less detectable for health workers and epidemiologists. In a recent study in north Karnataka, it was found that 20% of drinking water supplies were contaminated with Endosulphan (Cratchley *et al.* 2002), a pesticide that is also commonly used in wastewater-irrigated vegetable production.

To address pest problems in wastewater-irrigated vegetable cropping systems an integrated pest management (IPM) trial was conducted over two seasons using light traps and the soil bacterium *Bacillus thuringiensis* (*Bt*) (Tippannavar, 2001). The bacterium is a pathogen that can be used as a biological pest control against lepidopteran larvae such as *Plutella xylostella* and *Helicoverpa armigera*. The bacterium is mass-produced and with the use of a knapsack sprayer it is applied directly onto the pest or onto the crop for ingestion by the pest (CAB International, 2000). While there was some crop loss due to delayed treatments the results proved an overall success. In terms of extension success and the uptake of technologies the research work has had mixed results (bearing in mind that the trial was research- rather than extension-based). Once the trial was concluded, the farmer who had participated stopped using *Bt* spray and reverted back to applying organophosphate pesticides. The farmer's decision to revert back may have resulted from a lack of confidence to continue using biological pesticides without the regular attendance of the researcher and the fact that *Bt* is not widely retailed and hence inconvenient to purchase. Conversely, the farmers at Madihal have been keen to duplicate the light traps used in the trial

[1] Names of vegetables and crops are listed in Appendix 1.

and now use light bulbs (to attract moths at night) underneath which are located tubs of kerosene, which kills any moths that land in the fuel.

*4.3.3.2 Field crop and vegetable systems*

Once beyond Madihal village on the Dharwad *nalla* the remaining cropping systems are predominantly field crops with vegetables; these cropping systems are found at Govankoppa, Gongadikoppa and Maradagi villages and can also be found on the Hubli *nalla* at Gabbur village. The larger the farm size the more land put over to field crops, as vegetable production generally requires greater labour inputs. Beyond Maradagi village wastewater irrigation ceases and the cropping systems are rainfed, as during the dry season the quantity of wastewater flowing in the Dharwad *nalla* at this point is insufficient as a reliable irrigation source. For field crops, such as cotton and wheat, wastewater irrigation is simply used to start the field crop season earlier and when rainfall is erratic during the rainy season (see Table 2). This brings added advantages over rainfed agriculture as the crops that are harvested earlier bring higher market prices as, once the market is inundated with produce from rainfed systems, the market price tumbles.

During the *kharif* the choice of vegetables grown is not just based on market demands but also on what is consumed within the household, whereas during the dry season the market demands prevail and vegetables with high off-season prices are preferred, such as chilli. If cotton is to be grown, planting occurs during the dry season in April, the sewage irrigation being used to start the crop before the *kharif* season. If the wastewater levels are particularly low, check dams are built in the *nalla* to ensure sufficient wastewater for irrigating the field crop seedlings. The advantage of an early start to the crop is the earlier harvest than that of rainfed systems, which ensures crop sales before market inundation of cotton from rainfed agriculture. Many of the farms located in Maradagi - the last village on the Dharwad nalla that irrigates with wastewater - adopt a fallow during the dry season, as the wastewater flows are no longer a reliable irrigation source.

The greatly increased incidence of weeds and pests found in the intensive vegetable production systems equally applies to the field crop and vegetable systems. However, the nature of the cropping patterns and the increased distance these systems are located from Dharwad results in different priorities for the farmers. The control of weeds on seasonal vegetable plots is identical to that of the intensive vegetable production systems and is based on hand tillage, although there is a notable shortage of labour to conduct such weeding. Farmers in the outlying villages do not have the convenience of being able to draw on the urban unemployed (as and when required) during peak periods like their counterparts in Madihal. The shortage of labour is a constraint that is frequently expressed by farmers in Govankoppa, Gongadikoppa and Maradagi and it influences the decision by some farmers not to grow vegetables in the dry season when lucrative prices can be fetched for such produce. The weed control of field crops is more conveniently achieved with draught animals. Fields are prepared prior to planting with the use of mouldboard ploughs and then inter-row cultivations are used as the main weed control.

The main pests and diseases that affect intensive vegetable cropping systems are also present in the field crop and vegetable cropping systems, indeed many of the pests will target, defoliate and destroy both vegetable and field crops together. The infamous *Helicoverpa armigera* that is reported by farmers the length of both *nallas* can devastate cotton crops and is seen as the main pest problem by the farmers growing field crops irrigated with sewage. The fact that cotton does not enter the food chain brings little respite as farmers in an attempt to protect the crop blanket spray systematically, placing themselves at an extremely high risk of pesticide poisoning. Dent (2000: 322) highlights: the crop 'consumes 50% of the insecticides used annually in India even though it occupies only 5% of the cultivated area [and] 80% of synthetic pyrethroid consumption is confined to cotton alone'. The pest *Helicoverpa armigera* was also reported as a problem with aubergine, chilli, chickpea, and okra. Aphids and whitefly were also identified as pests affecting both cotton and vegetable crops. Rusts were reported on wheat crops in the kharif season, however farmers commented that it was not a serious problem.

### Table 2 Dharwad nalla: random sample of field and vegetable cropping calendars

| | June | July | Aug | Sept | Oct | Nov | Dec | Jan | Feb | March | April | May |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Village/Farm** | ***Kharif*** (monsoon rains)[1] | | | | ***Rabi*** (light rains)[1] | | | | ***Dry season*** (summer)[1] | | | |
| **Govankoppa** | | | | | | | | | | | | |
| Hulligeri | Aubergine, chilli, cluster bean, coriander, okra, ridge gourd (0.8 ha) (continuous cropping) | | | | | | | | | | | |
| Totad | Aubergine, chilli, ridge gourd (0.8 ha) | | | | Wheat (0.8 ha) | | | | Aubergine, chilli, ridge gourd (0.8 ha) | | | |
| Basavaraj | Chilli, cucumber, ridge gourd, aubergine (0.8 ha) | | | | Wheat (0.8 ha) | | | | Aubergine, chilli, cucumber, ridge gourd (0.8 ha) | | | |
| **Gongadikoppa** | | | | | | | | | | | | |
| Karikatti | Onion (0.4 ha), banana (0.4 ha) | | | | Banana (0.4 ha), wheat (0.4 ha) | | | | Banana (0.4 ha), fallow (0.4 ha) | | | |
| Annigeri | Okra, green gram (1.2 ha) | | | | Chickpea, wheat (1.2 ha) | | | | Cucumber, okra, ridge gourd (1.2 ha) | | | |
| Gangappa | Green gram, onion, (1.6 ha) | | | | Chickpea, wheat, (1.6 ha) | | | | Fallow | | | |
| Patil | Ground nut (4 ha) & cotton[2], green gram (2.4 ha) | | | | Chickpea (5.3 ha), wheat (1.2 ha) | | | | Fallow, cotton[2] | | | |
| Sab | Ground nut, green gram, onion (0.4 ha) | | | | Chickpea, sorghum, wheat (0.4 ha) | | | | Chilli, okra, (0.4 ha) | | | |
| Walmiki | Green gram, onion (0.8 ha) | | | | Chickpea, wheat (0.8 ha) | | | | Aubergine, okra, tomato (0.8 ha) | | | |
| **Maradagi** | | | | | | | | | | | | |
| Hampannavar | Cotton[2] (1.6 ha) & green gram, ground nut, onion (1.6 ha) | | | | Wheat (3.2 ha) | | | | Chilli, tomato (0.8 ha), fallow (2.4 ha), cotton[2] (1.6 ha) | | | |
| Bellar | Cotton[2], green gram, ground nut, onion, maize, ridge gourd (1.6 ha) | | | | Chickpea, safflower, wheat (1.6 ha) | | | | Chilli (0.4 ha), fallow (1.2 ha), cotton[2] | | | |
| Dewatagi | Chilli (1.6 ha) | | | | Chickpea, sorghum, wheat (1.6 ha) | | | | Fallow | | | |
| Hamipannavar | Cotton[2], onion, green gram (2.4 ha) | | | | Wheat (2.4 ha) | | | | Fallow | | Cotton[2], onion… | |

Note: Names of crops and vegetables are listed in appendix 1.

#### *4.3.3.3 Agroforestry systems*

In India, wastewater irrigated agroforestry has long been recognised as a strategy to dispose of urban wastewater, while also rehabilitating and greening wastelands (see Das and Kaul, 1992). In the peri-urban villages of Budarsingi and Katnur on the main Hubli *nalla*, all farmers bordering the *nalla* engage in some kind of wastewater irrigated agroforestry practice. In other locations, only sporadic planting of trees on farm boundaries and the occasional agroforestry practice can be observed. The benefits from agroforestry include reduced irrigation requirements and therefore reduced exposure of farmers to wastewater, as during the dry season, vegetable crops are irrigated every two days while tree crops are irrigated every ten days. Furthermore, farmers that have adopted agroforestry systems have reported a substantial increase in income from the produce as a result.

In the villages of Budarsingi and Katnur, the main wastewater irrigated agroforestry practices are ‘tree predominant’ orchard systems and agrosilviculture, consisting of spatially mixed perennial-crop combinations (Young, 1997). The two most important tree species are sapota *Achras zapota* and guava *Psidium guajava*; other common species are coconut *Cocos nucifera*, mango *Mangifera indica*, arecanut *Areca catechu* and teak *Tectona grandis*. Species found on farm boundaries include neem *Azadirachta indica*, tamarind *Tamarindus indica*, coconut and teak. Other less common species are banana *Musa paridasiaca*, ramphal *Annona reticulata*, curry leaf *Murraya koenigii*, pomegranate *Punica granatum*, lemon tree *Citrus limon*, galimara *Casuarina equisitifolia* and mulberry *Morus indica*.

Tree-predominant orchard systems are planted as a single crop of either sapota or guava or a mixture of the two, with tree spacing of 6-7 m. Next to the orchards many farmers plant small vegetable plots, which are also irrigated with wastewater. Farmers with larger landholdings also plant additional field crops adopting similar cropping patterns to the field crop systems found on the Dharwad transect. The agrosilviculture systems consist of tree rows containing a mixture of sapota and guava. The trees are spaced along the rows at intervals of 6-7 m and each row is planted approximately 9 m apart. The land between each row is used for field crops. Examples of some of the field crops grown include groundnut in the dry season and sorghum in the *kharif*. Many adaptations of these agrosilviculture systems were observed; examples included the planting of a teak row amongst the sapota and guava rows and the growing of vegetables between tree rows rather than field crops. Other practices observed included a wastewater-irrigated mulberry field for silk production with widely spaced sapota and guava trees planted amongst the mulberry and plots of wastewater irrigated coconut trees intercropped with arecanut. Two plots of wastewater-irrigated bananas were also visited.

Farmers in Budarsingi and Katnur villages identified rigorous weed growth as the main constraint to agroforestry. Even though fruit pests and disease were evident, the low incidence meant that many farmers took no control measures and as such pesticides were not used on the agroforestry plots. Weeds were identified as problematic, particularly *Parthenium hysterophorus*. Farmers attribute the wide spread of the weed to seeds that are carried in the wastewater and then pumped onto the fields. Farmers reported that even though the *Zygogramma* beetle was established, the beetle (an introduced bio-control agent) could not multiply fast enough to control the increasing weed problem (the beetle feeds on the *Parthenium hysterophorus* weed). As a result, removal by hand was the main weed control measure and consequently most farmers reported labour shortages. Additional crop problems reported by farmers included the early dropping of fruit from trees and the softening of fruit while still growing; farmers identified wastewater-irrigation as the causal factor for both of these problems. Indeed, a similar problem was reported with apples irrigated with wastewater, which resulted in ‘detrimental effects on fruit quality by decreasing flesh firmness and increasing incidence of core flush’ (Meheriuk and Neilsen, 1991: 1269).

#### *4.3.3.4 Fodder production*

An additional wastewater irrigation system can be found just outside Maradagi village on the Dharwad *nalla*. Since 1995, a small-scale dairy farmer has been irrigating a 0.4-ha plot of Napier grass[1] *Pennisetum purpureum* with wastewater and borewell water on an alternating daily basis. The grass is grown throughout the year and used as fodder for eight dairy cows and two bullocks stalled nearby. An additional supplementary feed made from a rice by-product is also fed to the livestock. Changing from dry feed to the Napier grass fodder, the farmer reports a milk yield improvement from 3-4 l per day to 8 l per day, an enterprising two-fold increase. The farmer has an additional 5 ha of rainfed land; nevertheless he chooses not to use wastewater irrigation on this land and leaves it fallow during the dry season. His

[1] Napier grass is sometimes used as an alternative to vetiver grass *Vetiveria zizanioides* as a vegetative barrier for soil and water conservation, as the latter can not be used for livestock fodder (Morgan, 1995).

reasons are labour shortages and time and organisational constraints, but considering the farmer is over 70 years old his reluctance to work intensely all year round is understandable, and in any case the vastly improved milk yields ensure a secure regular income.

## 4.4 Key issues

### *4.4.1 Risks presented by bio-medical waste*

As discussed before, most farmers have adopted some method for filtering the wastewater as it is pumped from the wastewater *nallas*. The rudimentary filtration is used to prevent soils becoming clogged with plastics, disposable syringes and other debris. Several farmers along both the *nallas* reported the presence of disposable needles and syringes in the wastewater, with one farmer having seen an intravenous giving-set in the *nalla*. In Govankoppa, a farmer complained of standing on needles buried in the soil up to 20 times in a single day. The foremost concern for these farmers is the cost of any medical treatment that is required if infection does occur. In Katnur, a farmer displayed a disposable syringe and needle that had been recovered from the filter fitted to the wastewater inlet pipe. He then recounted an 'experiment' he had conducted two years previously with the disposable syringe, when he had 'successfully' grown ten tomato plants after injecting each plant with 0.5 - 1 ml of undiluted pesticide. Despite the 'experiment' working he no longer uses the highly hazardous technique although he still has the needle and syringe. In addition to raising regulatory issues regarding bio-medical waste control, these examples highlight the importance of farmers taking action themselves. The fitting of rudimentary filters to the wastewater inlets is crucial to mitigate the spread of disposable needles, debris, and plastics onto farmers' fields.

### *4.4.2 Gender implications of wastewater irrigation*

Regardless of the cropping system being used, the high nutrient loading from wastewater greatly increases the incidence of weeds; as already mentioned, farmers also attribute this to seeds that are carried in the wastewater and then pumped onto the fields. Consequently, as the main weed control method is hand tillage, the weeding accounts for the high labour inputs associated with wastewater irrigated cropping systems. Household members meet these labour inputs and within the household women normally carry out these tasks, likewise, when farm labourers are hired they are more likely to be women due to the cheaper labour costs. Census data also confirms that a higher proportion of women are engaged in urban agriculture. Budds and Allen (1999) reported that the male population mainly seized the non-farm opportunities, as the wages are higher than in the agricultural sector (building labourers earn 70 rupees per day as opposed to farm labourers earning 50 rupees). As well as perpetuating their positions as the poorest social group, their exposure to the hazards of wastewater – pathogens and organophosphate pesticide residues - is also increased as they spend full days working on the fields. Furthermore, once the day's work is finished the women return to their households and carry out evening chores, including food preparation and cooking, thereby increasing the risk of pathogen transfer to other family members if basic hygienic standards are not maintained.

### *4.4.3 Risk reduction in livelihood strategies*

There are wide variations in how plants and animals absorb, retain and transmit pathogens and heavy metals. With careful crop selection food chains can be designed to reduce the transmission of pathogens and other pollutants. The adoption of agroforestry systems reduces farmers' direct contact with and exposure to wastewater, due to the reduced irrigating requirements of tree crops in comparison to vegetables and field crops; tree crops also absorb and accumulate fewer pathogens and heavy metals than vegetable crops. In addition, the use of organophosphate pesticides is greatly reduced, as the diverse agroecosystems become more stable and less vulnerable to pest populations. However, there are several reasons why farmers do not diversify and adopt more sustainable cropping systems, such as the use of wastewater-irrigated agroforestry. Poor farmers dependent on agriculture for their livelihoods will always mitigate what they potentially perceive as risks, and changing cropping systems is perceived as a high-risk strategy.

The livelihood strategies of poor farmers are often dependent on quick returns, which are gained from intensive vegetable production, whereas the initial returns from agroforestry are much slower. However, during the period of establishing an agroforestry plot, additional crops, such as vegetables or field crops can be intercropped with the tree seedlings, thereby preventing serious losses in earnings. The farmers who have adopted agroforestry practices have done so because they have either additional income generating opportunities or larger landholdings (see Table 3). This reduces their dependency on a single livelihood or small agricultural plot. Furthermore, farmers with larger landholdings are more likely to experiment with small plots of agroforestry and expand such experiments as they reap the benefits and gain confidence in the new practices.

This process is clearly occurring in Budarsingi and Katnur, where wastewater-irrigated agroforestry systems have spread as a direct result of farmers observing the practices, then adopting them once they are confident they work; in this case 'change' is no longer perceived as a risk and thus agroforestry practices are freely adopted. This process could be enhanced through the extension of appropriate IPM strategies using participatory approaches such as farmer field schools. These empower farmers through education and training which are designed to meet the needs of smallholders and marginalised farmers and incorporate traditional pest control methods. Therefore, the development of micro technologies at the farm level to reduce risk is a crucial component within this process and examples of this process are clearly evident in Hubli-Dharwad, where some innovative farmers have diversified their agroecosystems by incorporating agroforestry practices.

**Table 3 Livelihood diversification strategies of innovative farmers**

| Farm (village) | Innovation | Livelihoods | Remarks |
|---|---|---|---|
| F.G. Patil (Govankoppa) | Agroforestry | Sewage irrigated: 5.3 ha; rainfed: 8.1 ha | Certificate in Horticulture |
| F. Yattinagadad (Govankoppa) | Agroforestry | Sewage irrigated: 2.4 ha | Neighbours the above farm |
| N.F. Gauder (Govankoppa) | Agroforestry | Sewage irrigated: 1.2 ha; family members are carpenters | Assets: 4x4 vehicle |
| B. Doddamani (Maradagi) | Fodder production | Sewage irrigated: 0.4 ha; rainfed: 4.9 ha; 1 family member employed as university lecturer | |
| R. Mudhol (Gabbur) | Agroforestry | Sewage irrigated: 2.2 ha; family own 24.3 ha of guava plantation | |

### *4.4.4 Policy implications*

The situation in Hubli-Dharwad highlights the failures of political policies rather than that of bad farming practices. Diverse actors mould the wastewater irrigated farming systems that are located in the peri-urban areas, illustrating the contested political nature of urban and peri-urban agriculture. Firstly, the Hubli-Dharwad Municipal Corporation fails in its legal requirement to treat the discharged wastewater and are unlikely to implement such a programme in the near future on the grounds of cost. Wastewater treatment plants would certainly mitigate the public health and environmental risks that are associated with the wastewater *nallas*. However, even when the Karnataka State Pollution Control Board attempted to bring charges against the Municipal Corporation for its obligational failures, the National Government intervened and the charges were later thrown out. As Cratchley *et al.* (2002) highlight the "environmental legislation is very good, however implementation is never easy and seems to be compromised"; indeed, compromised to such a degree that, when it suits, political decisions can override national environmental legislation.

Secondly, the actual moulding of wastewater irrigated agriculture has been hugely influenced by pesticide dealers; this has resulted in farmers becoming completely dependent on local pesticide dealers for their biased agricultural advice, which is inevitably linked to pesticide sales rather than that of good farming practices. The lack of institutional support in the form of extension services for urban and peri-urban farmers has only compounded the situation and strengthened the position of the pesticide dealer. Extension services are not provided to urban and peri-urban farmers because their farms are located within the official city boundary. Furthermore, with the announcement of the loss of 7,000 out of the total 17,000 posts in the state agriculture department (*Deccan Herald*, 2001); the department's extension focus will no doubt continue to be the cash cropping progressive farmers rather than the marginalised wastewater irrigating smallholder.

The outright banning of wastewater irrigation would be both unpractical and infeasible, in addition, for urban and peri-urban farmers the poverty implications of such a measure would be vast. Anyway, as noted in section 1.2 of the Hyderabad Declaration on wastewater use in irrigated agriculture: "with proper management, wastewater use contributes significantly to sustaining livelihoods, food security and the quality of the environment" (IWMI and IDRC, 2002:4). Therefore, the attainment of a 'proper management' approach is vital if the public health and environmental risks are to be mitigated without threatening the livelihoods of marginalised farmers; the key to such an approach lies in education. In Hubli-Dharwad, centralised or decentralised wastewater treatment plants are unlikely to be implemented in the near future; therefore, farmers irrigating with wastewater should be encouraged and supported to adopt safer and more sustainable farming practices. The farmers along the wastewater *nallas* have clearly demonstrated a readiness to adopt alternative pest control strategies with some informal farmer-to-farmer networks already contributing to that process. However, the change from the current reliance on organophosphate pesticides to IPM strategies, and the conversion to agroforestry practices will require long-term support through participatory approaches such as the use of farmer field schools that empower farmers through education and training in sustainable agricultural practices. The particular nature of the farming systems along the Dharwad and Hubli *nallas* and the complex nature of IPM suggest a village-based extension approach is likely to be the most suitable. The public health benefits of such an approach could also be enhanced through public education, aimed at raising awareness in disease prevention through better food handling, preparation and cooking practices.

### 4.5 Acknowledgements

Andrew Bradford would like to thank the UK Economic and Social Research Council (ESRC) for financial contributing towards his attendance at the symposium.

### 4.6 References

Alagawadi, A.R. (2001). Professor of Agricultural Microbiology, University of Agricultural Sciences, Dharwad. Personal communication 19th May; 31st May; 6th June.

Bradford, A.M. (2002). 'Sewage Irrigated Agriculture: Annex F' In Brook, R.M. (ed.) *Filling gaps in knowledge about the peri-urban interface around Hubli-Dharwad. Department for International Development Project No. R7867. Final Technical Report.* University of Wales, Bangor, UK (Natural Resources Systems Programme, Department for International Development, p. F1-F22.).

Brook, R.M. (ed.) (2002) *Filling gaps in knowledge about the peri-urban interface around Hubli-Dharwad. Department for International Development Project No. R7867. Final Technical Report.* University of Wales, Bangor, UK (Natural Resources Systems Programme, Department for International Development, p. F1-F22.).

Brook, R. and Dávila, J. (eds.) (2000) *The Peri-Urban Interface: a tale of two cities.* Bangor, UK, School of Agricultural and Forest Sciences, University of Wales and Loondon, UK, Development Planning Unit, University College London.

Budds, J. and Allen, A. (1999). *Peri-Urban Profiles: Hubli-Dharwad, India.* London, UK, (Research Paper. Development Planning Unit, University College London).

CAB International. (2000) *Crop Protection Compendium:* 2nd Edition. Wallingford, UK, CAB International,.

Cratchley, R. Hollingham, M. and Joshi, S.G. (2002) 'Water resources around Hubli and Dharwad: Annex E'. In Brook, R.M. (ed.) *Filling gaps in knowledge about the peri-urban interface around Hubli-Dharwad. Department for International Development Project No. R7867. Final Technical Report.* Bangor,UK Natural Resources Systems Programme, Department for International Development, University of Wales. (p. E1-E101).

Das, D.C. and Kaul, R.N. (1992). *Greening Wastelands Through Wastewater.*, New Delhi, India,.

*Deccan Herald* (2001) 24th June. 7,000 posts in farm dept to go. Bangalore, India, National Wastelands Development Board, Ministry of Environment and Forests.

Dent, D. (2000). *Insect Pest Management.* 2nd Edition. Wallingford, UK, CABI Publishing.

Hillyer, K.J. Paril, A. and Hunshal, C.S. (2002). 'A study of the livelihood strategies of the poor and very poor in peri-urban areas of Hubli-Dharwad, and the impact of urbanisation upon them: Annex B'. In Brook, R.M. (ed.) *Filling gaps in knowledge about the peri-urban interface around Hubli-Dharwad. Department for International Development Project No. R7867. Final Technical Report.* University of Wales, Bangor, UK (Natural Resources Systems Programme, Department for International Development, (p. B1-F66).

Hunshal, C.S. and Sindhe, K. (1997). 'Wastewater: Problems and Opportunities: Paper 10'. In University of Agricultural Sciences, Karnataka University, SDM Engineering College, Dharwad, India and University of Birmingham, University of Nottingham and University of Wales, Bangor (eds.) *Baseline Study for Hubli-Dharwad City Region, Karnataka, India.* Introductory Workshop Peri-Urban Production System Research Programme, July 1997, Natural Resources International, p. 5.

Hunshal, C.S. Salakinkop, S.R. and Brook, R.M. (1997). 'Sewage irrigated vegetable production systems around Hubli-Dharwad, Karnataka, India' In *Kasetsart Journal (Natural Sciences),* vol. 32, no. 5 p. 1-8.

IWMI and IDRC (2002). International Water Management Institute and International Development Research Centre The Hyderabad Declaration In *Urban Agriculture Magazine*, vol. 8, no. 4.

Meheriuk, M. and Neilsen, G.H. (1991). Fruit quality of McIntosh apples irrigated with well or municipal waste water In *Canadian Journal of Plant Science,* vol. 71, p. 1267-1269.

Morgan, R.P.C. (1995). *Soil Erosion and Conservation:* 2nd Edition. Hazrlow, UK, Longman.

Tippannavar, P. (2001). Agricultural Researcher, University of Agricultural Sciences, Dharwad. Personal communication 19th May, 27th May.

Young, A. (1997). *Agroforestry for Soil Management:* 2nd edition. Nairobi, Kenya, ICRAF,.

## 4.7 Bibliography

Allison, M., Harris, P.J.C., Hofny-Collins, A.H., and Stevens, W. (1998). *A Review of the Use of Urban Waste in Peri-Urban Interface Production Systems.* Coventry, UK., Henry Doubleday Research Association, (addresses some technical wastewater irrigation issues and includes a useful bibliography).

Bakker, N.; Dubbeling M.; Gündel, S.; Sabel-Koschella; U. and de Zeeuw, H. (eds.) (2000) *Growing Cities, Growing Food: Urban Agriculture on the Policy Agenda.* Food and Agriculture Development Centre (ZEL), German Foundation for International Development (DSE) (addresses urban and peri-urban agricultural policies and includes a case study on waste recycling through urban farming in Hubli-Dharwad).

Birley, M.H. and Lock, K. (1999). *The Health Impacts of Peri-urban Natural Resource Development.*. Trowbridge, UK, Cromwell Press (Liverpool School of Tropical Medicine: addresses the health impacts of wastewater irrigation and includes case study material from Hubli-Dharwad).

Das, D.C. and Kaul, R.N. (1992) *Greening Wastelands through Wastewater.* India, New Delhi, National Wastelands Development Board, Ministry of Environment and Forests (useful technical manual on land rehabilitation through wastewater irrigated tree plantations).

Hussain, I. *et al*. (2002). *Wastewater Use in Agriculture: Review of Impacts and Methodological Issues in Valuing Impacts*., Sri Lanka, Colombo. (Working Paper 37. International Water Management Institute, Colombo: useful review of wastewater irrigation which contains an excellent extended list of bibliographical references on wastewater irrigation).

*Urban Agriculture Magazine* (regularly features articles on wastewater irrigated agriculture, and can be viewed and downloaded from the Resource Centre for Urban Agriculture (RUAF) Internet site at www.ruaf.org).

### 4.8 Appendix 1: Plant names

| Common name | Scientific binomial | Indian vernacular |
|---|---|---|
| Arecanut | *Areca catechu* | |
| Aubergine (eggplant) | *Solanum melongena* | Brinjal |
| Banana | *Musa paridasiaca* | |
| Cauliflower | *Brassica oleracea* var. *botrytis* | |
| Cabbage | *Brassica oleracea* var. *capitata* | |
| Chickpea (gram) | *Cicer arietinum* | |
| Chilli | *Capsicum annuum* var. *longum* | |
| Coconut | *Cocos nucifera* | |
| Cotton | *Gossypium herbaceum* | |
| Cucumber | *Cucumbar sativus* | |
| Curry leaf | *Murraya koenigii* | |
| Galimara | *Casuarina equisitifolia* | |
| Green gram | *Vigna radiata* | |
| Ground nut | *Arachis hypogaea* | |
| Guava | *Psidium guajava* | |
| Lemon tree | *Citrus limon* | Nimbu |
| Mango | *Mangifera indica* | |
| Maize | *Zea mays* | |
| Mulberry | *Morus indica* | |
| Napier grass | *Pennisetum purpureum* | |
| Neem | *Azadirachta indica* | |
| Okra (ladies finger) | *Abelmoschus esculentis* | Bhendi |
| Onion | *Allium cepa* | |
| Pomegranate | *Punica granatum* | |
| Ramphal | *Annona reticulata* | |
| Ridge gourd | *Luffa acutangula* | |
| Safflower | *Carthamus tinctorius* | |
| Sapota (sapodilla) | *Achras zapota* | |
| Sorghum | *Sorghum bicolor* | Jowar |
| Tamarind | *Tamarindus indica* | |
| Teak | *Tectona grandis* | |
| Tomato | *Lycopersicon lycopersicum* | |
| Wheat | *Triticum aestivum* | |