SUSTAINABLE SOLID WASTE MANAGEMENT STRATEGIES IN JUJA, KENYA

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Abstract

Integrated solid waste management includes source reduction, source separation, recycling and reuse as well as materials recovery. The waste materials that remain should be safely disposed into a sanitary landfill. Up to 2010 when this study was done, no Kenyan city had a sanitary landfill and solid waste piles along inner city streets was a common sight in Nairobi. This study found that the solid waste in Juja consisted of 80% food and other organic wastes, 10% plastics, 2% metal and glass, and 3% mixed refuse. The waste had a very low level of toxic substances. The majority of the households produced less than 3 kg per day, which translated to less than 0.5 kg/person/day. JKUAT-SWMM, a solid waste management model developed in this study, suggested that if 25% of the population would do composting using household compost digesters of 288 L, the area of a disposal site required for 1 million people would be 16 ha. The identified site was on fallow land that received an annual rainfall of 600-800 mm. A waste disposal facility in Juja Farm could cater for most of the towns in the area of interest, including Juja, Mangu, Kimunyu, Gatundu, Thika, Ruiru and Kahawa. The landfill would be accessible to institutions such as Jomo Kenyatta University of Agriculture and Technology in Juja, Mount Kenya University in Thika, Kilimambogo Teachers' College in Kilimambogo, and numerous secondary schools in the area.

Key words: Sustainable, solid waste management, Juja

1.0 Introduction

The term 'waste management' incorporates collection, transportation, processing and disposal of the waste. It also includes strategies for reducing the amount of waste to be disposed off. Sustainable solid waste management enhances maintenance of a healthy, aesthetic, and ecologically sound environment. In Juja, most people either dump waste in open spaces or burn it, creating water and air pollution. Waste management involves waste collection, sorting, storage, recycling and disposal. Disposal can be done in a landfill or an open dumping site. For years, solid waste has been burned, re-used, or dumped with a qualitative level of processing which depends on the economical, cultural, social and political developments of communities in their particular situations (Bagchi, 1994).

One of the methods available for solid waste reduction is composting, which is the biological degradation of organic matter into humus-like material that is useful as a soil conditioner. However, in the USA, composting has failed to make economic sense (Bagchi, 1994). The emission of dioxins, furans and mercury from waste as smoke may be dangerous to human health (Province of Saskatchewan, 2009). Burning of waste also emits particulate matter, sulphur oxides, hydrogen sulfide, carbon monoxide, nitrogen oxides and various volatile organic compounds (VOCs) into the atmosphere.

Carlson (1976) estimated that more than 90% of the refuse in North America ended up in sanitary landfills. However, he cautioned that in areas with shallow soils, leachate could easily contaminate surface and groundwater resources. Ideally the landfill should not be sited in an area that receives heavy rainfall as this would significantly contribute to run-off and leachate, which should be minimised as much as possible. Poorly managed leachate can contaminate water resources. Fatta *et al.* (1998) found that leachate from landfills had a high content of chlorides, and a high proportion of COD relative to BOD. Literature shows that the quality of leachate varies greatly from site to site, and in the same landfill depending on age of the waste and other factors (Chian and DeWalle, 1976; Ragle *et al.,* 1995).

In most developed countries, solid waste is disposed off in sanitary landfills. The buffering capacity of soil makes it possible for landfills to hold waste and prevent pollution of surrounding environment (Carlson, 1976). In selecting a landfill site, it is necessary to consider possible impacts on the environment and human health. Rivers, wetlands, lakes and other water bodies need to be protected against pollution. Communities living around the landfill also need to be protected from health hazards associated with the landfill. With the increasing environmental awareness, many people will resist proposals to build a dumpsite or landfill in the vicinity of their residences, business premises or even recreational areas. Like any another engineering project, a landfill project requires an EIA and a report to indicate any likely positive or negative impacts of the proposed landfill project (Government of Kenya, 1999).

Geographic information systems (GIS) are one of the most effective tools for project planning. Using GIS, it is possible to efficiently store, retrieve, analyse and display information according to user-defined specifications (Siddiqui *et al.,* 1996). GIS enables the identification of suitable waste disposal sites, for given constraints. Factors that influence selection of waste disposal sites include topography, settlements (urban centres and villages), roads (Highways and village roads), railways, airports, wetlands, infrastructures (pipelines and power lines), slope, geology, land use, floodplains, aquifers and surface water bodies (Sener *et al.,* 2006). The spatial analysis and the ability to perform spatial functions such as buffer and overlays are some of the capabilities of GIS necessary for landfill site identification (Basaiaoclu *et al.,* 1997). Sanitary landfill sites should be located sufficiently far from residences to avoid nuisance and hazard to public health. A buffer zone of 2 km around residences is considered a restricted zone, not involving waste disposal (Basaiaoclu *et al.,* 1997). However, it should be noted that public approval of a landfill site is one of the most important factors in deciding its usefulness.

The aim of this study was to document solid waste characteristics in Juja, assess the rate of solid waste production and management requirements, identify a suitable solid waste disposal site to serve Juja and its environs, and develop a solid waste management tool.

1.1 Description of the Project Area

The project area includes Juja Town and surrounding areas of Gatundu, Ruiru, Kahawa and Thika . The highest population is this area is at Juja town, about 40 km North East of Nairobi. The area is served by the municipal council of Thika and has grown from a population of less than 100,000 in 1982 (when Jomo Kenyatta University of Agriculture and Technology was started), to a population of nearly 1 million people in 2009. A solid waste disposal site in this area would not only serve communities in Thika District, but also parts of northern parts of Nairobi.

2.0 Solid Waste Characteristics in Juja

Solid waste samples were obtained from different homes, in the project area, for the purpose of identifying solid waste characteristics. A half of the samples were from low-income households (high population density areas), 25% from medium-income estates and 25% from high-income estates. The decision to adopt this sampling strategy was informed by the writings of Mugenda and Mugenda (2003). Therefore, samples were collected from 38 low income homes, 19 medium income homes, and 19 high income homes.

Data collection tools included interviews, observations and collection of actual bags of solid waste. The waste collected was weighed to determine quantities of food and other organic wastes, metal and glass, plastics and others. Each bag of solid waste was sorted into food and organic waste; plastics; paper; metal and glass; and mixed refuse. The last category included every other inorganic substance. The study found that food and other organic components formed 80% of the total waste. The other components formed the following fraction; plastics, 10%; paper, 5%; metal and glass, 2% and mixed refuse 3% as in figure 1.

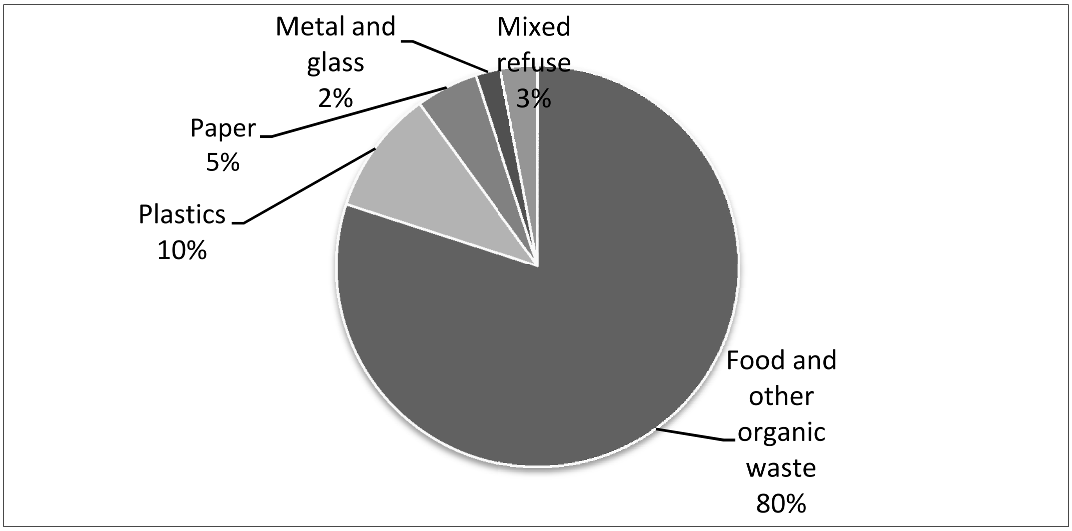

Figure 1: Solid waste characteristics

Development of a waste management strategy with a fair payment system for households requires information on solid waste production rates and solid waste characteristics (Benitez *et al.,* 2008; Rahman and Bin Yousuf, 2007). This study found that over 90% of the homes in Juja area generated less than 3 kg of solid waste per day Assuming that the number of persons per household was 6, the per capita waste production would be about 0.5 kg/person/day, see figure 2.

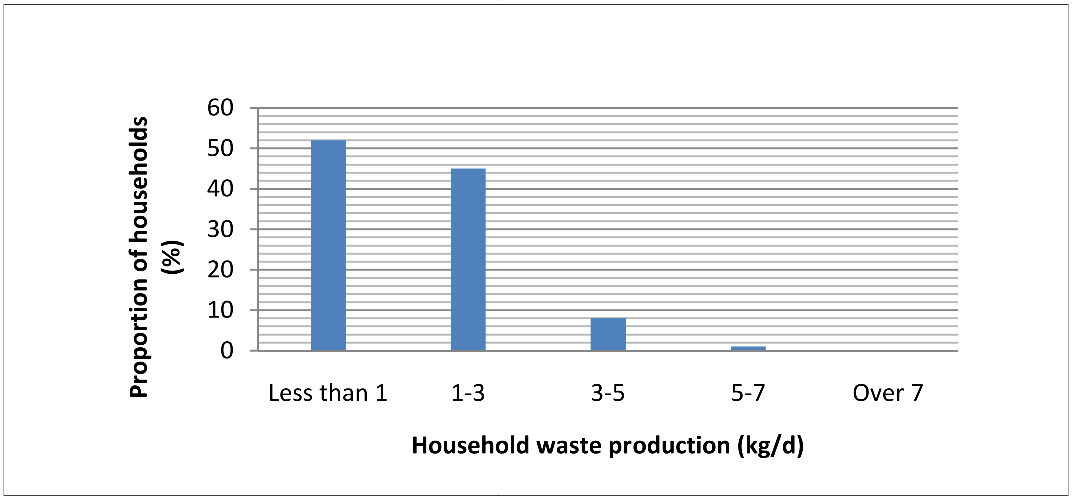

Figure 2: Solid waste production rate at household level.

3.0 Assessment of Solid Waste Management Requirements

Effective management of solid waste requires sufficient knowledge of daily waste production, solid waste characteristics, transportation requirements and quantities of solid waste that can be reused or recycled, among other details. A solid waste management model that estimates these quantities was developed in this study. This model, referred to as the JKUAT Solid Waste Management Model (JKUAT-SWMM), considers social as well as the technical aspects of solid waste management, see figure 3.

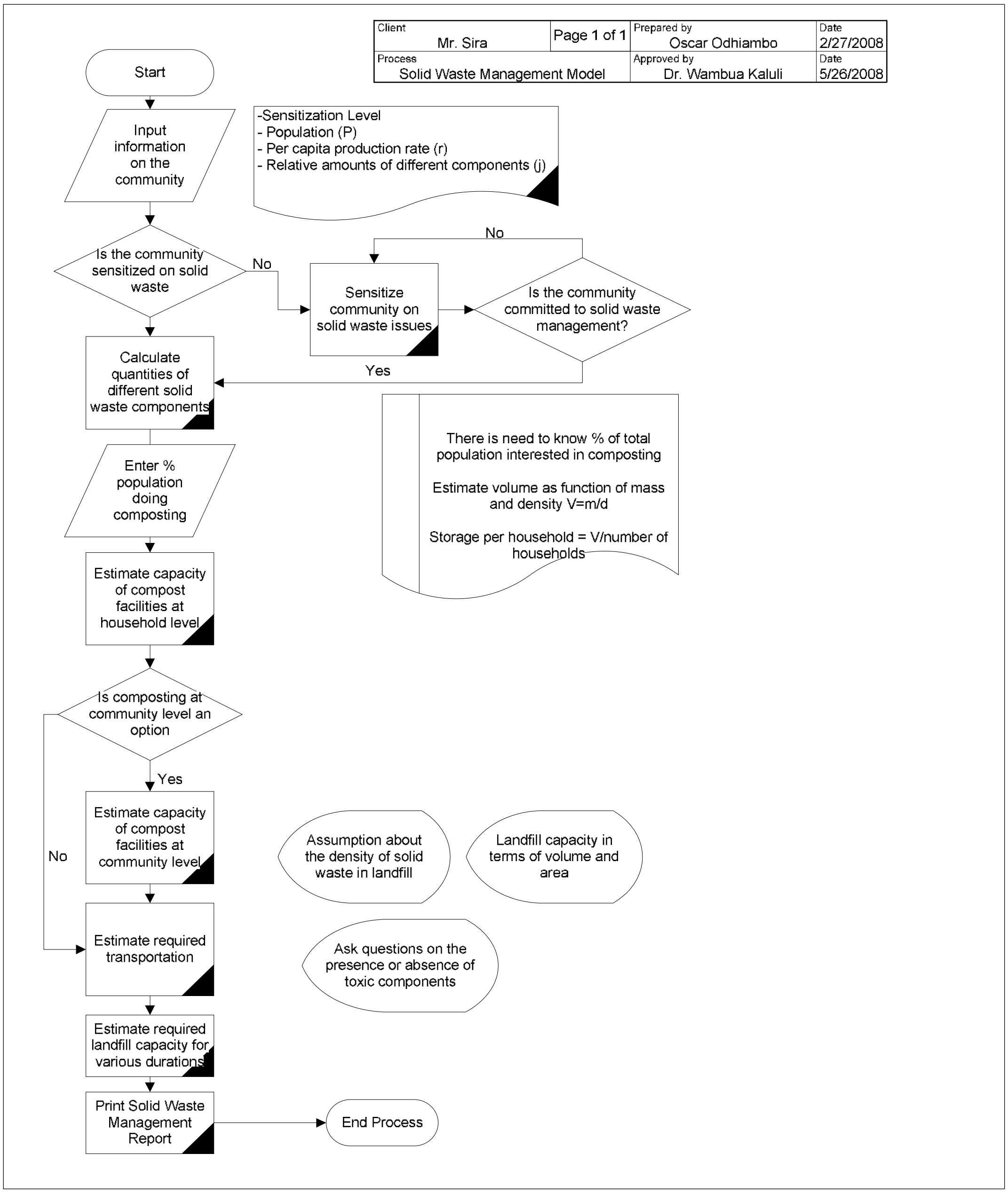

Figure 3: The JKUAT-SWMM flow chart

Sustainable solid waste management requires a thorough sensitisation of the population on solid waste management issues, so that all can participate in discussing alternative waste management options. Most households in Juja were not well informed on how to manage solid waste and less that 20% of the households owned waste bins. Out of those who had waste bins, 14% were served by private garbage collectors.

Inputs of JKUAT-SWMM included the population being planned for, waste production per capita, solid waste characteristics, the proportion of the population willing to engage in waste reduction practices (such as composting) and landfill design life. Knowledge of per capita waste production allows for the calculation of total volume of solid waste for a given population. The fraction of organic allowed for the calculation of total volume of waste that could be converted into compost allowed for the sizing of a household composting unit.

The output of this model included the volume of a household composting unit, waste transportation requirements and the area required for a sanitary landfill. Some assumptions have to be made in regard to packing density of solid waste in the landfill and the presence or absence of toxic substances in the solid waste.

Despite the fact that currently less that 20% of households in the study area had waste bins and practiced some form of solid waste management, this study assumed that 25% of the population would practice solid waste sorting and recycling. It was assumed that the proposed landfill had an active life of 25 years. Furthermore, calculation of landfill area assumed that waste would pile from the ground to a height of 15 m, at a density of 1,500 kg /m^3. Using JKUAT-SWMM, it was estimated that each household would require a composting digester with a volume of at least 288 L. For a population of 1 million people, daily transport of solid waste would require 57 truckloads, each of 7 metric tons, and the area required for a sanitary landfill would be 16 ha to serve for a period of 25 years. There would be a closure and post-closure period of up to 25 years, during which the landfill would be monitored and maintained (Carlson, 1976).

4.0 Identification of a Solid Waste Disposal Site for Juja

A sanitary landfill site has to be accessible and should be as far away as possible from human settlement. Therefore, a land use map of Juja was used to establish where people lived (Figure 4). From this perspective, the most feasible area was found to be the pasture land around Juja Farm, which was then generally an open area with a low human population density.

Other factors to be considered in landfill site identification were rainfall, soil properties and distance to roads and rivers.

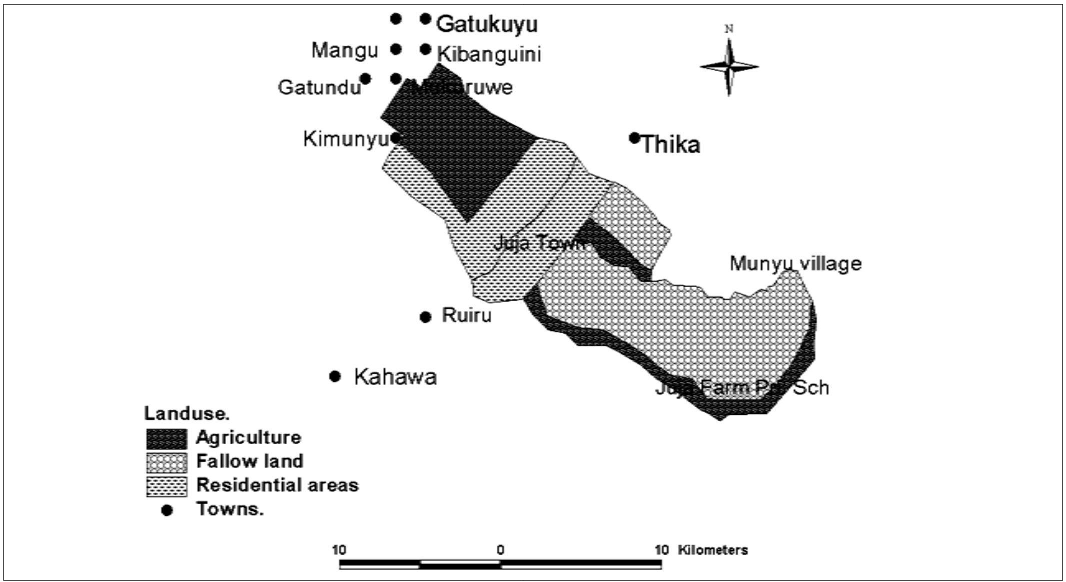

Figure 4: Land use map of Juja

4.1 Rainfall Considerations

The single most important consideration with respect to contamination is the introduction of water into the landfill and the emergence of that water carrying contaminant material (Hagerty *et al.,* 1973). Therefore, the area with the lowest amount of rainfall should be selected. This ensures that landfill management does not have to deal with unnecessarily large quantities of leachate and that valuable agricultural land is not used for non-essential purposes. The area around Juja Farm Primary School, where the average annual rainfall was less than 800 mm per year (Figure 5) and the human population was relatively low, was found to be the most suitable for a sanitary landfill.

4.2 Consideration of Soil Properties

Depending on soil characteristics, leachate from landfills can be a threat against groundwater quality (Fatta *et al.,* 1997). A landfill should be located where the soils do not allow excessive seepage into groundwater. The dominant soils around Juja Farm are vertisols (Figure 6), which according to Kimaru and Gacene (2003) are imperfectly drained and very deep grey to black soils with low permeability. This is also an area where some of the land is yet to be utilised (Figure 4) and the rainfall is relatively low (Figure 5).

4.3 Consideration of Rivers and Roads

To avoid nuisance impacts from solid waste facilities, including odour, noise and visual impacts which may affect community health, image and property values, it is necessary to provide some buffer areas. Landfill gas migration and dispersion affect odours up to 500 m downwind and may serve as indicators for potential health risks. Noise and visual impacts occur within 200 to 300 m of the site boundary. These areas can be designated as buffer zones or mitigation measures such as berms, vegetation and landscaping can be provided to protect sensitive land uses and reduce community annoyance (Zeis and Atwater, 1993).

Buffering can be done around places of human activity, roads, rivers, and anything else that can be negatively impacted by a landfill.

Any waste disposal facility should be distanced from rivers and other surface water bodies. The two major rivers in the study area are Ndarugu River on the North and Thiririka River on the south. The water from these rivers is used for domestic as well as agricultural purposes. Therefore, it is important that the water is protected from pollution. No landfill should be constructed within 100 m of a river or a stream (Basaiaoclu *et al*, 1997). To cater for this requirement, rivers were buffered at a distance of 150 m and roads were buffered at a distance of 300 m on both sides (Figure 7). The road and river map was overlaid with the soils maps and the general landfill map site map selected on the basis of rainfall and land use. The areas inside the road and river buffers were excluded as possible sites for the landfill. Space indicated north of Juja Farm Primary School is a potential location for a landfill site (Figure 8).

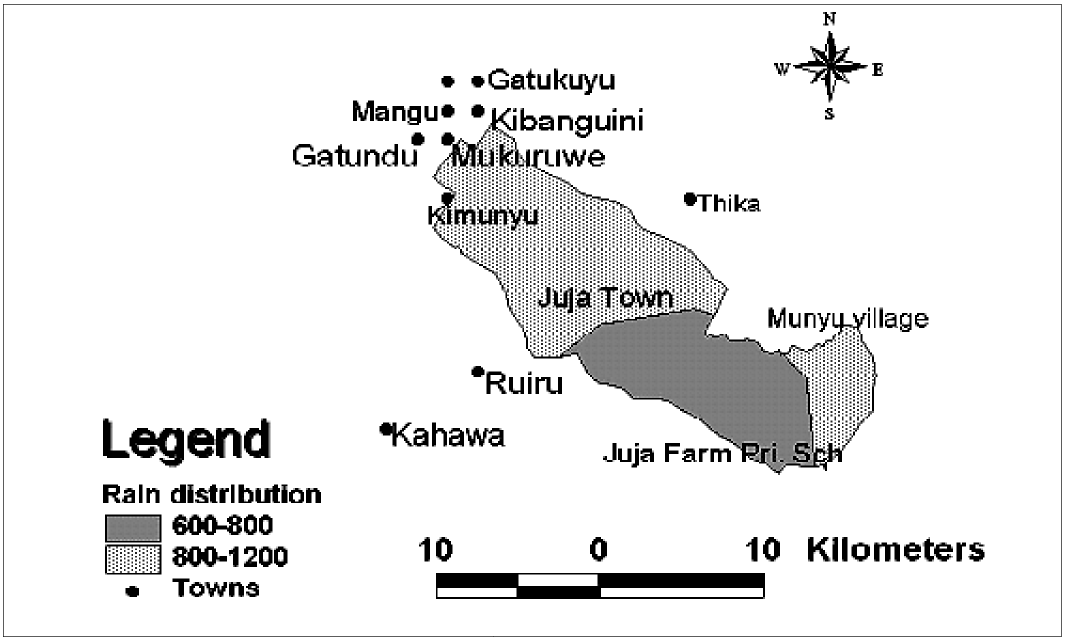

Figure 5: Rainfall distribution map in the proposed project area

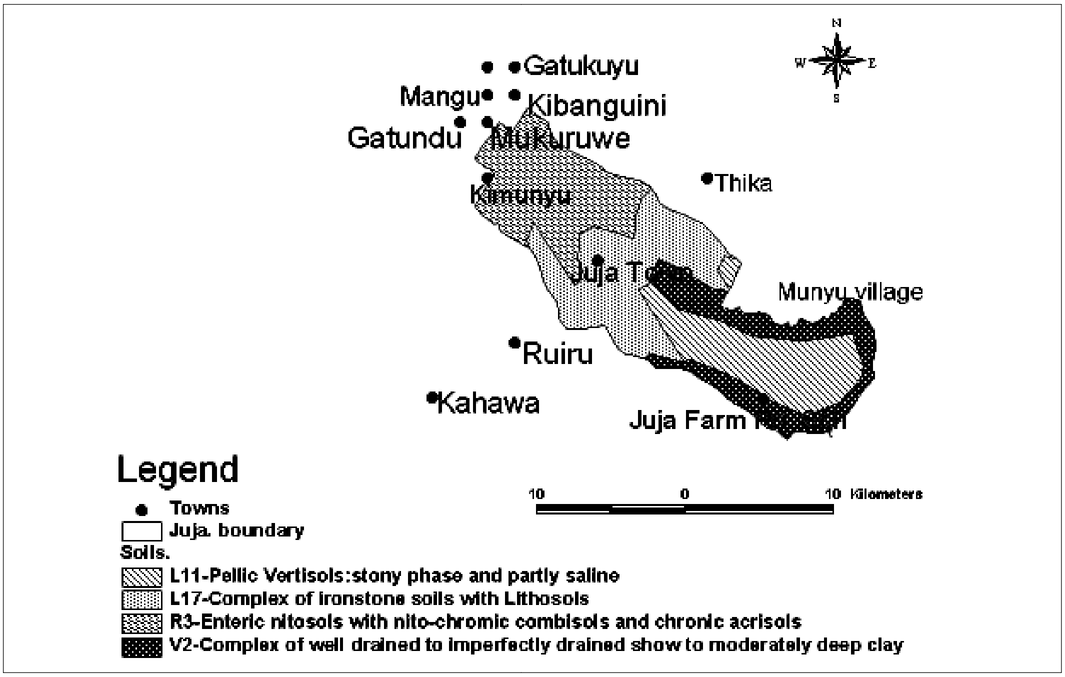

Figure 6: Soil map of the proposed project area

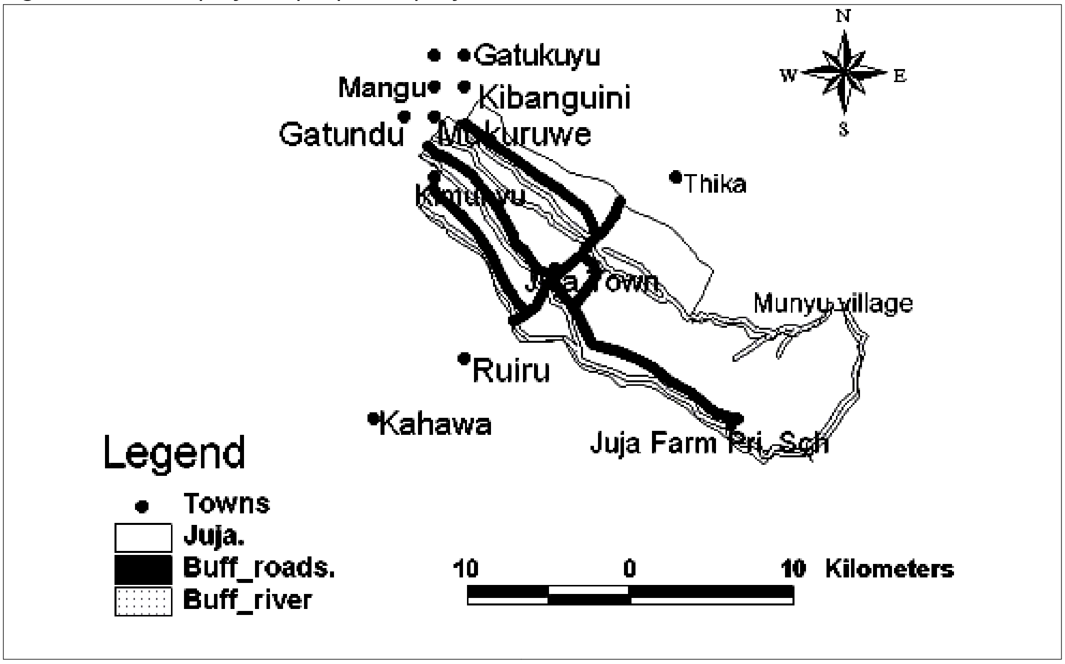

Figure 7: Buffering of roads and rivers

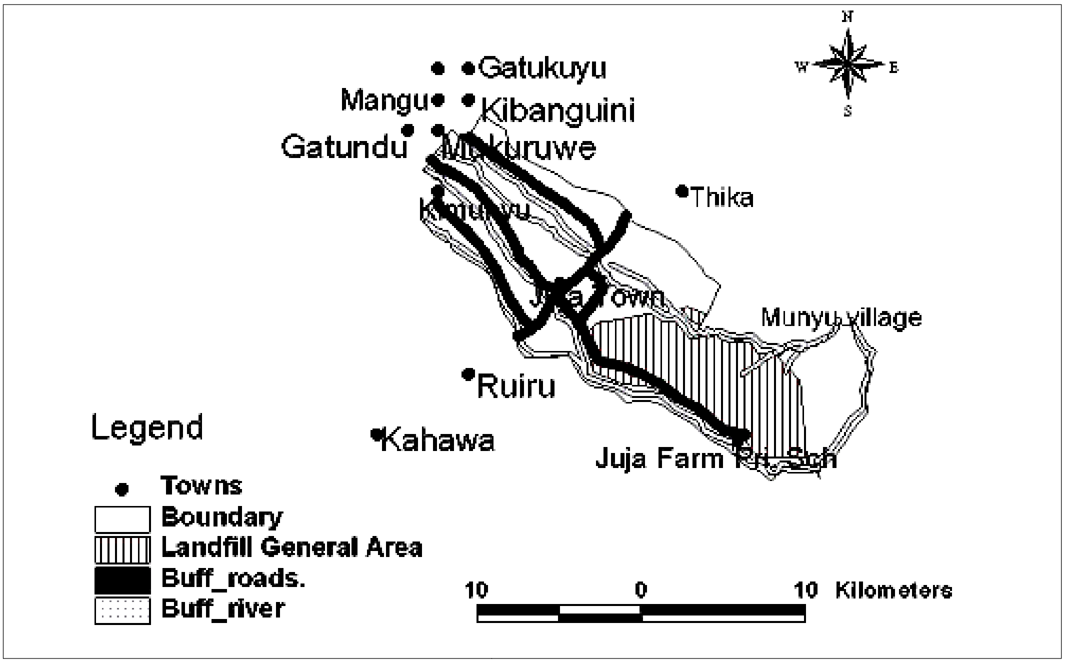

Figure 8: Proposed area for a landfill

Considering the land use of the area, rainfall conditions, roads and soil characteristics, there is a high level of confidence that the identified area will be suitable for a landfill. Vertisols (montmorillonite and kaolinite), which are abundant in the identified site, are suitable for use as landfill liners. Such soils adsorb heavy metals such as Cu, Zn and Cd from municipal solid waste leachate (Frost and Griffin, 1977). Adsorption increases with increasing pH and concentration of the heavy metals. Therefore, as long as the pH is high enough, the vertisols of Juja Farm will likely do a good job of removing heavy metals from leachate.

4.4 Proposed Landfill Site for Juja Area

Within the area indicated as acceptable for a landfill, a 16 ha piece of land, located 3 km North of Juja Farm Primary School should be secured for a landfill site. The proposed landfill is about 14.2 km from Juja town, and has the capacity to serve a population of up to 1 million people. The site is on fallow land that receives an annual rainfall of 600-800 mm. It is at least 3 km from the nearest river or major road. This site would cater for most of the towns in the area of interest, including Juja, Mangu, Kimunyu, Thika, Kahawa, Ruiru and Gatundu. The landfill could serve institutions such as Jomo Kenyatta University of Agriculture and Technology which is located in Juja, Mount Kenya University in Thika, Kilimambogo Teachers' College in Kilimambogo, and numerous secondary schools in the area.

5.0 Conclusion

From this study we concluded that solid waste in Juja consisted of 80% food and other organic wastes, 10% plastics, 2% metal and glass, and 3% mixed refuse. The solid waste production in Juja is less than 0.5 kg/person/day and the average household population is 6 people. If 25% of the population would do composting using household compost digesters of 288 L, the area of a disposal site required for 1 million people would be 16 ha. Considering factors such as rainfall, existing land use, soils, location of roads and rivers, the most suitable sanitary landfill site was located at Juja Farm, 3 km North of Juja Farm Primary School. The area is fallow land that receives an annual rainfall of 600-800 mm.

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