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Waste Utilization in Forest Lands of Florida [1]

Hans Riekerk[2]

INTRODUCTION

Waste disposal is one of the major longterm problems in our society. The problem is especially urgent for Florida with its limited area of uplands, extensive limestone karst topography and high watertable soils, sensitive lakes and streams, and reliance on surface and groundwater supplies for future population growth and land development.

One partial solution for disposal of municipal garbage, ash, sewage, waste water, and some industrial wastes is utilization on forest lands as a fertilizer. A proper design would include an evaluation of available field sites and soil capabilities; of water, nutrients, heavy metals and pathogen loading and decay rates; and types of vegetative cover (Thomas, 1977; Smith and Evans, 1977). Deliberate tertiary treatment of waste water by forested wetlands has been demonstrated for smaller sewage treatment plants (Ewel et al., 1982). Large-scale utilization of waste on forest lands needs more information on environmental effects and longterm land-use planning before being permitted by the Florida Department of Environmental Regulation.

Waste utilization on forest lands has the advantage of not involving a crop of the human food chain and access can be limited to reduce health hazards, especially during waste spray applications. Other advantages are the generally high porosity and absorptive capacity of forest soils, and the longterm nature of forest growth. This allows slow decom-position, weathering and denitrification of introduced wastes (Nutter et al., 1979; Lane and Shade, 1985). Some disadvantages are the long hauling distances and associated transportation costs; the problems of temporary storage and application on rough or forested lands; weed control; and seasonal soil water storage capacity for effluent irrigation (Cole, 1982; McKee et al., 1986; DeWalle, 1979). The frequent reluctance of rural populations to accept wastes from urban areas on their lands is notoriously difficult to resolve (Deese et al., 1982).

Waste application and recycling on forest lands in Florida pose some unique problems because of the wet summer climate, the preponderance of extensive poorly-drained flatwoods, and the presence of karst topography (Brown and Fiskell, 1983). Liquid waste creates a problem with excess moisture due to seasonally high watertables of the poorly-drained flatwoods landscape. This problem requires sufficient temporary waste storage capacity and/or lower rates of waste application over larger areas. The use of a swamp as a biological filter for waste water will need sufficient flow length through dense vegetation and/or peat to accommodate wet-season flow rates (Odum,

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2. Hans Riekerk, Former Associate Professor, School of Forest Resources and Conservation, Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, 32611.

1985). Well-drained soils underlain by porous limestone have been shown to produce less than half the surface storm runoff of pine flatwoods, but may drain waste-contaminated leachates directly into groundwater through sinkholes and interconnected cave and channel systems (Faulkner, 1975).

Substances of environmental concern include pathogens, excess nitrogen and phosphorus, and toxic materials. Bacterial disease organisms tend to be short-lived in exposed soil and water, but viruses may survive in dark, warm, moist conditions for a longer time. Excess nutrients in lakes and streams may cause algal blooms with subsequent mass decomposition. This depletes dissolved oxygen which in turn results in fish kills. Phosphorus usually becomes strongly fixed by fine-textured and organic-rich forest soils and lake bottom sediments, but may readily leach from poor sandy soils. Nitrogen moves easily as nitrate which may be toxic at higher levels.

This circular will summarize research information and give application guidelines for a few types of waste applied to forest lands in Florida. Shredded and composted municipal garbage, digested municipal sewage, and industrial pulp sludges have been tested for pine growth as well as for adverse environmental effects. Irrigation of cypress swamps and tree species trials with sewage effluents and liming of acid flatwoods soil with coal-ash for a nitrogen-fixing tree species will be reported.

WASTE UTILIZATION INFORMATION

Municipal garbage

Municipal garbage is disposed into landfills located preferably 15 or more feet above the watertable. The waste materials contain considerable quantities of plant nutrients but the nature of the waste makes land spreading and tree planting very difficult.

Composted garbage applied to an excessively drained sandy soil in north Florida to improve moisture retention did not affect slash pine (*Pinus elliottii*) growth at rates up to 20 dry ton/acre of compost (Bengston and Cornette, 1973). A trial at the Austin Cary For Forest of the University of Florida used garbage that was shredded after removal of metals and moistened with sewage for composting, and applied at 29, 58, and 116 ton/acre to pine flatwoods plots (Smith et al., 1979). These applications were either spread and disked or placed in furrows and covered by soil with a bedding plow prior to planting with slash pine.

Overall average pulpwood yield at 1.5 ton/acre for all application rates was more than twice that of the controls after 5 years of tree growth. However, yield from the highest garbage application rate was somewhat less than from lower rates. This probably reflected interactions between enhanced tree nutrition and increased weed competition. Average pulpwood yield of 40 ton/acre remained twice that of the control after 13 years of tree growth and showed a slight increase with garbage application rate (unpublished data, K. Munson, 1984). Crown closure at age 9 on the high-rate plot reduced weed competition significantly.

Chemical analyses of the soil sampled after 8 years at different depths showed nutrient enrichment proportional to the garbage application rate in the surface soil, but no effects were found below one foot depth (Fiskell and Pritchett, 1979). Heavy metals remained fixed in the soil-garbage mixtures of the acid soil, as also described by others (Kiekens, 1984). About two ton/acre of calcium added with 116 dry ton/acre of garbage caused the surface soil pH to rise up to 0.5 pH units (Fiskell et al., 1979).

The main operational problem was with inefficient shredding of garbage because of frequent failures to detect chunks of metal. The coarseness of the ground-up material made it very difficult to incorporate the high application rate into the soil (D. M. Post, personal communication). Weed competition during the first years after planting presented a problem by reducing the potential for pine growth.

Sludges

More information is available about the applicability, tree growth, and site effects of using sewage and mill sludges on forest lands in Florida. Paper mill sludge was applied in a northeast Florida pine flatwoods area at rates of 0, 4, 9 and 17 dry ton/acre sludge followed by soil incorporation and bedding (Neary and Comerford, 1983). Application of 4 oz/acre of a.i. DPX-T5648 (Oust) herbicide on the beds reduced weed biomass by about 60%. Slash pine seedling survival after one growing season was 20% higher on the control and low rate plot than on the medium and high rate plots. Pine volume growth after one growing season was 6, 3 and 2 times that of the control for the low, medium and high sludge application rates, respectively. The difficulty of incorporating the mire created by the high sludge application rates resulted in poor pine survival and growth.

A one-year leaching study was conducted with an industrial sewage sludge applied by hand to plots in a five-year-old slash pine plantation on a flatwoods soil at the Austin Cary Forest of the University of Florida in north-central Florida (Comerford and Fiskell, 1983). The application rates were 2, 5 and 10 dry ton/acre sludge on small plots and 12 dry ton/acre sludge on soil in lysimeters buried in the field. About 3% of the amount of nitrogen applied with sludge in the lysimeter pots leached equal amounts of ammonium and nitrate nitrogen. Heavy metal mobility was highest for zinc at 2.70% of that applied with sludge, with 1.05, 0.09, 0.08 and 0.02% leached of the applied manganese, copper, nickel and cadmium, respectively. Low mobility of heavy metals was also evident from the leaching data of the plots regardless of the rate of sludge application. Only the 10 dry ton/acre sludge treatment plots showed significant increases of nitrogen and phosphorus concentrations in tree foliage after one year. Another study on similar soils nearby demonstrated the effects of spraying 2 and 12 dry ton/acre sludge between rows of young trees in multiple applications during the course of one year (Fiskell et al., 1984). Analyses of soil solutions during that year and of soil sampled 2.5 years later showed results similar to the single application experiments in that most of the plant nutrients and heavy metals remained in the top soil without lateral movement into the adjacent soil.

Municipal sludge was applied with a side delivery tanker to slash pine 10 months after planting and just prior to planting on a well-drained soil in northwest Florida at rates of 0, 10, 20, 30, 40 and 50 dry ton/acre (Riekerk and Lutrick, 1986). Average volume growth and yield improvement of the established seedlings after 10 years of growth were 0.054 ft^3/tree/year and 28.9 ft^3/acre/year, respectively, per 10 dry ton/acre of sludge. Tree growth and yield improvement of the trees planted after sludge applications was 2 to 3 times lower than that of trees planted before sludge was added, mainly due to more weed competition, disease and mortality. Soil and tissue analyses showed that the sludge applications increased soil acidity (probably due to nitrification processes) and phosphorus in the surface soil. Heavy metal mobility was minimal (Lutrick et al., 1986).

A study of young high-density biomass plantations in Florida included 5 to 15 dry ton/acre sewage sludge applications after tree planting (Rockwood et al., 1983). First-year slash pine biomass yield on a flatwoods site in North Central Florida was comparable to that for a commercial fertilization rate, but sand pine (*Pinus clausa*) on deep sandy soils of Northwest Florida did not show a significant response. Tree survival after sludge applications was reduced for *Eucalyptus grandis* and *Casuarina cunninghamiana* in South Florida due to weed competition, but height growth of surviving trees was improved. Average first-year *Eucalyptus* yield improvement was about 2 ton/acre per 10 dry ton/acre of sludge as compared to 14 ton/acre yield of tree biomass after a heavy commercial fertilizer treatment. Surface soil analyses of the various trials showed significant nutrient increases at all higher sludge application rates except for potassium, or with the low application rate in the Eucalyptus plantation. There was a trend for more soil acidity after sludge treatments. Foliar analyses showed nitrogen and phosphorus increases proportional to sludge application rates. Cation nutrients in foliage showed an opposite trend mainly due to dilution by dry-weight biomass increases.

Waste waters

The use of waste waters in the Florida landscape is often limited by the lack of moisture storage capacity in sandy soils and seasonally heavy rainfall. However, sewage effluents have been used to irrigate a droughty forest soil near Tallahassee in Leon County (Smith and Evans, 1977). Thirty tree species were planted on the sandy soil and then were irrigated with up to 8 inch/week of municipal sewage effluent. Three-year height growth analyses showed that hardwood species responded much better than did the coniferous species. Growth of 31-foot height and 80 dry ton/acre biomass was achieved by eastern cottonwood (*Populus deltoides*), and 24-foot height and 29 dry ton/acre of biomass was achieved by sycamore (*Plantanus occidentalis*), while the three-year growth by slash pine was only 16 feet and 16 dry ton/acre biomass. The effluent irrigation treatments essentially changed the originally dry site into a wet site to which the moisture-loving tree species adapted readily. Ten years later the fastest growing species were estimated to exceed 60 feet in height before removal (C. Goodheart, personal communication). Elsewhere the gradual conversion of forest land to wetland conditions by effluent irrigation and the logistics of harvesting and site preparation have led to single-use dedication of such areas for disposal only (Sopper and Kerr, 1979).

Sewage effluent from some small towns in northern Florida has been discharged into cypress (*Taxodium distichum*) swamps for decades (Ewel and Odum, 1985). These disposal sites provided an opportunity to study longterm effects of sewage on growth of swamp vegetation and absorptive capacity of bottom sediments. One system, near Waldo in Alachua county, had discharged effluent for 41 years into a cypress strand now about 100 years old (Nessel et al., 1982; Nessel and Bayley, 1985). It was found that the annual growth rate in basal area of trees near the outfall pipe was 100% more than during the 19 years prior to the treatment period. A nearby control swamp was used as a reference to account for normal stand development and climatic variability. Annual tree growth 0.2 miles downstream was 78% higher than the control. Chemical analyses showed 36% more phosphorus in the foliage and 447% more phosphorus in sediments of the sewage-treated swamp as compared to the control. Water quality was monitored for a few years at another cypress swamp site of longterm sewage effluent discharge near Jasper in Hamilton county. Tree diameter analyses suggested growth was reduced by the earlier raw sewage disposal but was eventually improved by treated effluent discharges as compared to a control (Lemlich and Ewel, 1984). The water quality data showed an effective removal of nitrogen and a sufficient reduction of coliform count in the swamp at 1.5 miles downstrearn of the outfall pipe (Tuschall et al., 1981). However, only 36% of the effluent phosphorus was removed by the swamp, suggesting that little fixation was in the vegetation and bottom sediments. Slow flow and stagnation of effluent in the swamp during a dry observation year drastically increased all water quality levels.

A cypress dome near Gainesville, Alachua county, was treated experimentally with one inch/week of sewage effluent from a small community during 5 years (Dierberg, 1980; Ewel and Odum, 1985). Biomass of the understory (mainly water plants) increased from about 0.1 dry ton/ acre to 1.6 dry ton/acre, and pond cypress seedlings showed 50% more height growth where effluent was added. However, mature trees showed little increase in annual diameter growth as compared to a control swamp. Phosphorus retention was more than 90% of the input with sewage, but the concentration in surface water still was about 6 ppm as compared to 0.02 ppm in the control. Total nitrogen in water also showed a significant increase due to the sewage effluent treatment. Most of the nutrient loading was fixed by organic matter that accumulated in the bottom sediments. There was evidence that some of the swamp water moved laterally into the surrounding shallow water table. Investigations of disease organisms showed little risk as a health hazard, but viral dissemination still needed more study.

Coal ash

With increasing power generation in Florida, more coal waste such as fly-ash is being produced (Oven, 1983). Ash utilization in the nation was processed mostly for building materials and road beds but a fraction was used for soil amendment. The normally alkaline ash has a strong liming effect and might be used to neutralize acid flatwoods soils in Florida. A small study near Gainesville in Alachua county reported a seven-fold increase of biomass yield by Australian pine (*Casuarina cunninghamiana*) when planted in a flatwoods area supplemented with 57 dry ton/acre of fresh fly-ash (Riekerk and Korhnak, 1984). *Eucalyptus viminalis* showed leaftip burn and no growth response. Slash pine showed chlorosis of growing tips but had improved height growth after a few years. Performance by southern pine species was also less than that for hardwoods on a 12-year-old ash basin in South Carolina (McMinn et al., 1982). Liming of the forest soil in the Austin Cary forest study increased the surface soil pH from about 4 to over 6, and a similar pH change in runoff water. This pH change caused higher extractability of soil phosphorus and some heavy metals but only little amounts of these elements reached runoff water.

SUMMARY

The above review of research results from forest lands in Florida shows that, in general, waste materials can be used to improve yields with few ecological consequences or human health hazards. The basic precautions are to take care that the proper soil types have been selected for the particular type of waste. The proper tree species should be selected and established prior to waste application. Waste materials should be applied annually at low rates, preferably during dry periods.

For example, concentrated nitrogen-rich wastes require wet and neutral soils to promote the denitrification process, but require hydrologically closed systems to prevent runoff contamination. Sludges containing heavy metals can be used on soils containing sufficient clay and/or organic matter in the profile. Alkaline ashes can be used to neutralize acid soils or can be mixed with nitrogen-rich sludges to counteract the acidifying nitrification process. Liquid sewage effluent requires forested wetlands of sufficient path length, and with organic bottom sediments. In all cases, a well-established forest stand is necessary to avoid costly measures for the control for the considerable weed growth associated with waste utilization on land. Furthermore, a young stand of vigorously growing pioneer species utilizes more of the introduced nutrient elements. The need for waste disposal at minimum cost would favor a high application rate at infrequent intervals. Usually, such amendments will significantly overload the absorptive and processing capacity of the forest lands. Therefore heavy applications of waste should be avoided, since they may cause direct contamination of open waters by overland runoff, and contamination of ground water by deep seepage or through sinkholes during wet seasons (Wilbert and Archie, 1981).

FEASIBILITY OF WASTE UTILIZATION

In addition to the forest growth and ecological effects of waste utilization, the practice involves the logistics and management of application of the wastes within state regulatory constraints, as well as a consideration of economic and social aspects.

Methods of waste management and application are varied and often have to be adapted for specific site conditions. The use of ground and composted garbage was limited severely by metal in the raw material damaging the cutting blades. Metal detectors and magnets have improved the efficiency somewhat, but not to the point of making it technically feasible (D.M. Post, personal communication). Presorting at the household level would be required. High rates of composted garbage applications were difficult to incorporate into the soil, necessitating burial in furrows between planting beds.

Sludge applications from a tanker truck with simple gravity delivery from the back or sides worked well if the site was well drained and stumps eliminated from the truck passages. Multiple passes for heavy application rates damaged the soil to the point of bogging down equipment and destroying tree seedlings (M.C. Lutrick, personal communication). Dumping truckloads of sludge on cleared forest land with subsequent spreading using a tractor blade was feasible, but required tree planting afterwards with attendant weed and wildlife problems (Wilbert and Archie, 1981; Berry, 1980; McKee et al., 1986). An operational procedure was adopted by the city of Seattle for large-scale sludge utilization on forest lands in Washington. This procedure included storage in temporary lagoons from which sludge was pumped into a 2000-gallon tanker with a remote-control spray cannon on a skidder frame. The application rate was up to 21 dry ton Per acre every five years into established plantations from skid trails spaced 300 feet apart (Nichols, 1980; Ag-Chem, 1982; Anon., 1984; EPA 1984).

The feasibility of wastewater application follows standard irrigation guidelines based on several factors. These include wastewater discharge, weekly application rate, irrigation rate, sprinkler spacing, line pressure and nozzle size relationships (Meyers, 1979). Forest lands have good infiltration capacities and do not need the annual removal of irrigation systems as a practice for agricultural crops during harvest and regeneration operations. However, common hillslope conditions require pressure and/or spacing adjustments to be made between contour lines. Continuous pumping or sufficient slope to drain all pipes is required to prevent pipe bursting during cold weather (Nutter et al., 1979). Care should be taken to remove shrub vegetation interfering with sprays. Application of sewage effluent to forested wetlands requires only a low-pressure outfall designed to control optimum daily flow rates and distribution (Fritz and Helle, 1985). Spray irrigation of liquid sludge containing 3% solids with modified sprinklers caused impairment of infiltration into the gravelly forest soil after a 10-inch application, requiring dilution with water (Stednick and Wooldridge, 1979).

The feasibility of utilization of coal ash depends mainly on the desired degree of neutralization of soil acidity, the accessibility of cleared forest land for a compost spreader, and ash transport distance to the site (Riekerk, 1984). Dust control is often required and can be achieved by soil disking.

Guidelines from the Environmental Protection Agency (EPA, 1984) and the Florida DER (FDER, 1984) for sludge applications set annual nitrogen loading rates at less than 500 lbs/acre to prevent significant nitrate pollution of ground water. The FDER therefore limits annual applications of Grade I and II sludges on nearly level forest lands to 6 dry ton/acre and requires that it be at least 200 feet from state water bodies. The water table has to be at least 2 feet below the soil surface and the resulting soil-sludge mixture should have a pH of at least 6.5 at the time of application. Grade I sludge contains less than 30 ppm cadmium, 100 ppm nickel, 900 ppm copper, 1000 ppm lead and 1800 ppm zinc. The annual application rate of Grade II sludge should contain less than 10% of a total allowed for each site of 4.45 lbs/acre of cadmium, 111 lbs/acre of nickel and of copper, 222 lbs/acre of zinc and 445 lbs/acre of lead. Table 1 lists some equations to calculate application rates of waste materials and their mineral elements.

Few economic evaluations of waste utilization are available but generally indicate no significant cost advantage over the use of commercial fertilizers. This suggests that incentives for landowners, if they are to accept waste materials for soil and site improvement, have to come from disposal fees. For example, the dollar value of a sludge-treated forest stand in the Pacific Northwest amounted to 165% as compared to the control, but the net value was only positive for cheap forest lands (<$200 per acre) when interest rates were less than 5.2% per year (Schreuder et al., 1981). The alternative of landfill disposal had a negative net dollar value for interest rates up to 15% per year. Most (89%) of the cost of sludge utilization was incurred by transport before it reached the forest site. Sludge hauling by truck was competitive with rail transport up to 20,000 cubic yards per year within a 100-mile range in the Eastern U.S., and provided greater routing flexibility (Nye et al., 1982). Increasing the annual transport volume from 10,000 to 100,000 to 1,000,000 cubic yards reduced transportation costs for an 80-mile distance from $800 to $600 to $300 per 10,000 cubic yards, respectively.

Economic analyses were made of wastewater processing by cypress wetlands in Florida for a range of discharge rates and land values (Ewel and Odum, 1978; Fritz and Helle, 1985). The cost was about $158 for 200,000 gallon/day of wastewater discharge with a low-pressure pipe network into an isolated cypress dome of $2,000/acre value. The cost for a cypress strand valued at $1,000/acre was $82 per day. These compared to $188/day for an high-pressure upland spray irrigation system. Increasing the daily discharge rate reduced the unit cost somewhat for all three systems, but the reduction was less for the cypress dome because of the cost of maintaining hydrologic isolation. Waste water treatment by forested wetlands was cost effective only for discharges less than 500,000 gallon/day and application rates of one inch per week (Ewel et al., 1982).

Sociological aspects usually represent the main barriers for waste utilization (Burd, 1981; Deese et al., 1982). Public aversion to sewage sludge and garbage is often emotionally based. Legitimate concerns include health hazards, odors, truck traffic, loss of property value, accidental spills, and adverse ecological or environmental effects. Health hazards include pathogens as well as toxic substances entering the human food chain. Longterm residence of introduced heavy metals could limit some future land uses and thus discourage private landowners. Early and tactful education of the landowners and local public involved are key elements in the acceptance of a project.

Equations for calculation of waste application rates

I. Waste Volume x Bulk Density = Waste Weight

a. X cubic yards x 27 x Y pounds/cubic feet = 27XY pounds = 27XY/2000 tons

b. X gallons x 1/7.48 x Y pounds/cubic feet = XY/7.48 pounds = XY/14,960 tons

c. X cubic meter x Y grams/cubic centimeter = IOOOXY kilograms = XY metric tons

II. Liquid Waste Volume x Concentration of Solids = Solids weight

a. X gallons x Y percent solids = 0.08345 XY pounds

b. X acre-inches x Y percent solids = 6798 XY pounds

c. X cubic meter x Y percent solids = 10 XY kilograms

III. Waste Weight x Concentration of Element A = Weight of A

Note : The equations below are for percent values of elemental concentration. If the concentration is given in parts per million (PPM) divide the answers by 10,000. If the concentration is given in parts per billion (PPB) divide the answers by 10,000,000.

a. X tons x Y percent of A = 2OXY pounds of A

b. X pounds x Y percent of A = XY/100 pounds of A

c. X kilograms x Y percent of A = IOXY grams of A

d. X metric tons x Y percent of A = IOXY kilograms of A

IV. Waste Weight [1] / Application Area = Application Rate

a. X tons / Y acres = X/Y tons/acre

b. X pounds / Y acres = X/Y pounds/acre

c. X metric tons / Y hectares = X/Y metric tons/hectare

d. X kilograms / Y hectares = X/Y kilograms/hectare

[1] NOTE: Or mineral element weight

Short-term and long-term effects, regulatory permit compliance and legal recourse, as well as benefits to the landowners need to be addressed. Established demonstration sites with documented data materially aid in such efforts. Managers of public lands would be more inclined to establish such demonstration sites and provide a more reliable foundation for longterm waste utilization projects than would private landowners.

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