SOILS IN LOW DENSITY RESIDENTIAL AREAS

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Summary

Residential areas are considered “low density" when they have low percentages of impervious area or isolated areas of disturbed soils and <300 persons/km^2 population density. These areas contain a high amount of urban (human-altered and –transported) soils. If heavily-used or unprotected from raindrop impact, these soils may cause increased runoff, flooding, and erosion plus soil, surface water and groundwater contamination, all of which pose a threat to human health and safety. Two soil-related

concerns for managers of low-density residential areas are water quality for human use and agricultural productivity from inputs of waste as fertilizer. Four examples of urban soil description and management in low-density residential areas show the range of impacts and the variety of creative management options: 1) human waste management, 2) rural ponds, 3) unpaved roads and trails, and 4) riparian corridors.

1. Introduction

Residential areas are considered “low density" when they have low percentages of impervious area or isolated areas of disturbed soils and <300 persons/km^2 population density. Low-density residential areas are affected by urban development at localized sites but are not enclosed by contiguous urban blocks. Low-density residential impacts on soils occur around isolated dwellings, small villages, camps, and frequent gathering places such as rural schools. Human-altered (also called "urban") soils in these areas include terraced gardens; (unpaved) compacted roads and trails; cut and filled areas associated with buildings, levees, railroads, roads, and trail construction; ponds, ditches, and canals; water supply canals; levees and stormwater diversions; human burial and waste-disposal sites. If heavily-used or unprotected from raindrop impact, these soils may cause increased runoff, flooding, and erosion plus soil, surfacewater and groundwater contamination, all of which pose a threat to human health and safety. Two soil-related concerns for managers of low-density residential areas are water quality for human use and agricultural productivity from inputs of waste as fertilizer.

1.1. Temporary and potentially reversible nature of scattered soil disturbances

Many of the problems associated with human-altered soils in low-density residential areas are temporary or the resulting damage to the soil system is potentially reversible. For example, occasional septic system failures may damage the adjacent lawn or contaminate the residential well for that property, but have minor impact on the aquifer or surface waters overall. Constructed soils that affect water infiltration or flow on a small scale can be redesigned in case of failure or extreme weather. Waste disposal known to cause health risk can be placed elsewhere. In most cases, remedies can be carried out within the property boundaries of the individual owner. Natural processes rebuild organic matter, decrease compaction, and degrade or diffuse contaminants to improve the soil and water quality following infrequent, minor, or isolated impacts. Common problems that are partially reversible if they are infrequent and scattered include topsoil loss following erosion and contamination of soil and water with microbes, toxic compounds, or metals from household waste. Erosion increases when excess runoff is caused by disturbance of water-flow (into and through soil) due to human compaction or sealing.

1.2. Common soil problems get worse when isolated sites are joined together

Low-density areas behave like boundary zones with an edge effect. Urban soils with problems due to expanding population are a minor component of the landscape, and soil management for agriculture, forestry, or livestock enterprises minimizes the impact of the urban disturbance. As urban areas expand, the edges of these disturbed zones begin to link into corridors that have potential to either function as barriers to hydrology in the area or as conduits for dispersion of contaminants across the landscape. Rural ponds, roads, and riparian corridors function as conduits for human impacts in solid waste, surface waters, or for indirect dispersion of human health risks (bacteria, diseases, and contaminants transported on animals or produce). The potential to balance human-affected soil genesis (layer formation) with geologic and other genetic factors of soil formation (horizonation) is retained in low-density areas. This balance contrasts with medium and high-density areas where urban "waste" production exceeds the available disposal area for sustainable management.

1.3. Low density areas function as urban disposal areas or independent sustainable systems

Low-density areas fall into two major categories: 1) recipients of urban outputs from nearby population centers (disposal areas) or 2) sustainable systems or systems with boundaries that function independently of population centers. An example of the first is small towns with landfills or farms receiving waste from cities, and an example of the second is villages with surrounding farms or waters receiving only the village waste.

Severe impacts on water and vegetation are often due to unplanned geographic expansion of the low-density areas and extended periods of residence in seasonal cottages. Signs of urban misuse are contamination of lakes and drinking water supplies as well as changes in plant communities. Four examples of urban soil description and management in low-density residential areas show the range of impacts and the variety of creative management options: 1) human waste management, 2) rural ponds, 3) unpaved roads and trails, and 4) riparian corridors.

2. Nightsoil: Human Waste Disposal on Soils

Attitudes toward local management of human waste reflect contrasting value placed on it as fertilizer compared to waste material for disposal. Changing approaches across time and place share the common link of soil as the recipient of the "nightsoil" before or after dilution with water or solids. Historically, the land application of nightsoil as fertilizer has been more prevalent than restricted disposal of "nightsoil" due to the risk of disease from spread of pathogens in soil, food, and water. Management techniques for human waste are highly dependent on funding and nearby soils suitable for wet or dry disposal.

2.1. Dilution pathways for human waste to soil

In low-density residential areas, human waste disposal follows one of two dilution pathways to the soil. Dilution by water deposits waste into rivers, swamps, or septic absorption fields and the flow of water carries contaminants to the soil. Pathways for human and household waste to the soil disposal area range from pressurized flush toilets and sewer pipes fed by water piped into the home, to gravity-controlled open channels that are fed by rainwater and village wastewater and located along the sides of streets. In parts of Tanzania, China, Cameroon, and Pakistan there are systems of open drains that carry waste directly to the agricultural areas where soil may be enriched by nitrogen, organic matter, phosphorus, metals, and bacteria.

The waste becomes diluted with soil or with intermediate bedding materials such as straw or sawdust. The solids may be composted, stored in septic tanks, or spread directly on surface soil as fertilizer for vegetables or field crops. The solid waste from septic tanks often is disposed first into landfills or sewage treatment plants and later onto soil, or it is spread directly onto soil using wagons or dry manure spreaders. Composting was a common practice in medieval times especially around Monastery communities. Latrines were sometimes located on the second floor of buildings above gardens so that nightsoil (human urine and feces) fell directly into compost heaps without dilution. Kitchen middens and pub gardens were historical sites of vegetable production using nightsoil as fertilizer. Middens and gardens were located close to lodging places for ease of disposal of daily waste from collection containers or chamber pots. Whether or not the nutrient value or the disease risk of the nightsoil was understood, the disposal opportunity was clear.

2.2. Chemistry and physics of human waste and soil disposal areas

The chemistry of human sewage influences the potential impact of the waste on soils and related water supplies. Human sewage has a narrow carbon to nitrogen ratio of 10 to 12 indicating that there is rapid decomposition of the organic matter in human waste. Nitrate forms of nitrogen are water-soluble and are produced through microbial activity as the pH of waste-enriched soil is lowered. Nitrate in excess of plant uptake contaminates wells and leads to human health problems from drinking water.

In USA, individual home or commercial lots in low-density residential areas generally rely on septic systems to treat and then disperse wastewater and solids. Soil type is a major factor in the success of these systems. Many systems are installed on disturbed soils after building construction. The soils often have been cut or filled and compacted by heavy vehicle traffic. Mounds are commonly created to extend the depth of soil to meet local requirements for septic drain fields or to raise buildings above flood-prone elevations. Although requirements for depth are clearly stated, human-influenced limitations to the function of the soil (imported or residual) are less likely to be examined closely.

2.3. Local planning for soil-based human waste management

Site suitability for waste disposal often is based on land values rather than soil and crop nutrient needs. Areas that are not desirable for other development are targeted for waste disposal. Wastes also are deposited commonly in areas where any environmental impact will be external to the community. Examples are 1) surface water or eroding soil flowing away from the residential area, 2) disposal sites across political boundaries sometimes involving a cash payment to the receivers, 3) wet areas and depressions where excess nutrients leach into the groundwater, 4) cropland application at rates above plant nutrient needs or removal of plants for offsite sale to export contaminants, and 5) ravines and bedrock lines depressions where subsurface lateral flow or mass movement threatens the stability of the waste deposits.

Case studies of low-density residential human waste management are described in publications listed in the Bibliography. They cover:

- Bangladesh—village nightsoil treatment of agrosanitation
- Thailand—human waste management for rural factories
- India—anaerobic digestion of human excretia for biogas fuel

3. Ponds

Small ponds in low-density residential areas have multiple uses around the world. They serve as direct water supply for humans, livestock, and wild animals as well as serving as potential groundwater recharge sites. They provide erosion, flood, and pollution control and stormwater storage in residential and urban fringe areas. Ponds provide rich habitat for animals and wetland plants. Stored water is used for food production, fire-protection, and recreation.

3.1. Ponds for stormwater and sediment storage

Ponds established in intermittent or ephemeral watercourses serve as stormwater retention, flood and erosion control devices. Stormwater retention and flood control functions are important in regions where natural runoff is high or where impervious surfaces or soil compaction has accelerated natural runoff rates. A series of these ponds along a watercourse can reduce stream velocity, delay the flood water peak, and give stored water time to percolate to groundwater.

Stormwater ponds in low-density residential areas are used to hold water runoff from impervious urban surfaces and yards, thereby allowing the clay and soil organic matter to act as a filter for sediment and pollutants. Parking lots and roads in particular are sources of petroleum products, anti-freeze salts, heavy metals, and products released by asphalt weathering. Yards in affluent suburbs may contain excess fertilizers, pesticides, and herbicides.

Ponds located adjacent to bare soil areas slow down runoff water and allow it to drop suspended sediment. Roadside diversions and culverts are used to channel runoff and sediment from roads and roadsides into settling ponds rather than straight into streams. Such ponds act as effective sediment traps, but soon lose their efficiency as they fill with sediment.

Sediment fill reduces storage capacity, which contributes to downstream flooding. Ponds that do fill with sediment must be dredged, breached, or revegetated. However, erosion control in surrounding uplands, especially bare soil areas, is a less costly and more practical alternative prevention measure.

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*Examples of Case Studies about Nightsoil

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Biographical Sketches

Joyce Mack Scheyer is a soil scientist with the National Soil Survey Center of the United States Department of Agriculture - Natural Resources Conservation Service. Dr Scheyer provides national technical leadership for the use and management of soils in urban areas. Her projects are varied and include describing urban soils using soil survey techniques, estimating dietary and inhalation risk from soils in urban gardens, and modeling soil aggregation as an index of erodibility and contaminant transport. She is active with national and international workgroups in urban soils.

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