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DETERMINATION OF LAND SUITABILITY FOR WASTEWATER IRRIGATION USING MULTI-LAYERED GIS APPROACH

Angela Lane, Katie Beecroft, Sian Cass

Lowe Environmental Impact, PO Box 4667, Palmerston North 4442
Email: angela@lei.co.nz.

Abstract

An alternative to surface water discharge of treated wastewater is application to land via irrigation. Identification and evaluation of suitable land for the irrigation is an essential step in the design and consenting process.

A desktop investigation process using a geographical information system (GIS) has assisted with identifying suitable land for irrigation of wastewater. This desktop investigation process is based on using fundamental soil layers (FSL) and New Zealand land resource inventory (NZLRI) layers and combining selected parameters to establish ‘zones’ of suitability. This system gives areas for irrigation based on their mapped soil, geological and in some cases, hydrogeological and climatic properties. Following this GIS process, acceptance of using and feasibility of acquiring parcels of land needs to be determined through field investigations and consultation with interested parties.

Through incorporating GIS layers, a five-step process is used to determine the suitability of land. First, parameters are nominated that impact on irrigation (e.g. nutrient uptake potential, soil attributes, hydrological parameters); second, rules are then established around each parameter which enable any location to have a score applied; third, a scoring system is then used for each parameter that ranges from 0 (unsuitable) through to 5 (most preferred) for land application; fourth, the scores given for each parameter assessed are then added to give a total score for a specific land area; and fifth, five zones are then determined based on the total scores and are listed as Zone A (most suitable for land application), Zone B (moderately well suited), Zone C (minor limitations for suitability), Zone D (significant limitations for suitability) and Zone E (severe limitations for suitability).

A combination of factors determines irrigation suitability. For example, land that is flat and well drained with limited flood risk may score highly (Zone A) compared to land that has a degree of slope >30° or is poorly drained and has a high flood risk (Zone E).

Undertaking a desktop investigation using GIS to determine land areas for the application of treated wastewater provides an avenue for more focused field investigations.

Key Words

Land Suitability, Land Treatment, Municipal Effluent, Wastewater, Geographical Information System, GIS, Fundamental Soil Layer, Land Resource Inventory

Introduction

Wastewater discharge to water has historically been common in New Zealand but is considered undesirable and is a contentious issue for any community. When proposing a change to a wastewater system cultural, environmental, financial and recreational values all require consideration.

Treated municipal wastewater discharges to land provide an opportunity to utilise the water and nutritional value of the wastewater; thus creating an opportunity as a resource rather than a waste product. Using treated wastewater for irrigation can provide benefits to agricultural, horticultural, and recreational facilities such as golf courses and parks. The removal of a direct discharge to water, and the near complete use of wastewater applied nutrients has environmental benefits of reducing nutrient enrichment into water ways and of reducing the reliance on groundwater and rivers for "clean" water irrigation.

To take advantage of wastewater as a resource; identification and evaluation of suitable land for irrigation is an essential step in the design and consenting process. The utilisation of geographical information systems (GIS) streamlines the land selection process by narrowing the choices into the most environmentally suitable land parcels for receiving wastewater applications.

The desktop GIS investigation must be followed by further selection with consideration of the cultural, financial and recreational values for the community of concern; plus regulatory constraints. In addition to the community values and regulations; in-field investigations provide more detail for appropriate land selection. This investigation process has assisted several New Zealand communities with identifying suitable land for irrigation of wastewater.

Determination of Suitable Land for Wastewater Application

Often land near to a wastewater treatment plant is not well suited to wastewater irrigation for reasons such as proximity to neighbours, flooding potential, proximity to a waterway and poorly or excessively drained soils. While these issues are not insurmountable with good irrigation design, they are limiting and may warrant examination of land further away from a treatment plant.

Detailed and in-field land assessment of a large area is a time-consuming and costly undertaking. A preliminary quick and reliable approach is needed to narrow the land area into a cost-effective size for detailed investigation.

A preliminary assessment of the suitability of land for wastewater irrigation can be undertaken through a desktop study using GIS. A combination of fundamental soil layers (FSL) and New Zealand land resource inventory (NZLRI) layers can be used in GIS to generate 'zones' of suitability for wastewater irrigation within a nominated area (i.e.10 km radius). These zones provide a hierarchy of suitability for receiving wastewater and are established using a five-step process as outlined in Figure 1 and detailed below.

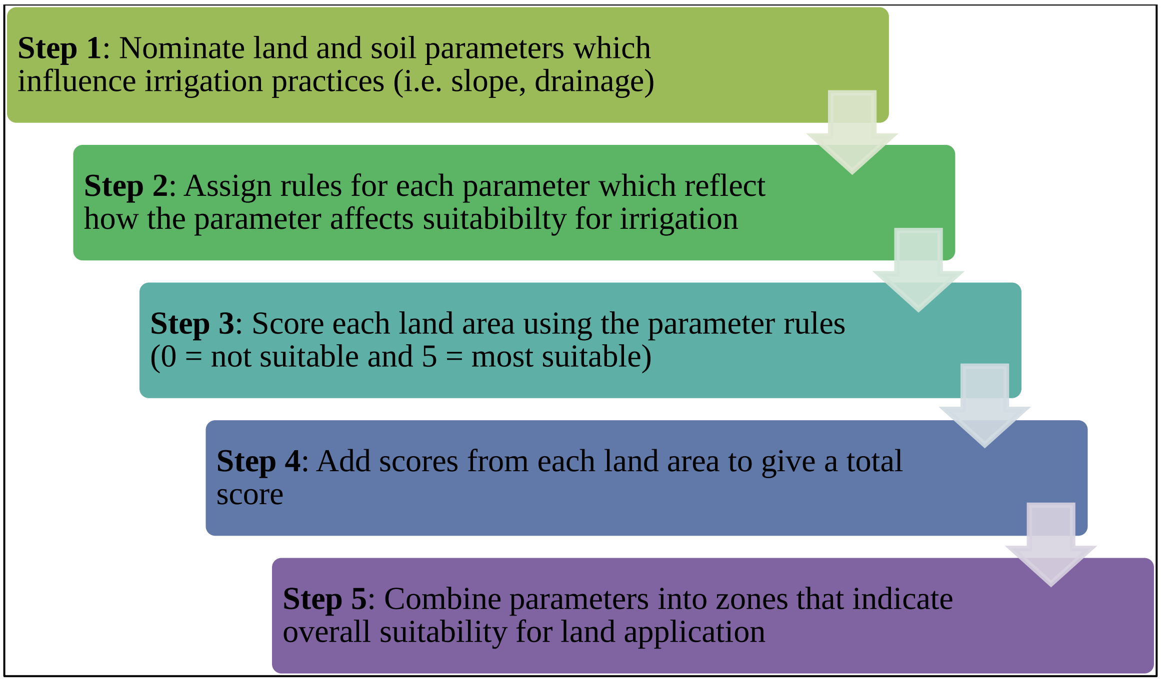

Fig. 1: Five step GIS process for selection of land suitable to receive wastewater irrigation

Step 1: Nominate Parameters

There are a wide range of soil, environment and land use parameters which influence irrigation practices. Step 1 begins with selecting the key parameters that reflect the area to be investigated. For example, an area which includes hill country needs slope to be included as a parameter, and a location at high altitude will utilise soil temperature as a parameter to account for seasonal snowfall. To give a balanced approach, five or more parameters need to be included. Examples of parameters that have been utilised by various investigations from northern Hawke's Bay to Southland are listed below.

- Land use;
    - Nutrient uptake potential.
- Soil attributes;
    - Slope and stability.
    - Soil drainage and permeability.
    - Depth to restrictive layer.
- Hydrological and hydrogeological attributes;
    - Mounding risk.
    - Flood return interval.
    - Riparian buffers.
- Climate;
    - Soil temperature.

Step 2: Establish Rules for Each Parameter

Step 2 applies rules to each parameter which enable any location to have a score applied. Table 1 outlines the slope parameter and gives the divisions. In this case NZLRI slope classes are used and presented in the GIS layer. The consideration of how slope impacts suitability of a location for receiving treated wastewater irrigation results in a rule that increasing slope reduces the suitability for irrigation, reflecting higher management inputs, larger land areas required and limitations for infrastructure. Based on this rule a score is applied to each slope class as shown in Table 1.

A number of accessible national resource databases, such as the FSL and the NZLRI layers can be used for each parameter for this stage of the investigation. The data from these resources is often made available as GIS information. The map scale of the data is given for each parameter and should be regarded to be accurate to this scale. This is generally 1:50,000 or 1: 63,000. A higher degree of variation can be expected at field scale however, it is the purpose of the GIS investigation to determine whether land application is broadly feasible within the selected investigated area before further field investigations are completed.

Table 1: The rules applied to each score for the slope parameter

Scoring	NZLRI Slope Class	Description
5	A	flat, 0 - 3°
4	B	gentle slopes, 4 - 7°
3	C	rolling, 8 - 15°
2	D and E	hill slopes, 16 - 20° and 21 - 25°
1	F and G	steepland 26 - 35° and >35°

Step 3: Scoring Land Areas

The relative importance of the parameters varies and, in many cases, is subjective. However, there is a need to consider the collective suitability of a particular site or area based on the merits of each parameter. This can be achieved using a weighted scoring system whereby each parameter is given a percentage (the weighting), which indicates its importance relative to other parameters.

Each location within an investigated area is given a score for each parameter from 1 to 5 based on suitability, with 1 being least preferred for land application and 5 being most preferred (e.g. Table 1). This then enables sites (and individual points on a map) to be compared.

An example is shown in Figure 2, of the assessed slope parameter of an investigation area around Wairoa in the northern Hawke’s Bay. This investigation area includes land in a 10 km radius from the town’s wastewater treatment plant (WWTP). A “traffic light” colouring system has been used, where green is well suited through to red as least suited for irrigation.

The most suitable land (green) shown in Figure 2 has low angle slopes and occupies a large portion of the investigation area (37%).

Gentle slopes, highlighted in yellow (4 – 7°), cover only 2% of the total Investigation Area, and have slight or moderate limitations for irrigation.

The areas rated as 1 and 2 in red and orange respectively (16 - >35° slope) are located predominantly towards the W, NNW and NE of the WWTP and cover 55% of the investigation area. These slopes are considered to have a significant or severe limitation to irrigation.

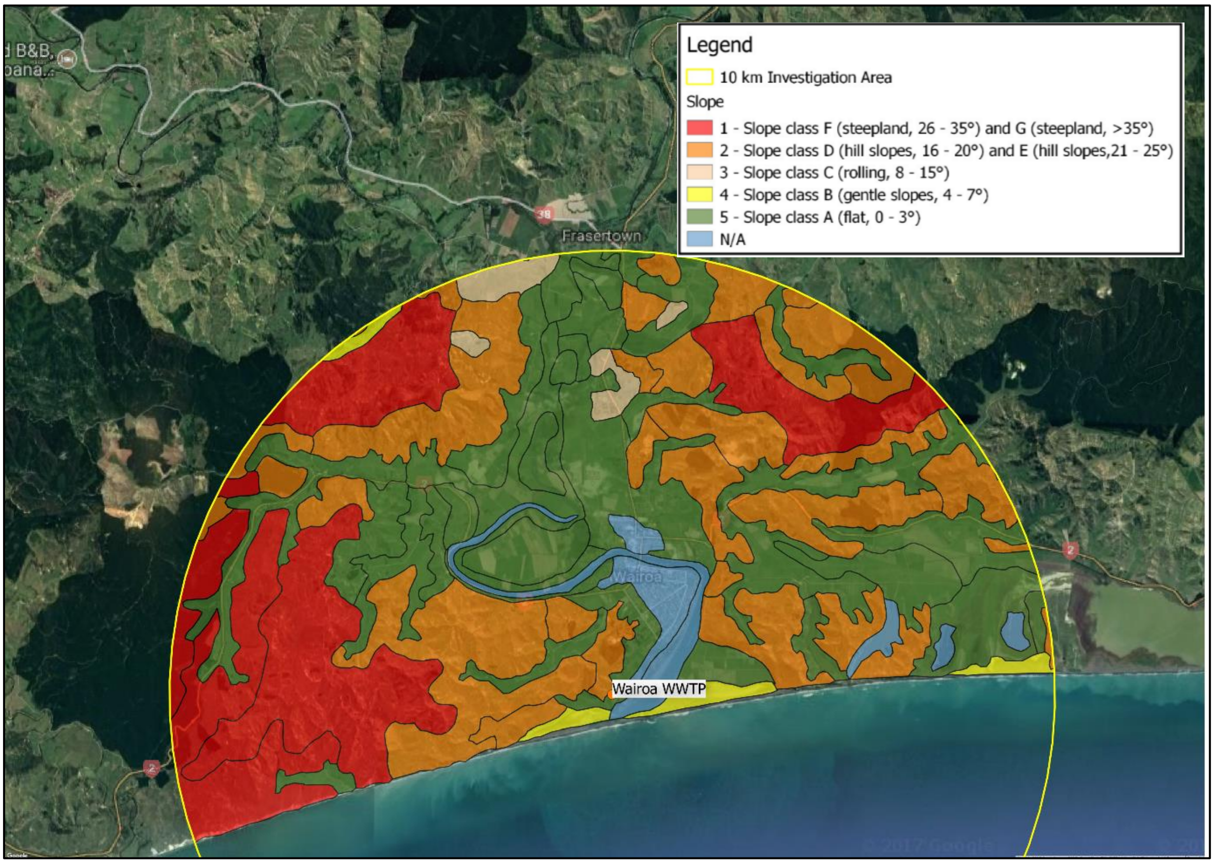

Figure 2: Soil Slope and Stability

Step 4: Add Scores at Each Location

Step 3 is repeated for each parameter nominated in Step 1 resulting in a series of scored GIS layers. When the layers are overlaid together, scores from individual parameters for an individual point (or polygon) on a map are combined to give a total score at any location of the investigated area. The total can be compared with other points or polygons. This allows the summation of the parameters to be compared across the investigated area. The described parameters when combined are considered to give a semi-quantitative assessment of the suitability of an area for land application of wastewater at any point within the investigation area.

Step 5: Combining Parameters into Zones

To make the comparison easier, the combined totals can be grouped. These groupings are referred to as Land Application Suitability Zones. Five suitability zones are established as outlined in Table 2.

Table 2: Zone description and design considerations

Zone	Description and Design Considerations
A	**Well Suited** Requires smaller land area, as more water can be applied to a given area High value and/or short rotation crops Non-deficit irrigation – nil or limited storage required Greater number of irrigable days High rate of nutrient removal Routine cultivation and harvest, with short withholding periods.
B	**Moderately Well Suited** High value and/or short rotation crops Non-deficit irrigation or partial deficit irrigation Can irrigate in shoulder seasons (April, May, September, October) for drier than average years – some storage likely to be required Moderately high rate of nutrient removal Short withholding period for grazing or cultivation and harvest
C	**Minor Limitations** Pasture or restricted range of annual crops Predominantly deficit irrigation, requiring large storage or combined water discharge Larger land area requirement Withholding period prior to grazing or cultivation and harvest is extended
D	**Significant Limitations** Plantation forestry, pasture, shallow rooting crops Deficit irrigation over summer months, requiring larger storage/combined water discharge Low nutrient loading Limitation to cultivation and harvest Extended withholding period for stock trafficking
E	**Severe Limitations** Requires largest land area Conservation plantings Low deficit irrigation for short season, requiring larger storage/combined water discharge No cultivation, infrequent harvest.

Figure 3 shows the Zone maps for the Wairoa investigation area. The Zone map enables some general trends and recommendations to be identified, for instance:

- The closest area of Zone A land, surrounds Wairoa township and are small (lifestyle block) parcel sizes which are not likely to be suitable for irrigation of wastewater. The nearest area of Zone A land with land parcels which may be of suitable size are 8 km north of the WWTP.

- Areas of Zone B (yellow) land occur on flat and gentle slopes with well-drained soils. These areas require more consideration of irrigation management than Zone A soils. Only 7% of the Investigation Area is Zone B land and is generally adjacent to Zone A land.

- Half of the Investigation Area includes Zone C (light brown) land which is marginally suitable. This land could still potentially be workable to enhance the summer productivity of north facing hill slopes which are more prone to drying out. Other benefits include the irrigation of pine plantations which are located within this Zone and 1 km north of the WWTP. A higher cost and management requirement are associated with irrigation of Zone C soils compared to Zone A and B soils.

- Areas of Zones D (orange) tend to occur in those areas as having limitations due to shallow depth to a restrictive layer or very steep slopes.

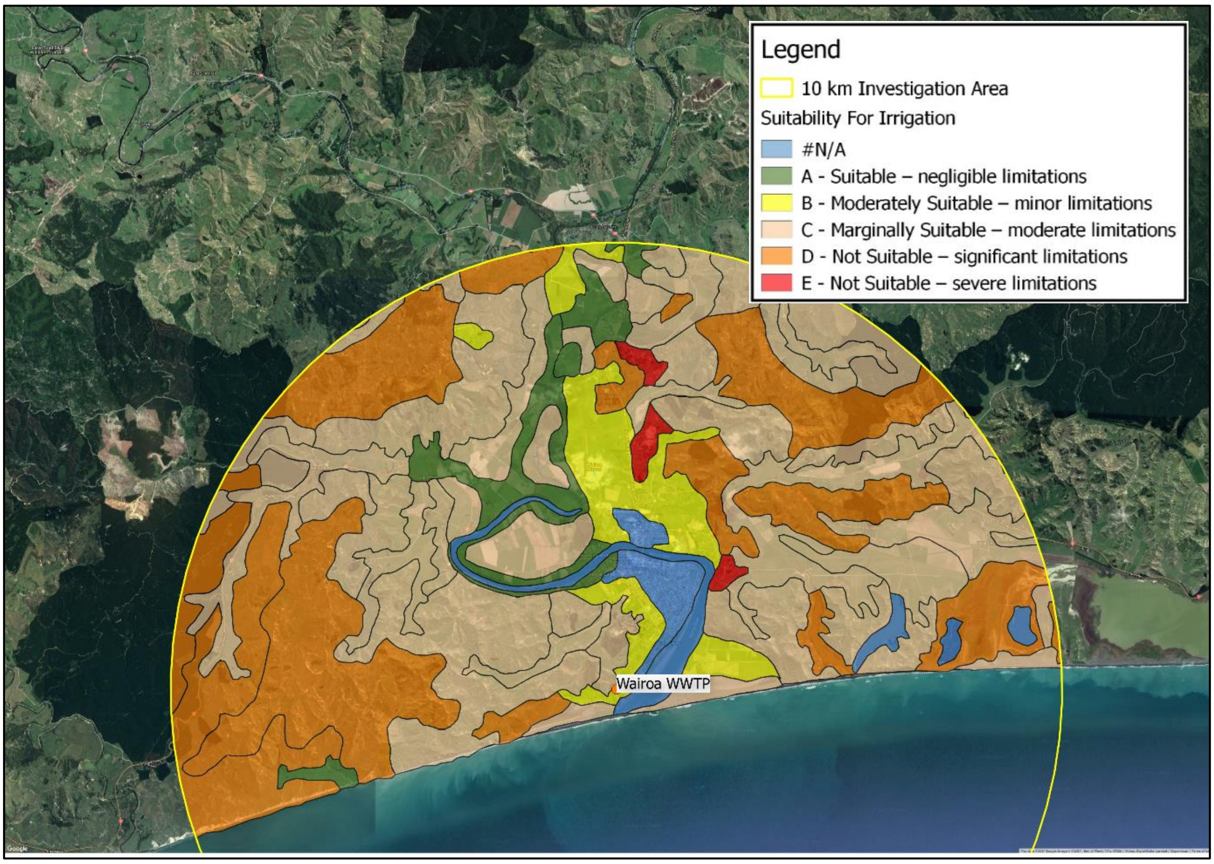

Figure 3: Zone Suitability for Wastewater Irrigation

Site Selection

The Zone map helps to identify areas to target for further, more detailed investigation. It also identifies limitations which can be incorporated into land size and management planning. As part of a more detailed examination, which should include some field investigations, the following parameters might be considered for the targeted areas:

- Property ownership and residential housing;
- Land management (crop sensitivity, industry limitations);
- Reticulation requirements (distance and elevation);
- Land area available; and
- Special use locations and values (cultural sites, archaeological, historic, water take, native forest, recreational etc.).

By this stage a few preferred areas can be identified and it is considered preferable for stakeholders to help score and weight the assessment criteria. The analysis required to complete these layers is substantial and it is considered that these parameters should be examined following initial identification of preferred areas.

Conclusions

Determination of land areas to target through a GIS based desktop investigation is valuable for application of treated wastewater to land. This step-wise process is designed to provide an overall assessment of options for a potential wastewater discharge system. The outcome of the desktop investigation provides an avenue to discuss options with community and council. If land application is a favourable option, then additional stages including field investigations, would be required to confirm the desktop identified characteristics.

References

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