COMPUTER MODEL FOR TREATMENT OF SMALL VOLUME WASTEWATER

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ABSTRACT

Computer modelling is now commonly used to determine the land area needed for successful application of the Vetiver System (VS) in large scale wastewater treatment. Major input parameters needed for the modelling process include long term (50-100 year) and accurate climate data, soil type and depth, ground water level and accurate quantity and quality of the wastewater input.

Obviously for low volume treatment, these parameters are not easily available or non-available. To date, all low volume wastewater treatment projects using VS is based on trial and error methods and experience. To overcome this, a scientifically based Model is needed.

This paper presents a more accurate method in determining the land area needed for this low volume application based on more recent knowledge and experience with VS.

Keywords: sewage effluent, landfill leachate, coffee wastewater, modelling

INTRODUCTION

Computer modelling is now commonly used to determine the land area needed for successful application of the Vetiver System (VS) in large scale wastewater treatment. Major input parameters needed for the modelling process include long term (50-100 years) and accurate climate data, soil type and depth, ground water level and accurate quantity and quality of the wastewater input and local EPA limits for discharged water (Truong and Truong, 2011).

Obviously for small scale application, which produces low volume effluent, these parameters are not easily available or non-available, hence an accurate determination of the land area needed is very difficult to make.

While the application of VS for large scale projects continues to spread around the world, there is an increasing need for its use in small scale projects to treat low volume domestic and small community wastewater in developing as well as developed countries. To date, all the small scale wastewater treatment projects using VS is based on trial and error methods and experience. To overcome this, a scientifically based Model is needed to convince authorities of its effectiveness and accuracy.

OBJECTIVES

To develop a scientifically based computer Model for treatment small volume input from:

- Individual coffee farmer or small cooperatives in Colombia, Latin America and globally
- Individual household and small communities sewage effluent and small volume landfill leachate in countries around the world

BACKGROUND OF THE COLOMBIAN COFFEE INDUSTRY

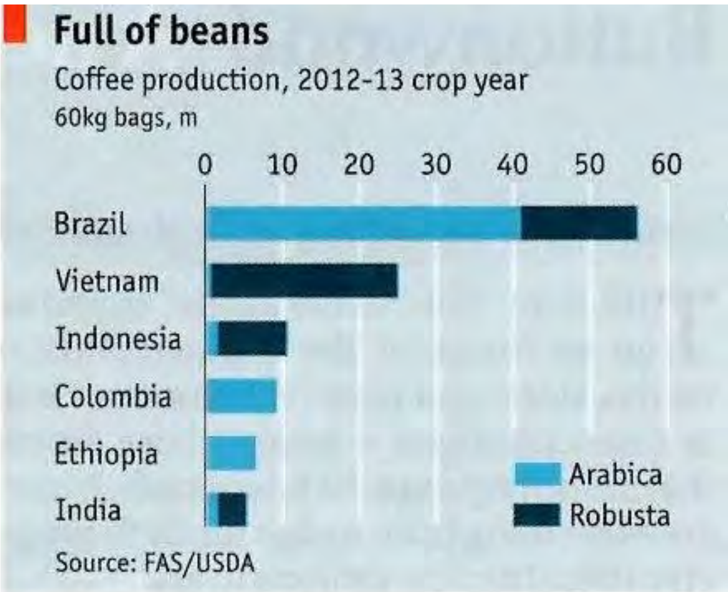
Coffee is the main agricultural export product of Colombia and the majority of suppliers are small plot individual farmers. Colombia produces about 12% of coffee in the world and is the main supplier to some of the biggest international coffee processors such as Nestle and Kraft. For 2012-13 coffee production, Colombia is the fourth largest coffee producer in the world, after Brazil, Vietnam and Indonesia, while the major proportion of coffee produced by the three largest producers are Robusta, almost the entire Colombian production (almost 10M 60kg bags) is of higher quality Arabica type, the highest Arabica type supplier in the world (*The Economist, 13 July 2013*).

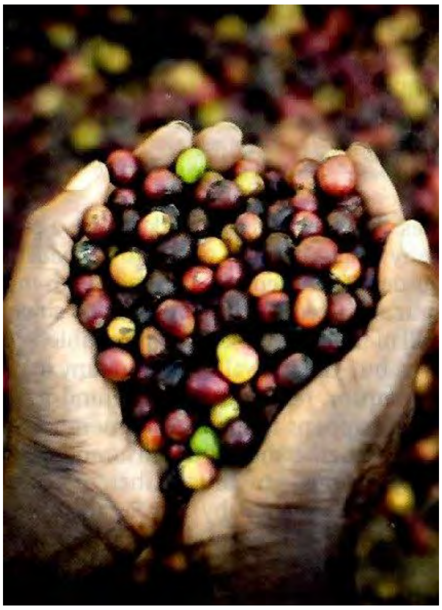
Central Mills are the main processing centers for the plantation and farmer harvested coffee. These Mills operate at full capacity during the main season but at very low capacity the fly crop season. The cost of operating at low capacity during the fly crop is 2-3 times higher than during the main crop. To be sustainable, closure during the fly crop season is an option for the Central mills; if this option is taken then small producers have no outlets for their produce. According to the Colombian Coffee Federation, there are 563,000 Colombian families grow coffee, 96% of these are farms under 5ha in rural areas.

According to the Rainforest Alliance (RFA), coffee is farmed on about 12 million hectares worldwide and most of the farms are in areas regarded as high priorities for conservation. In the past coffee had been widely grown under the leafy canopy of native rainforest trees. But now a new farming system in which the sheltering forests are cleared and coffee bushes are packed in dense hedgerows and doused with agrochemicals. These monoculture farms produce more beans, but at a tremendous environmental cost, the traditional agroforestry system provides good wildlife habitat is lost. Wildlife disappeared, soils washed downhill and streams were choked with silt and agrochemicals. To encourage the maintenance of the traditional agroforestry system, RFA has provided certification to help small farmers improving the negotiating leverage and access to premium markets. Certification is one way to guarantee that small coffee farms maintain wildlife habitat and other environmental benefits, while protecting the livelihoods of small coffee farmers. The small family farms often adopt the old coffee culture and the traditional agroforestry system providing good wildlife habitat is maintained.

If the environmental requirement can be met to achieve RFA certification, there is a great incentive for individual farmers or small groups to process their own cherry on site during the fly season. This would be a big boost to these small suppliers income, particularly at the current falling price trend; the price of a 60kg bag was USD105 four years ago, now only worth less than USD50. This trend is likely to continue in the near future as demand in the USA, Europe and Japan is falling.

The double impact for Colombia farmers is the low Arabica price and rising cost of production due mostly to wages rises. Coffee is a very labor intensive crop; picking is still done largely by hand.





The Economist, 13 July 2013

BACKGROUND OF SEWAGE EFFLUENT DISPOSAL

The global need for a scientifically based computer model for the disposal of low volume of wastewater is more urgent than the Colombian coffee industry, as this has direct impact on health issues as well as water supply (Truong, 2010 and Truong and Cruz, 2010). This has been clearly demonstrated in Aceh province, Indonesia, where American Red Cross and Danish Red Cross have but over 3 000 houses to resettle the victims of the 2001 Tsunami. Each of these houses has a vetiver based sewage effluent disposal system. Similar disposal units have been used in Australia, India, Indonesia, Morocco and Papua New Guinea.

Although these treatment units were highly successful and very effective, their design has been based on trial and error, and experience gained from other low volume treatment projects, not on a scientifically based Model.

PRINCIPLES OF WASTEWATER TREATMENT WITH VETIVER SYSTEM

Vetiver is highly suitable for the treatment of domestic, municipal and industrial wastewater due to its extraordinary attributes such as very high level of tolerance and absorption of pollutants in wastewater, very high water use rate under wetland conditions (Danh *et al*, 2009). But most important of all is its capacity to produce a very high biomass under a wide range of climatic conditions and adverse soil conditions.

The ability of vetiver grass to remove pollutants and water from the growing medium depends solely on its biomass production, hence the faster and higher biomass production the faster and more effective the treatment process is.

Therefore, if the biomass production can be estimated for a certain environment, the efficiency of the treatment process can be predicted and subsequently the land area needed can be worked out reasonably accurately (Truong *et al*. 2008)

MODELLING FOR SMALL VOLUME EFFLUENT

Research data collected over the last 20 years from projects funded by TVNI and Royal Development Project Board of Thailand, Veticon Consulting developed **EDVI-2** to determine land area needed to treat a small volume of effluent. **EDVI-2** is a very simplified version of **EDVI** (Effluent Disposal by Vetiver Irrigation) model. With the main aim of simplifying its use, the land area needed can be determined using a series of chart and tables instead of a computer. However to be of acceptable for wide application, the Model has to be scientifically sound and a minimum data set is needed.

Input data set

Weather data: These are standard weather data recorded and readily available at the nearest weather station or city of the site.

- Rainfall (mm/year)
- Pan Evaporation (mm/day)
- Potential Evapo-transpiration (PET), calculated from 70% of Pan Evaporation (Deesaeng *et al*, 2002)

Effluent input data:

- Monthly effluent input volume
- Monthly N input. (Volume x N level in effluent)
- Monthly P input. (Volume x P level in effluent)

Nitrogen Disposal

Chart 1 shows that to dispose 1kgN/month you need 80m2 of land and Minimum irrigation volume of 329L/day and Maximum volume of 1 600L/day and Maximum, as shown on Table 1.

Chart 1: Land area, minimum and maximum volume required for Nitrogen disposal

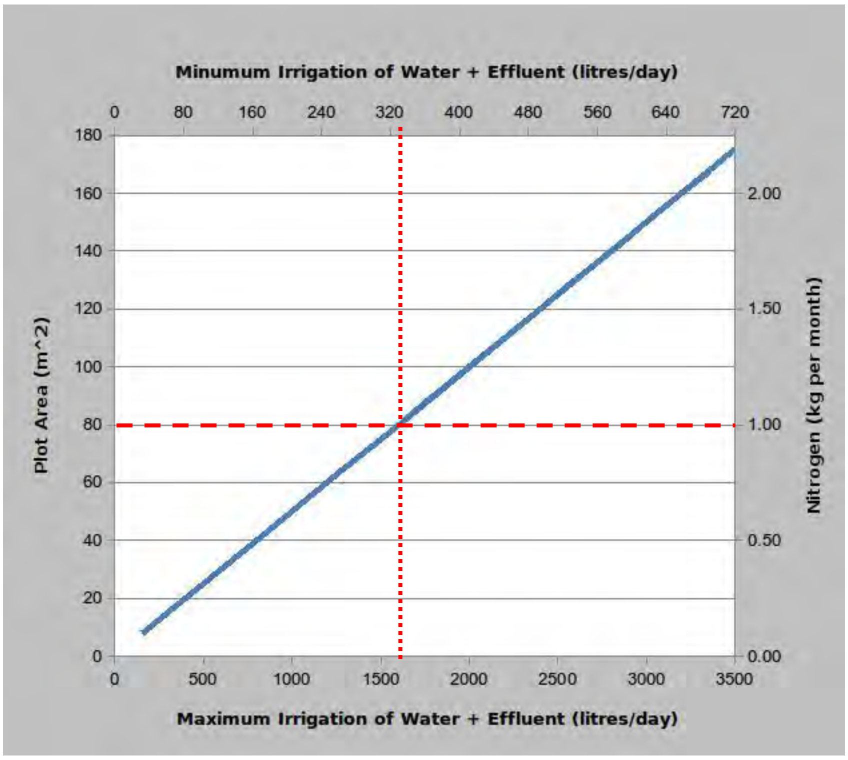


Table 1: ***Land area, minimum and maximum volume required for Nitrogen disposal***

N per month (kg)	Land area needed (m^2)	Min input* (L/Day)	Max input** (L/Day)
0.1	8	33	160
0.2	16	66	320
0.5	40	164	800
0.8	64	263	1280
1.0	**80**	**329**	**1600**
1.5	120	493	2400
2.0	160	658	3200
3.0	240	986	4800

Notes

* The minimum input indicates the water needed to keep vetiver in good conditions, below which vetiver growth would be affected

** The maximum input includes effluent or/and water for dilution if the effluent is too saline

Phosphorus Disposal

Chart 2 shows that to dispose 0.1kgP/month you need 80m2 of land and Minimum irrigation volume of 110L/day and Maximum volume of 1 600L/day and Maximum, as shown on Table 2.

Chart 2: ***Land area, minimum and maximum volume required for Phosphorus disposal***

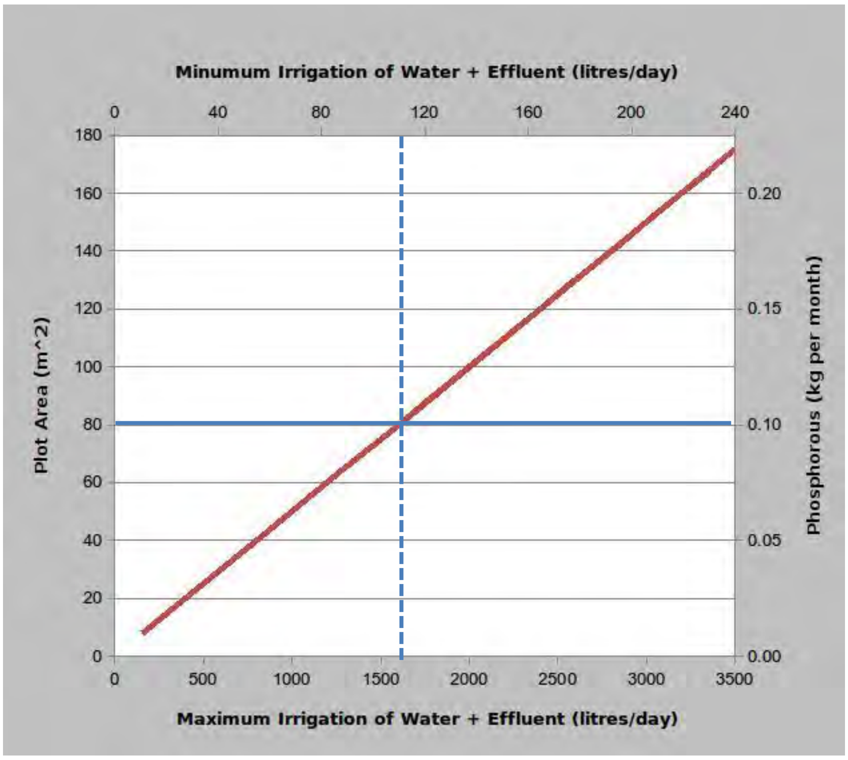


Table 2: ***Land area, minimum and maximum volume required for Phosphorus disposal***

P per month (kg)	Land area needed (m^2)	Min input (L/Day)	Max input (L/Day)	
0.01	8	11	160	
0.02	16	22	320	
0.05	40	55	800	
0.08	64	88	1280	
0.10	80	110	1600	
0.15	120	164	2400	
0.20	160	219	3200	
0.30	240	329	4800	

Land Area Needed

As both N and P in the effluent are needed to be treated at the same time, so the largest land area is required to treat both N and P. For example, tables 1&2 show that an effluent with N input of 1kg/month and P input of 0.08kg/month will need 80m^2 to treat N and 64m^2 to treat P. ***The recommended area for vetiver planting is 80m^2***

Effect of Rainfall

The land areas in Tables 1 and 2, are applicable only when the annual Rainfall is equal to annual Potential Evapotranspiration (PET) and there will be no net water storage in the soil in the long term. In the case where the rainfall exceeds the annual PET (Positive case) the land area needed will be increased or reduced accordingly as in Negative case. However, the land areas needed are not sensitive to small differences in the Rainfall and PET rate, for example when rainfall exceeds PET by 30mm/month, only 5% extra land is required.

Table 3 presents the variation in land area required in the extreme case. For example, when the differences in the Rainfall and PET is 150mm/month, land area will be increased from 80 m^2 to 107m^2 in Positive case and reduced to 64m^2 in Negative case.

Table 3: ***Land area required when Rainfall is higher or lower than Potential Evapotranspiration***

Land area needed (m^2)	Positive case (m^2)	Negative case (m^2)
8	10.7	6.4
16	21	13
40	53	32
64	85	51
80	**107**	**64**
120	160	96
160	213	128
240	320	192

A simplified summary of how to use EDVI-2 to calculate land area, irrigation volume is shown in Appendix

ESTABLISHMENT AND MANAGEMENT OF THE VETIVER PLANTING

For a successful application, the following establishment and management procedures are recommended:

- **Planting material:** For fast establishment good quality Vetiver, either bare root plants or polybags with at least three active shoots must be used
- **Watering:** Watering with river or rain water after planting is a must in the first few weeks until the plants are about 50cm tall. Watering to keep the soil moist only, do not flood it.
- **Effluent application:** Effluent can be gradually introduced to the planting when Vetiver is about 50-60cm tall
- **Weed control:** Weed control by hand may be needed during the first 6 months, once established Vetiver will shade the weeds out. As very low

concentration of Glyphosate weedicide (RoundUp) will kill Vetiver, ***Never use RoundUp for weed control on Vetiver planting***

- **Trimming:** To encourage tillering in the first year, vetiver can be trimmed to 40-50cm high every 3 months
- **Cutting:** After one year Vetiver should be cut down to 30-40cm when flower heads emerged or every 3 months
- **Biomass:** The biomass must be removed from the plot after cutting. This biomass does not contain any contaminants or heavy metals and it is safe to use for handicraft or animal feed.

APPLICATIONS

Using EDVI-2 model, the followings are examples of how to determine the land area needed to treat coffee processing water and sewage effluent based on available data

Ethiopian conventional coffee processing water

Case Study 1

Volume 300L/day
N input/month= 300L/day x 30days x 0.013gN/L = 117g= **0.117kg**
P input/month= 300L/day x 30days x 0.0043gP/L = 38.7g=**0.039kg**
Land area needed for N: **Approximately 10m^2**
Land area needed for P: **Approximately 30m^2**
Recommended area for vetiver planting: 30m^2

Case Study 2 (Higher N and P input)

Volume 300L/day
N input/month= 300x 30x 0.023g/L = 207g= **0.21kg**
P input/month= 300x 30x 0.0073g/L = 65.7g=**0.066kg**
Land area needed for N: **Approximately 16m^2**
Land area needed for P: **Approximately 50m^2**
Recommended area for vetiver planting: 50m^2

Australian sewage effluent disposal (septic tank)

Case Study 1: Domestic Household with three persons

Volume 450L/day
N input/month= 450x 30x 0.030g/L = 405g= **0.40kg**
P input/month= 450x 30x 0.010g/L = 135g=**0.013kg**
Land area needed for N: **Approximately 35m^2**
Land area needed for P: **Approximately 100m^2**
Recommended area for vetiver planting: 100m^2

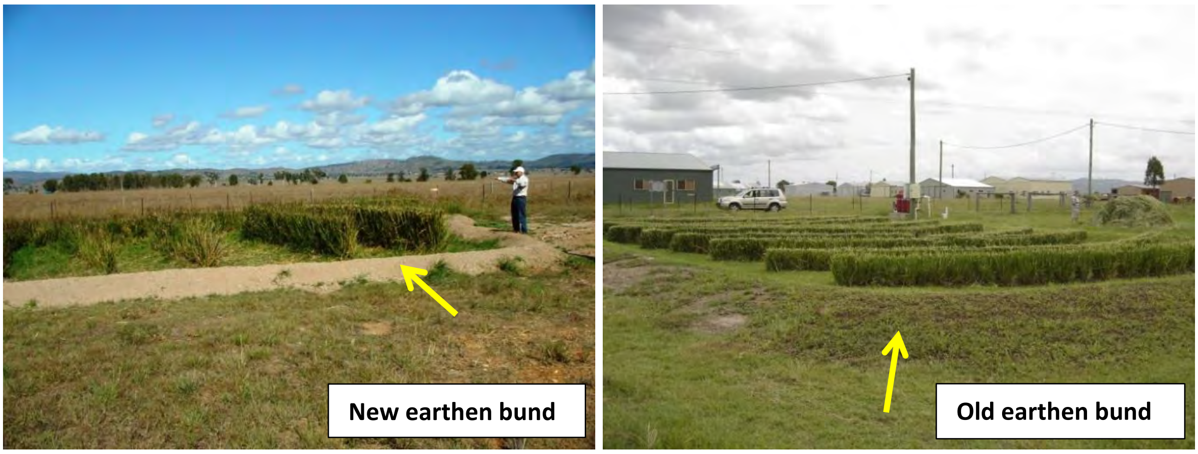
Case Study 2: Domestic Household with three persons and higher N and P input
Volume 450L/day
N input/month= 450 x 30x 0.041g/L = 553g= **0.55kg**
P input/month= 450x 30x 0.022g/L = 297g=**0.30kg**
Land area needed for N: **Approximately 40m^2**
Land area needed for P: **Approximately 240m^2**
Recommended area for vetiver planting: 240m^2

DESIGN AND CONSTRUCTION OF THE DISPOSAL AREA

Where EPA regulation allows deep drainage

The simplest design and construction of the disposal basin is to build a bund wall around the basin. For small basin (up to 500m^2) only a small bund (top width: 50cm and height: 30cm) is needed. Any shape can be used to fit the available land, but on sloping land a rectangular shape is better for even water distribution (gravity fed irrigation). The bund is needed to prevent effluent spreading during heavy rain.

Planting should be spread to cover the whole basin at density of 5plants/m^2, not necessary in rows like these below.



A small community effluent disposal pond in Queensland, Australia

Where EPA regulation prohibits deep drainage

In locations where no deep drainage is allowed as an EPA requirement, the simplest design and construction of the disposal basin is to excavate the required area to 1.5m deep, line the bottom and side wall with impermeable geofabrics, refill the pit with the excavated soil or sand. A small bund is needed to prevent effluent spreading during heavy rain.

Planting should be spread to cover the whole basin at density of 5plants/m$^{2.}$

Landscaping and Erosion control

This Model is based on the planting density of 5plants/m^2, ***the important point is 5 plants are needed***, they don't have to be in square plot, and they can be spread out in row. For example when an area of 80m^2 is required, 400 plants are needed, either in single or multiple rows. This planting layout can be combined with erosion control on sloping land or fence line demarcation as part of the landscaping of the garden.

Row planting for domestic sewage effluent disposal in backyard in Australia

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APPENDIX

Input data needed

Weather data:

- Rainfall (mm/year)
- Pan Evaporation (mm/day)
- Potential Evapo-transpiration (PET),

Effluent input data:

- Monthly effluent input volume
- Monthly N input. (Volume x N level in effluent)
- Monthly P input. (Volume x P level in effluent)

Nitrogen Disposal

Chart 1 shows land area, minimum and maximum volume required for disposal of a certain monthly Nitrogen input. For example to dispose 1kg of N/month, land area needed is 80m^2 and minimum volume is 329m^2 and maximum volume of 1600m^2

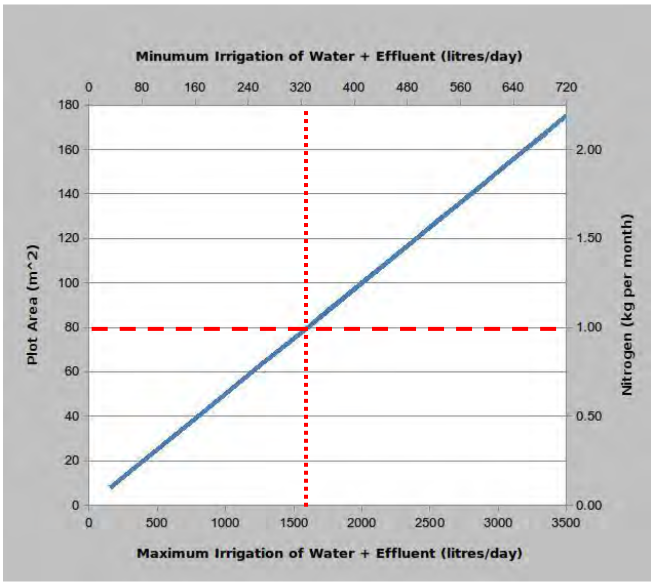

Table 1 shows land area, minimum and maximum volume required for disposal of other monthly Nitrogen inputs from 0.1 to 3.0 N/month.

N per month (kg)	Land area needed (m^2)	Min input* (L/Day)	Max input** (L/Day)
0.1	8	33	160
0.2	16	66	320
0.5	40	164	800
0.8	64	263	1280
1.0	**80**	**329**	**1600**
1.5	120	493	2400
2.0	160	658	3200
3.0	240	986	4800

Phosphorus Disposal

Chart 2 shows land area, minimum and maximum volume required for disposal of a certain monthly Phosphorus input. For example to dispose 0.1kgP/month you need 80m2 of land and minimum irrigation volume of 110L/day and maximum volume of 1 600L/day

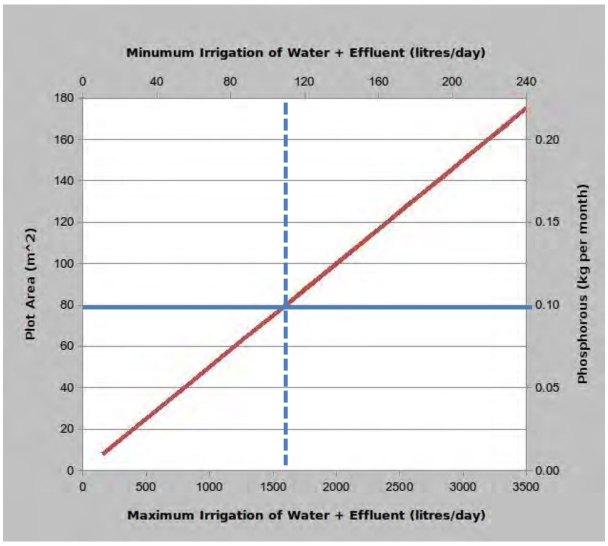

Table 2 shows land area, minimum and maximum volume required for disposal of other monthly Nitrogen inputs from 0.01 to 0.30 P/month.

P per month (kg)	Land area needed (m^2)	Min input (L/Day)	Max input (L/Day)	
0.01	8	11	160	
0.02	16	22	320	
0.05	40	55	800	
0.08	64	88	1280	
0.10	**80**	**110**	**1600**	
0.15	120	164	2400	
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