Electronic Supplementary Materials

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Effects of shrub on one-dimensional suction distribution and water infiltration in a three-layer landfill cover system

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Experimental

1 Experimental set up and instrumentation

Fig. S1 shows a schematic diagram of the soil column testing system used in this study. Each soil column consisted of two equal transparent acrylic cylinders, each 800 mm tall, so the total height of one soil column was 1600 mm. The inner diameter of the soil column was 280 mm and the outer diameter was 300 mm (i.e., the wall thickness was 10 mm). Each soil column was equipped with a constant-head water supply system for the wetting test. Each water supply system consisted of a water storage tank (Mariotte's bottle), an electronic balance and a pipeline system to connect the soil column to the water storage tank. The water storage tank was placed on an electronic balance (resolution 0.5 g) so that the amount of water infiltrating into the soil layers could be measured. There was a hole at the bottom of each soil column to allow for any percolation from the soil above, and the outflow was periodically weighed. Fig. S2 shows a photograph of the setup of the two soil columns and the constant-head water supply systems.

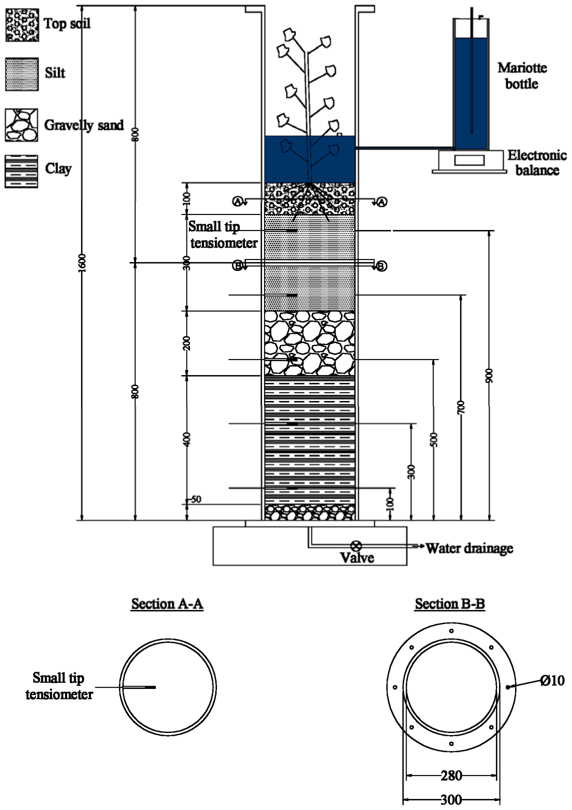

Fig. S1 Schematic diagram of soil column testing system (unit: mm)

Six small tip tensiometers (Model 2100F), manufactured by the Soilmoisture Equipment Corporation, were used to measure matric suction. The suction range of each tensiometer was from 0 to about 90 kPa, and the accuracy was ±2 kPa. The tensiometers were installed through pre-drilled holes on the wall of each soil column at depths of 0.05, 0.15, 0.35, 0.55, 0.75, and 0.95 m below the topsoil surface. Before installation, de-aired water was used to flush out air bubbles trapped inside the tensiometers. The response time was checked by evaporating water from the ceramic cup of the tensiometer, developing about 80–90 kPa of suction, and then immersing the ceramic cup in water. We found that the response time was less than 5 min for all tensiometers. The tensiometers were then calibrated. First, zero kPa suction was checked by placing the ceramic cup and the pressure gauge at the same elevation. Then, by putting the ceramic cup 1 m higher or lower than the pressure gauge, readings were checked at each 100 mm interval. We found that the error ranges were within the tensiometer accuracy of ±2 kPa. All tensiometers were saturated again and soaked in water before installation in the soil columns.

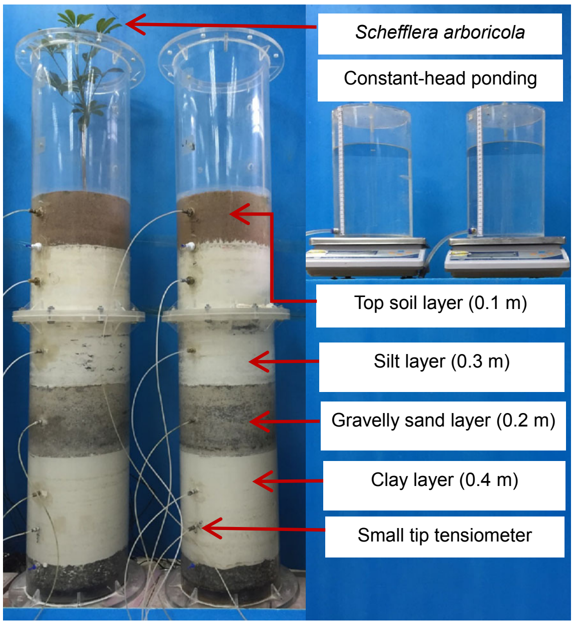

Fig. S2 Photograph of the setup of soil columns with shrub (left), without shrub (right) and constant-head water supply systems

2 Soils and plants

Three-layer landfill cover systems with topsoil were prepared for the two soil columns. One soil column was planted with *Schefflera arboricola* while the other was left bare as a reference (Fig. S2). The soil layers from top to bottom of each soil column were: topsoil (0.1 m thick), silt (0.3 m), gravelly sand (GS) (0.2 m) and clay (0.4 m), respectively. The thicknesses of the soil layers were similar to those used by Ng et al. (2015, 2016) (i.e., silt 0.4 m, GS 0.2 m and clay 0.4 m thick) who investigated the effectiveness of a three-layer landfill cover system using a flume model test and numerical analysis. In those two studies, these thicknesses performed well in a three-layer cover system under an extreme rainfall condition (rainfall intensity equivalent to a 100-year return period in Hong Kong). The topsoil was completely decomposed granite (CDG), which is commonly found in southern China. It contained about 1% gravel, 94.3% sand and 4.7% fine content. The silt was a mixture of kaolin clay (12%), quartz powder (75%) and quartz sand (13%). The GS was a mixture of quartz sand (diameter=2 mm) (50%) and gravel (diameter=5 mm) (50%). The fine-grained silt and coarse-grained GS layers functioned as a capillary barrier. Material mixtures were used such that their grain size distribution could be adjusted to maximise the capillary barrier effects between the silt and GS. Kaolin clay was used for the bottom clay layer. A compacted clay layer beneath the CCBE was used to intercept and reduce the water infiltrating through the upper two layers because of its lower water permeability at a high degree of saturation in a humid climate. The physical properties of the soils were first determined (Table S1). After preparing the soils to achieve the optimum moisture content, each soil layer was compacted to its targeted degree: 80% for the topsoil and silt, and 95% for the clay. A 50-mm thick gravel layer was first placed into the soil columns to allow excess water to drain out of the columns (Sinnathamby et al., 2014; Ng et al., 2015, 2016). Geotextile was then placed over the gravel layer before compaction of the clay layer to prevent soil particle migration. There was no geotextile between the silt and GS layers. Each soil layer was compacted using an under compaction method (Ladd, 1978). The soil surface of each layer was scarified before adding another, to achieve a better contact. Vacuum grease was applied to the inside face of the soil column before compaction to reduce preferential flow.

Table S1 Physical properties of tested soils

Soil type	Topsoil	Silt	GS	Clay
Unified soil classification system	SW	ML	SP	CH
Specific gravity	2.64	2.70	2.71	2.52
Atterberg limits				
Liquid limit (%)	–	22	–	67
Plastic limit (%)	–	16	–	32
Grain size distribution				
d_{60} (mm)	1.4	0.027	1.2	0.006
d_{30} (mm)	0.4	0.007	0.17	0.001
d_{10} (mm)	0.1	0.002	0.09	–
Coefficient of uniformity	14	–	13.3	–
Coefficient of curvature	1.14	–	0.27	–
Fine content (<75 m, %)	4.7	25	0	77
Optimum water content	0.15	0.18	–	0.36
Maximum dry density (Mg/m^3)	1.79	1.76	1.69	1.25
Compacted dry density (Mg/m^3)	1.43	1.41	1.69	1.19
Void ratio	0.48	0.75	0.41	1.04
Saturated water permeability, k_s (m/s)	1.5×10^{-7}	2–5 $\times10^{-5}$	3–5 $\times10^{-2}$	1–6 $\times10^{-9}$

The plant selected for investigation in this study was *Schefflera arboricola*, which is an evergreen shrub of the *Araliaceae* family, native to China and found in other tropical and sub-tropical countries. The leaves are palmately compound, with 7–9 leaflets, each 9–20 cm long and 4–10 cm broad. It has a fibrous root system consisting of several main roots that branch and develop many lateral roots. It is excellent for erosion control. This species was chosen because it is readily available in China (Skerman and Riveros, 1990), and is tolerant of drought, neglect and poor growing conditions, making it well suited for ecological restoration and land rehabilitation. Commercially sourced seedlings of *S. arboricola* were put in plastic bags containing the same topsoil as the soil columns, and grown on. Before transplantation, a hole 100 mm in diameter and 100 mm deep was dug at the centre of the topsoil layer in the planted soil column. Then, a one-year-old seedling with a shoot length of

520 mm, a root zone depth of 100 mm and a root zone width of 100 mm, together with soil bulk, was transplanted in the pre-drilled hole. Soil was backfilled between the plant soil bulk and the column soil to prevent a gap. During the adaptation period, the plant was irrigated three times a week. No fertilizer was added to the soils to eliminate any possible osmotic suction. After growing for three months, and when the new leaves had emerged, the tests were conducted.

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