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Full Length Research Paper

Selection of geo-synthetic filter materials as drain envelopes in clay and silty loam soils to prevent siltation: A case study from Turkey

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Geo-synthetic envelope materials are used in subsurface drain pipes to prevent the entry of soil particles into drains commonly installed to reclaim waterlogged salt affected lands. In-spite of its expensive cost, generally in the world, gravel and sand are traditional envelope materials to prevent the siltation in drain pipes. For this purpose, tube permeameter laboratory research was conducted for comparing geotextile with gravel and sand under the extraordinary hydraulic gradient regarding clogging and preventing siltation in the laboratory condition. Three type of geotextiles (woven and non-woven) and sand-gravel were tested on two type of soil (clay and silty loam). All geotextiles were better than sand-gravel envelopes for preventing the siltation and their clogging level did not create any risk for hydraulic conductivity.

Key words: Envelopes, siltation, geotextile, sediment, hydraulic permeability, synthetic fabrics.

INTRODUCTION

From the beginning of the 19th century subsurface drains has been installed to improve crop growing conditions in agricultural soils. Since then almost simultaneously problems with drain pipes to prevent the entry of sediment with varying degrees of success were reported. Especially silts and fine particles are considered to be the problem in subsurface land drainage system with regard to the risk of mineral clogging (Vlotman, 1998).

In the 1990's, gravel, prewrapped organic and synthetic fabrics (geotextiles) have become the most common drain envelope materials used to protect corrugated plastic drain pipes from the entry of sediment. In order to achieve a better drain performance in reclamation projects generally, envelope materials are required.

Geotextiles are preferred to granular envelopes, mainly for economic reasons and because of the fact that appropriate granular materials are often not available continuously or locally. A number of filter criteria have been proposed for geotextiles but generally these are not universally applicable (Knops et al., 1979; Dierickx, 1980; Irwin and Hore, 1979; Eggelsmann, 1980).

Thin synthetic envelope materials for use on subsurface drainage tubes installed in silty soils, were tested in laboratory. Four different envelopes tested in laboratory were selected for experiments *in situ*. All four envelopes were successful in preventing soil from entering drain pipes while maintaining drainage rates greater than the design drainage rate of 10 mm/day (Rollin et al., 1987).

The need for a drain envelope depends primarily on the soil properties and the soil characteristics in the region where subsurface drainage is planned. It has not been confirmed that experiences in one region can be transferred directly to another. There are no global guidelines to determine the need for a drain envelope. To date, the best method of determining the need for drain envelopes is to construct field test lines in a range of soils occurring in the area. This is expensive and time consuming (a minimum of 3 to 5 years). Generally the construction of pilot areas lags behind the deadline for decision-making (Dieleman and Trafford, 1986).

Specifications for drain envelopes in seven Indian pilot areas (Kumbhare and Ritzema, 2000) were investigated. Soil particle size determination was carried out to characterize the soils. For sandy loam and clay soils, the required drain envelope pore size (O_{90} value) was established based on the (d_{90}) characteristic particle size of the soil. For these soils and four different types of envelope materials, one dimensional flow permeameter research was conducted for better understanding of soil

Table 1. Some chemicals and physical properties of the soils used in the experiment.

Soil sample	Soil texture				Volume	Hydraulic permeability	
	Clay (%)	Silt (%)	Sand (%)		Weight (g cm^{-3})	(mm day^{-1})	(m day^{-1})
Carsamba	8.41	50.96	40.63	SiL	1.20	172.80	0.17280
Saraykoy	52.30	38.80	8.90	C	1.34	29.98	0.02998

	pH	EC (dS m^{-1})	Cations (meq l^{-1})				Anions (meq l^{-1})			CEC (meq/100g)	ESP
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	$HCO_3^{=}$	Cl^{-}	$SO^{=}_4$		
Carsamba	8.17	0.45	2.29	1.59	0.75	0.04	1.38	1.25	1.79	29.37	3.00
Saraykoy	7.86	0.53	2.75	0.56	2.26	0.16	3.29	1.05	1.04	35.09	4.18

$SO^{=}_4$ - Found by calculation; * in saturation extract.

particle retention and hydraulic functioning of synthetic envelopes. In this paper, the need for drain envelopes, their selection and design criteria for five regions in India are discussed. Permeameter research reveals that soil particle retention and hydraulic functioning considerably depend on the drain envelopes used. It was observed that clogging risk of drain pipes without envelope in clay soil containing more than 40% clay and sodium absorption ratio (SAR) up to 8.0 was negligible. Therefore, subsurface drainage system installations in such type of soils do not require envelope material. In sandy loam soil the drain pipe without envelope was susceptible to clogging and needs envelope material. The study showed that the tested enveloping materials whose O_{90} values (300 µm) can be safely used for sandy loam soils.

Laboratory studies on drain envelope materials were carried out to investigate disappointing drainage performance in calcareous (sandy loam and loamy sand) soils. Results showed that the entrance resistance of the laterals without envelope is less than that with envelope materials. This is attributed to the ratio of O_{90}:d_{90} being less than 1, leading to clogging. However, even the laterals without envelope materials have a trend of increasing entrance resistance, and need envelopes to decrease the entrance resistance. The paper indicates that the envelopes used should be made with materials where the O_{90}:d_{90} ratio is greater than one (Omara et al., 2000).

Vlotman et al. (1999) reported that the decision should be made on the basis of laboratory tests in order to select the most suitable drain-pipe envelope material. During the second half of the 20th century, numerous land drainage systems using new materials for the drain channels that often function inadequately due to biochemical and mechanical clogging were developed. The design of drainpipes and envelope materials used for these land drainage systems was based on both theoretical and experimental investigations. Theoretical investigations are associated with field data on the performance of drainage materials. A thorough knowledge, not only of the flow conditions, but also of the physical soil properties in the vicinity of the drains is imperative for a correct interpretation of field data (Stuyt and Dierickx, 2006).

A drain envelope, or "sock," is a material placed around a drain pipe to provide either hydraulic function, which facilitates flow into the drain, or barrier function, which prevents certain sized soil particles from entering the drain. Drain envelopes are not filters. Filters become clogged over time; drain envelopes do not. Many types of envelope material exist, from thick gravel and organic fiber to thin geotextiles. The useful life of a synthetic drain envelope is quite long, provided it is not left in the sun for a long time and exposed to too much ultraviolet radiation. Fine-textured soils with a clay content of 25 to 30% are generally considered stable, so they don't need drain envelopes. A geotextile sock is recommended for coarse-textured soils free of silt and clay. These soils are considered unstable even if undisturbed, so that particles may wash into pipes. The need for an envelope in intermediate soils (clay contents less than 25 to 30%) is best left to a professional contractor or soil and water engineer because soil movement is more difficult to predict (Wright and Sands, 2008).

For this reason an experiment was conducted to find out the degree of the risk of being clogged in different geotextiles which were chosen with regard to granulation in drain depth.

MATERIALS AND METHODS

In these experiments two types of plain soils were used. The one was from Carsamba and the other was from Saraykoy. They were taken from the depth of drain pipe, and used as experimental materials. Some chemical and physical properties of the soils were given in Table 1. According to Table 1 Carsamba soil is silty loam and Saraykoy is clay. Both of them were free of any salinity or a sodium alkalinity. Tests carried out for each envelope material and soil combination are of three replications and, the averages of the replicated test results were used for evaluation.

Three geotextiles were used for drain pipes. They were selected according to soil particle-size curves, and pore opening sizes of the geotextile were 0.210 mm. One of them was non-woven (Amaco) and the other two were woven type synthetic fabrics (Typar and

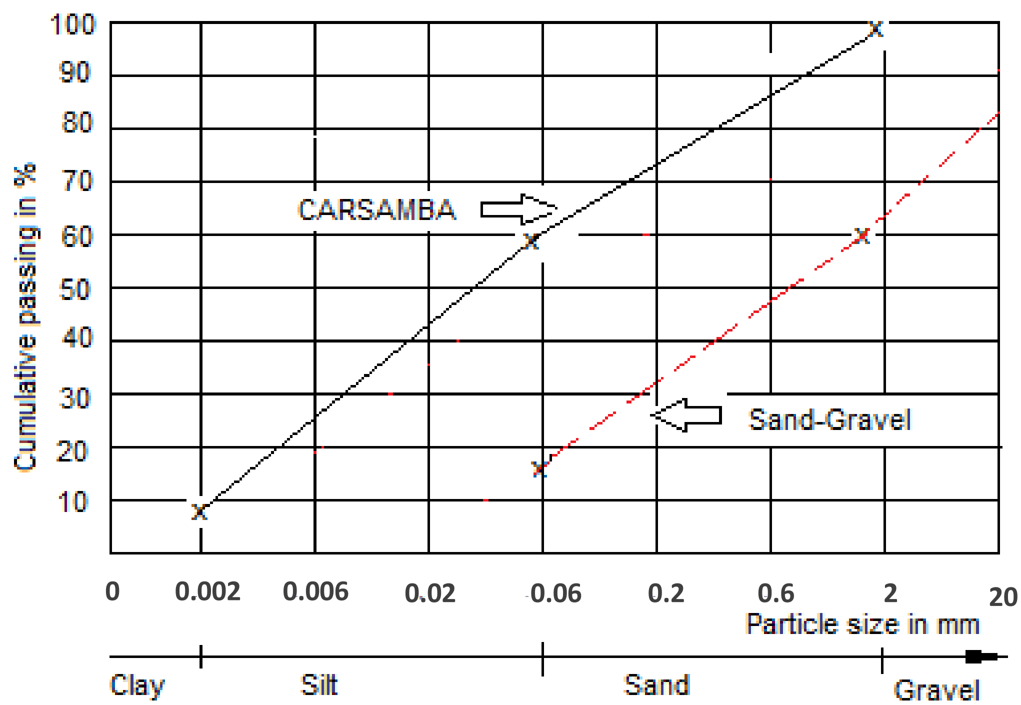

Figure 1. Carsamba soil and granular (sand-gravel) drain envelope.

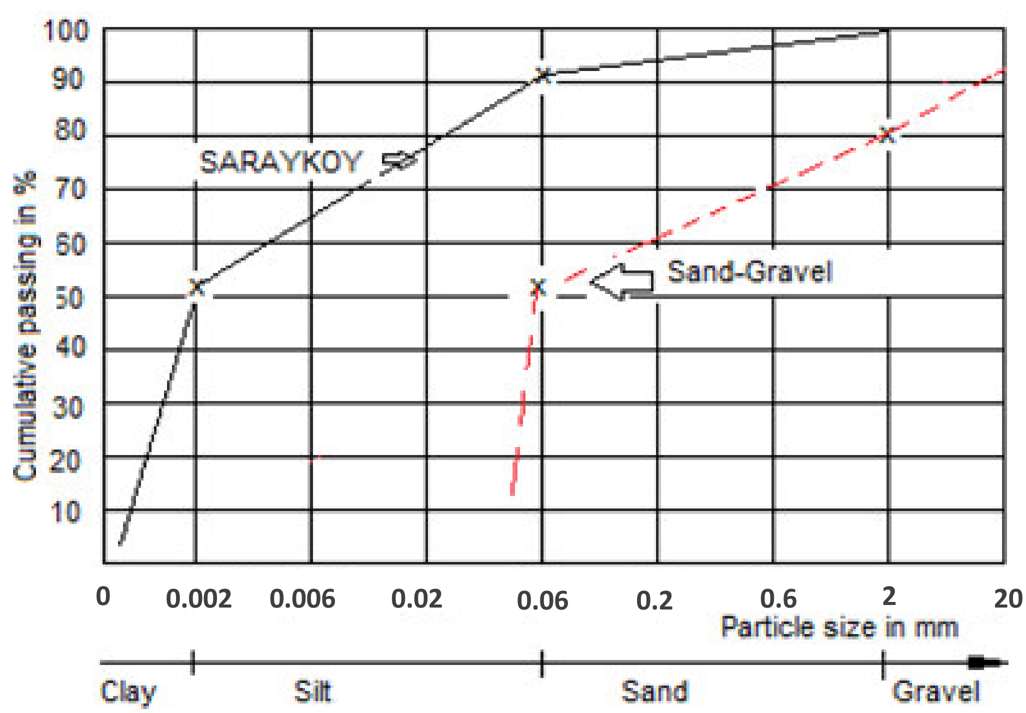

Figure 2. Saraykoy soil and granular (sand-gravel) drain envelope.

Vatex). Terzaghi's envelope criteria were taken into consideration to prepare well graded sand-gravel mixture as an envelope for Carsamba and Saraykoy soils (Figures 1 and 2) (Dielman et al., 1986).

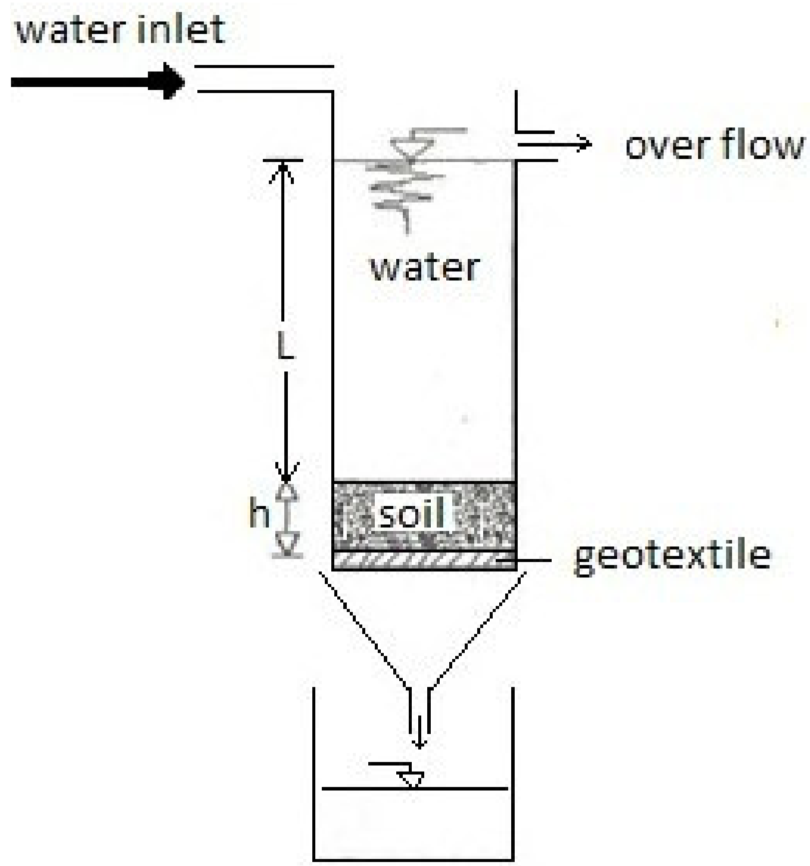

Figure 3. Diagram of vertical flow permeameter.

RESULTS AND DISCUSSION

This filtration performance tests were conducted to estimate the retention of soil particles on thin synthetic envelope materials under specific hydraulic gradients. The most unfavorable situation occurring along a subsurface drainage system was simulated by selecting conditions that exist in front of the slots of the drainage tubes installed in saturated soils (Figure 3) (Rolin et al., 1987). Since water must enter the tubes through slots that represent only about 1% of the total area of the tube, The value of hydraulic gradient was 20, and this value were used in all tests. Installation of drainage system in wet condition can be regarded as an unfavorable condition since the disturbed soil around the drains can easily be carried by water. To enable this condition prior to the filtration test the soil samples were saturated according to their bulk volume, 50% water and 50% soil. The filtration time and the shape of curve enable us to understand the formation of stabilization and siltation performance of the envelope materials:

$$\text{Hydraulic gradient} = \frac{h+L}{h}$$

According to Darcy's law (Richards 1954):

$$\text{Permeability} = \frac{q\,h}{a\,s(h+L)}$$

Permeability (cm h^{-1})
h = height of soil (cm)
l = height of water level (cm)
q = total amount of water which passed through system (cm^3)
a = tube cross section area (cm^2)
s = time (h)

All soil-envelope combinations tests were carried out until a fixed point permeability value was attained. Test durations varied among themselves. Durations were different for sand-gravels (240 and 420 h) and synthetic envelopes (10 and 20 h).

Initial permeability values in sand-gravel envelopes were found to be 60% higher in comparison with those of geotextiles. At the beginning, in geotextiles, the permeability values continued to increase up to a peak point, then, turned down and began to decrease till a fixed value was attained. But in the sand-gravel envelopes,

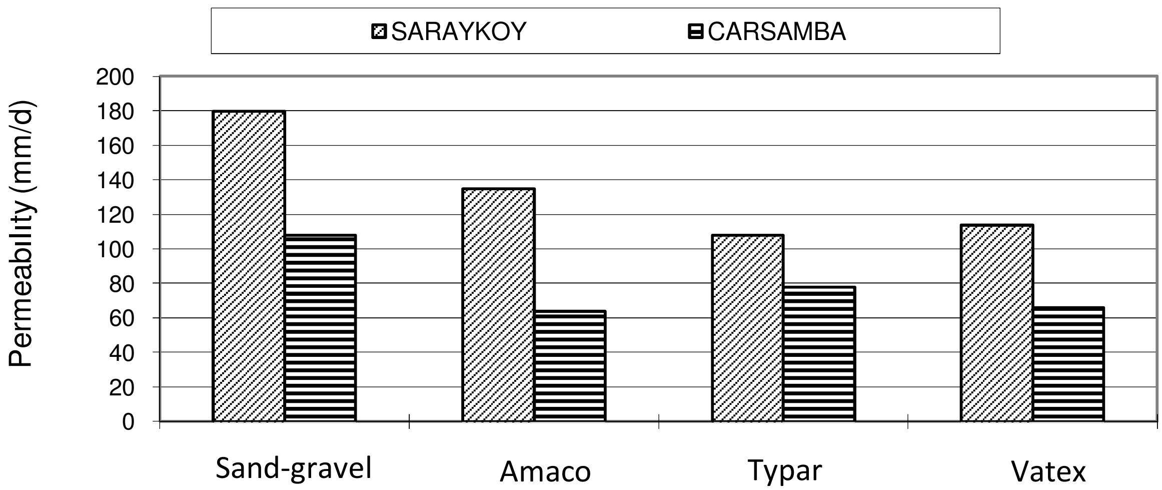

Figure 4. Permeability level of soil-envelope compositions.

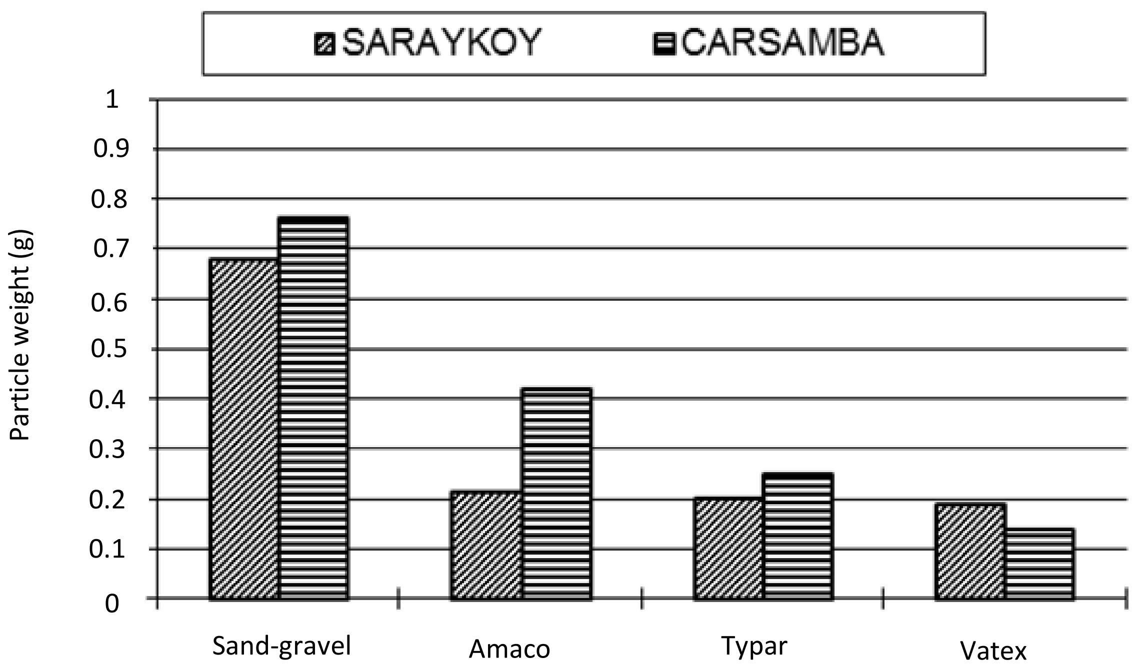

Figure 5. Particles being passed through the tube, the duration of stabilization of soil particles in soil (cake formation).

once the permeability test began the graphic took the shape of decreasing curve and the time spent was observed to be longer than that of synthetic materials.

In periods when higher permeability value was attained, significant amount of particles passed through the tube. Once the filter started to be clogged, permeability value and quantity of siltation began to be declined as well. The permeability curve explained that a low permeability envelope permitted a faster stabilization of the soil by accelerating the cake formation in the soil. Geotextile properties and their small filtration opening size allow the soil in the drain vicinity to remain fairly permeable (Lennoz-Gratin, 1987).

In-spite of the fact that all the drain envelope materials used for Carsamba and Saraykoy soils were theoretically suitable, they showed variations in terms of preventing siltation and meeting the required permeability performance. Result of the experiment revealed that due to their permeability value which is higher than 10 mm/day, geotextiles and sand-gravel envelopes (Figure 4) were found to be suitable materials as an envelope (Rolin et al., 1987). Results also showed that (Figure 5) geotextiles performed the function of preventing siltation 6 and 7 times much better than sand-gravel envelopes for clay and silty loam soils.

If a risk of being silted comes into question in drain pipe installed in fine textured soils, then, suitable geotextiles should be given preference to as filter material instead of sand-gravel. Filter materials should also be tested in a quick method in laboratory conditions before installation (Wright and Sands, 2008).

REFERENCES

Dielman PJ, Trafford BD (1986). Drain Testing. Irrigation and Drainage Paper no: 28. Food and Agricultural Organization of the United Nations, Rome, Italy, 172pp.

Dierickx W (1980). Electrolytic Analogue Study of Effect of Openings and Surrounds of Various Permeabilities on the Performance of Field Drainage Pipes. Report 77, National Institute for Agricultural Engineering. Merelbeke, Belgium

Eggelsmann R (1980). The Right Envelope Materials for Various Soil Types. Zweite Int. Drantagung, Oltmans, Bad Zwischenahn, West Germany.

Lennoz-Gratin C (1987). The use of Geotextiles as Envelopes in France in Connection with Mineral Clogging Risks. Elsevier Applied Science Publishers Ltd. England

Irwin RW, Hore FR (1979). Drain envelope Materials in Canada. ILRI Publications, Wageningen, 25: 14-38.

Knops JAC, Zuidema CL, Wansomeren CL, Scholten J (1979). Guidelines for the Selection of Envelope Materials for Subsurface Drains. ILRI Publications 25 Wageningen.

Kumbhare PS, Ritzema HP (2000). Need Selection and Design of Synthetic Envelopes for Subsurface Drainage in Clay and Sandy Loam Soils of India. Role of Drainage and Challenges in 21st Century. Vol. IV Proceeding of the Eight ICID International Drainage Workshop, New Delhi India, pp. 163-175.

Omara MA, El-Ghani MBA, Abdel Gawad ST (2000). Internal Clogging of Synthetic Envelopes and Its Effect on Their Performance in Calcareous Soil. Role of Drainage and Challenges in 21st Century. Vol. IV Proceeding of the Eight ICID International Drainage Workshop, New Delhi India, pp. 325-336.

Richards LA (1954). Diagnosis and Improvement of Saline and Alkaline Soils. Department of Agricultural Handbook 60. USA.

Rolin AL, Broughton RS, Bolduc GF (1987). Geotextiles and Geomembranes. Elsevier Applied Science Publishers Ltd., England, pp. 99-122.

Stuyt LCPM, Diericx W (2006). Design and performance of materials for subsurface drainage systems in agriculture. Wageningen UR, Alterra, Centre for Water and Climate, P.O. Box 47, 6700 AA Wageningen, The Netherlands

Vlotman WF, Willardson LS, Dierickx W (1999). Envelope Design for Subsurface Drains. International Institute for Land and Reclamation and improvement (ILRI) Wageningen, The Netherlands, 260pp.

Vlotman WF (1998). Drain envelopes. Annual Report International Institute for Land and Reclamation and improvement (ILRI) Wageningen, The Netherlands.

Wright J, Sands G (2008). Planning an Agricultural Subsurface Drainage System. Agric. Water Manage., 95(3): 179-189.