Proceedings, Symposium 25th International Course on Land Drainage

Twenty-Five Years of Drainage Experience

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International Institute for Land Reclamation and Improvement/ILRI
and
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Preface

Like most other techniques, land drainage began by trial and error. Landowners and land users, not content with the condition of their fields, tried to improve them – or even entire regions – by digging channels, constructing outlets such as sluices, and installing pumps driven by wind or steam. If the fields were still too wet, they were then drained by open trenches or, beginning in the eighteenth century, by subsurface conducts.

Over time, land drainage also became an indispensable part of the cultivation and settlement of low-lying coastal areas and of the irrigation of lands in arid zones. In the coastal areas, it reduces salinization from seawater and, in the irrigated fields, it reduces the even greater salinization that occurs because of accumulation. In less extreme cases, land drainage can secure better yields and lead to more economical crop production.

Land drainage techniques evolved through experience and were being practised successfully long before the underlying principles were well understood. In fact, it was some one hundred years after the first widespread application of subsurface drainage that the processes occurring in the soil were finally adequately analysed and formulated. Now, however, these theories are well established and are being applied on a large scale.

More recently, new developments in land drainage have mostly been concerned with the transfer of techniques to areas where they have never before been used, like the humid tropics. A striking example of such a transfer is the subsurface drainage of irrigated fields in arid regions, where, only a few decades ago, this technique was virtually unknown. Now these regions are the main centre of drainage activity.

Today, new materials and improved installation methods can offer solutions to problems still unsolved – while sometimes giving rise to new ones. In this respect, theory is much less developed, and the old ways of trial and error are still the only appropriate ones. But it is just this mixture of art and science, practice and theory, experiment and experience that makes land drainage so attractive.

In this book, we have compiled the results of the Silver Jubilee Symposium, which was held jointly by the International Institute for Land Reclamation and Improvement and the International Agricultural Centre to mark the occasion of the twenty-fifth anniversary of the annual International Post-Graduate Course on Land Drainage. On the basis of these results, we have tried to summarize the state of the art worldwide.

W.H. van der Molen
Chairman of the Board,
International Post-Graduate Course on Land Drainage

Editor's Introduction

The Silver Jubilee Symposium was held in Wageningen (The Netherlands) from 24 to 28 November 1986 to mark the twenty-fifth anniversary of the annual International Post-Graduate Course on Land Drainage. Under the theme 'Twenty-Five Years of Drainage Experience', the Symposium attracted 108 professionals from 37 countries, including 24 participants of the 1986 Land Drainage Course and 24 participants from previous years.

Preparations for the Symposium had been initiated early in 1985 by the International Institute for Land Reclamation and Improvement (ILRI) and the International Agricultural Centre (IAC). At that time, these two institutes, who co-operate to give the Course on Land Drainage, appointed a committee to organize a symposium on the development of land drainage during the past twenty-five years, in which emphasis would be placed on the practical aspects of drainage (e.g. design criteria, construction, operation and maintenance) and attention be given to problems, solutions, and future developments. The members of the Organizing Committee were J.W. van Hoorn (Chairman), C. de Jong (Co-Chairman), J.A.H. Hendriks, J.T.A. Groenevelt, G.A. Ven, and E.J.L. Hotke-Staal.

Five major topics were discussed in separate sessions during the Symposium:

1. Drainage in the humid temperate regions;
2. Drainage in the (semi-) arid regions;
3. Drainage in the humid tropical regions;
4. Drainage machines and materials;
5. Organization of the maintenance of drainage projects.

The topics were introduced by one or two keynote lectures, whereafter a number of country papers were presented and discussed. The sessions were chaired by W.H. van der Molen, I.A. Risseeuw, W.C. Hulsbos, and C.L. van Someren. A visit to an exhibition of drainage machines and materials was also arranged.

Because most of the country papers contained elements of more than one of the major topics, the Editorial Committee of the Symposium decided to order the Proceedings as follows:

- Conclusions and recommendations of the Symposium;
- Keynote lectures;
- Country papers grouped by climatic region;
- Discussion of the sessions.

The keynote lectures appear in their original form. Most of the country papers were edited to improve their readability, which made it necessary at times to shorten the text, eliminate tables, and combine figures. These changes, however, do not in any way affect the authors' ultimate responsibility for the contents of their contribution.

The members of the Editorial Committee, R. van Aart, J.W. van Hoorn, L.K. Smedema, and J. Vos, would like to express their gratitude to the authors of the keynote lectures and of the country papers, and to all the other participants for their active involvement in the Symposium. A list of the participants can be found in Appendix 1.

We sincerely hope that these Proceedings will find a place in the literature and prove to be helpful to the many people around the world who are interested in the drainage of agricultural lands.

For the Editorial Committee,

J. Vos
Editor

Contents

Conclusions and Recommendations

1. For drainage of fine textured soils of low permeability requiring very close spacing mole drains in combination with pipe drains laid in trenches filled with highly permeable backfill can be applied.
   In unstable soils moles filled with gravel can be a good technical solution.
2. Clogging of drains by ochre formation appears to be mainly a problem encountered in humid temperate regions. No serious cases are reported until now from drainage projects in arid regions.
3. The computer can be used for:
   - drainage design, calculation of spacing, pipe diameter, length, etc.;
   - investigating the effect of drainage on crop growth and yield, and on soil and water salinity by simulation models;
   - assessment of spatial variations in drainable surplus by groundwater models;
   - cost optimization studies.
4. Drainage should be considered as a part of watershed management that also includes soil and water conservation, irrigation, and crop management.
5. Drainage projects should be designed in such a way as to maximize the positive impacts on society, and be evaluated in that respect.
6. Subsurface drainage in arid regions differs from that in humid temperate regions with respect to objectives, criteria, field investigations, design options, construction practices, equipment and materials.
7. Monitoring for engineering and/or socio-economic purposes should be incorporated in the design and operation of large drainage projects.
   The design should clearly describe the aim of the monitoring, and the ways and means to achieve it.
8. In humid tropical regions surface flow and interflow predominate over groundwater flow.
   Subsurface drainage can find its application for deep rooting crops.
   Notwithstanding the rainfall being higher than in the temperate regions, the discharge criteria for subsurface drainage do not seem to be higher since the soil profile is a limiting factor for groundwater flow.
   Since little experience with subsurface drainage of dry foot crops exists, more research is recommended.
9. Improvement of drainage for rice can be obtained by development or management strategies or a combination of both, in which irrigation management plays a major part.
   A special case is rice cultivation in rotation with other crops on tile drained land in arid regions.
   Special precautions are needed in that case.

10. Most failures in drainage projects are due to faulty construction or lack of maintenance.
    The application of corrugated plastic pipes and recently developed trenchers for plastic collector drains with in-built installation for quality control will contribute to better construction.
    Composite drainage systems with a minimum length of deep open drains will contribute to minimize the burden of maintenance.
11. Gravel remains for the time being the most reliable filter material.
    In view of the cost of gravel the development of design criteria for synthetic materials merits the highest priority.
12. The application of trenchless machines is currently limited to a depth of two metres.
13. Organization of maintenance is a bottleneck for the success of drainage projects.
    At the design stage due attention should be given to minimize future maintenance as well as its organization, including training and financing.
    Research programmes should pay more attention to maintenance aspects.

Keynote Lectures

The development of drainage in humid temperate regions

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Introduction

In humid temperate regions mankind settled first in those locations with natural drainage systems in the form of rivers and brooks. Agriculture started on the higher and dryer soil types.

With the increase in population more land was needed for food production and soon people learned that the best soils for agriculture were situated in the river valleys and coastal plains, provided that they were protected from flooding. From the early middle ages onwards dike building and river regulation allowed the reclamation of vast areas of agricultural land by digging canals and ditches for the removal of excess rainfall and seepage water. This system itself, often called the main drainage system, was not sufficient to obtain reasonable drainage conditions and additional farm drainage in the form of ditches and furrows had to be applied.

The Greeks already knew that they could improve the quality of their vineyards by digging trenches and filling them with stones. The Romans seem to have applied clayware pipes for drainage purposes. However, it was not until the middle of the 19th century before subsurface drainage was introduced to Europe after the system had been demonstrated at the Great Exhibition in London in 1851. This relatively expensive system was then applied to better agricultural soils that could compensate for the high costs. The world of agriculture realized that certain drainage was necessary to protect the crops from flooding and to achieve a certain trafficability of the soil, but it took a long time before it was convinced of the need for good drainage, despite the fact that the first German Dränanweisung that appeared in 1857 (Schirmer 1959) already published figures for discharge capacities of drainage systems that differ only slightly from those used today.

The Dutch Ministry of Agriculture made a survey of the drainage conditions around 1915. The report showed that drainage conditions were very poor. Flooding, even in summer occurred regularly and the capacity of many pumping plants and main canals was too low. At that time winter flooding was still considered necessary to maintain soil fertility.

In the period between the two World Wars drainage conditions were improved considerably in many countries by enlarging the capacity of the main drainage systems and pumping plants. In literature the first publications advocating drainage as a measure to increase production then appeared.

After World War II the demand for more food, and especially the acceleration in agricultural mechanization brought about a new interest in drainage, and many governments tried to stimulate drainage by allowing grants for installation. Although trench diggers and mole ploughs had already been available for a long time in the USA and England, they only replaced manual labour in the 1950's. With the introduction of more powerful machinery it soon became clear that speed of installation was limited by the use of conventional burned clay and concrete pipes. New techniques such as the in situ formation of a concrete pipe (Ede 1957) were surpassed by the introduction of plastic tubing. The use of this material gave rise to all kinds of new techniques. In The Netherlands for instance, the first polyethylene pipes were pulled into the soil by means of a mole plough. In other countries methods were developed to form tubes from plastic strips, like the Janert system (Janert, 1955) in the DDR, and the American system described by Fouss and Dennon (1962). This technique, also known as mole lining, disappeared with the introduction of the corrugated pipe, although the present Big-O system in the USA actually belongs to that type.

Despite the efforts of conventional pipe producers to reduce transport and handling costs by paletting, the corrugated pipe gained the upper hand and nowadays is used in the majority of cases.

With the introduction of this type of pipe, the competition between mole-lining and trenching changed into that between trenchless and trench drainage.

The above developments and the favourable economic conditions in agriculture caused an acceleration of the drainage of agricultural land. With the worsening of economic conditions since the 70's and the surplusses in agricultural production, agriculture in many countries now faces the growing objections of environmentalists who fear that improvement of drainage damages wildlife habitat, and intensive agriculture causes damage to the environment.

Drainage as a tool to increase production has changed into a means to lower production costs by allowing better trafficability of the soil, the possibility of an early crop growth, and prevent damage caused by animals and machinery.

Drainage design

At the time of introduction of pipe drainage the system was applied by individual farmers. Depth and spacing were chosen on the basis of guesses and practical experience. Around 1920 flow theories, nowadays known as drainage equations, started to appear in literature, but it was not until about 1945 before they were applied to design purposes. This was especially the case where groundwater drainage took place, and the government was involved in design or financing. In Germany the previously mentioned Dränanweisung is used, while in the UK and the USA the governments issued a special guide (MAFF, 1983, Soil Conservation Service, 1971). In The Netherlands the Government Service for Land and Water Use designed systems for private farmers on which grants were based.

With the withdrawal or reduction of grants design is often left to private contractors who generally work on the basis of experience. In countries with special drainage problems (heavy soils, peat soils) such as UK, France, Ireland, standards and methods are still being formulated.

Drainage theory

As indicated in the announcement of this symposium, emphasis will be placed on practice rather than on theory. Theories themselves will be therefore left out, but they will still need to be reviewed as and when it is important to understand what is happening.

Around 1962 a large number of analytical drainage theories were available for the flow of water towards drains. These theories were for both steady and non-steady states, and can be used for design purposes and for the analysis of field experiments. Since that time not much has been changed and it might be stated that solutions are available for the most practical problems, and even for rather complicated conditions like multi-layered situations.

Problems for which no analytical solutions are available, can nowadays be solved by means of numerical methods, thanks to developments in the world of computers. This implies that enough solutions are available to design a system for groundwater drainage. There is, however, one exception and this concerns fine textured soils with low permeability. Despite a considerable amount of research, there is no common opinion about the drainage of these soils. Both in England and Ireland (Galvin 1978) the use of mole drains is advocated as a remedy. A combination of conventional drainage with trenches filled with permeable backfill and moles perpendicular to this system, with a very narrow spacing of 2 to 4 m also seems to be a solution in certain cases (Bailey 1978). Groot (1973), who analysed a series of field experiments in the Sava valley in Yugoslavia, supports the conclusion of Van Hoorn (1960) that subsurface drainage is preferable in the event that there are layers with a higher permeability within the range of the drain depth.

In other cases a subsurface drainage system with highly permeable backfill may offer a solution, provided that this backfill remains permeable during the lifetime of the system. Further details are given in the reports of Spoor and Galvin (this Symposium).

In any case the flow towards drains in these situations is complicated and difficult to analyse (Lesaffre 1985) and rather expensive field experiments have to be carried out for the design of a system.

One has to conclude that our knowledge about the flow of water in this type of soils is still very scarce. New methods to determine soil properties and to detect flow patterns in heavy soil are now being tried out (Bouma 1977, 1981, 1985).

A second restriction to the use of drainage theories for design is the fact that design criteria have to be set for both the steady and non-steady theories. In the former case one has to assume a given discharge at a certain watertable depth. In the second case a rate of fall in the watertable is used. The drainage criterion is a problem in itself, and this will be discussed under the heading 'Effects of drainage on agriculture'.

Apart from the hydrological design, there is still the problem of hydraulic design, i.e. what diameter of drains should be used. Here one is concerned with the transport of water in the drainlines themselves. Apart from a variety of flow resistance equations to be used (Manning, Colebrook, Chezy-Bazin), there is a fundamental difference in design. In most countries the so-called transport principle is applied, i.e. it is assumed that the design discharge has to be transported in full over the total length of the pipe (cf. Soil Conservation 1971). In The Netherlands the drainage principle is used, i.e. the flow in a drain-line is zero at its upper end and increase to the design discharge at its outlet. (Wesseling 1964, Van Someren 1972).

This controversy may be explained by the fact that under Dutch conditions large slopes hardly exist, so that surcharge of drain-lines does not occur, while in most other countries, steeper slopes are applied.

Performance of drainage system

The second type of use of drainage theories is in analysing field data, in other words the performance of drainage systems. Until about 1960 drainage experimental fields were mainly used to study the effect of drainage on groundwater behaviour and on agricultural production. They were meant to obtain information about the required drain spacing where no practical experience was available in similar types of soils.

With the introduction of new pipe and envelope material, a large number of field experiments were carried out to investigate the behaviour of these materials. Perhaps the most important development for analysing data of these fields was the drainage theory developed by Ernst (1962). By splitting up the flow into a number of components, he introduced the concept of resistances.

With the aid of this concept the behaviour of pipes and materials could be characterized by the so-called entrance resistance. Wesseling and Van Someren (1972) gave various values for this parameter for drainpipes and envelopes applied in The Netherlands. Wesseling (1978) gave a discussion of the extent to which the material properties have to be taken into account in the design.

The concept of resistances offers the possibility not only to compare the behaviour of various materials, but it also enables a comparison of the results from field and laboratory tests (cf Knops 1978, Wesseling and Van Someren 1972). The reason why this concept has not been accepted outside The Netherlands may be due to the fact that the Ernst theory never has been published in English and the resulting drainage equations seem to be rather more complicated than the well-known equations of, for example Kirkham, Hooghoudt, Kirkham and Toksöz.

Despite a careful choice of pipes and filters, and the necessary precautions during installation, drain pipes might eventually become clogged. Maintenance of the system in the form of jetting for instance, necessary in order to keep the system working.

This method is exclusively applied in flat countries (cf. Busser and Scholten 1978). A lot of attention is paid to flushing of drain pipes particularly in Europe. The reason for this may be that in Europe drain pipes with a diameter of about 60 mm are used generally while in the USA for instance, diameters of 100 mm and more are common. Moreover the slopes under which drain pipes are laid may also play a role. The problems in jetting or flushing of drain pipes are as yet unsolved. There are several aspects to be considered such as type of jetting equipment, water pressure to be applied, type of soil and filter material, length of lines, etc. During the sessions on drainage materials this problem is certainly to appear once more.

Another still unsolved problem is the clogging of drain-lines by ochre formation. Research on this problem especially has been done in de FRG (Kuntze 1978), in the USA (Ford 1978) and in The Netherlands (Ven 1985). In certain areas iron may render a drainage system inactive within one or two years. Sometimes jetting may be a temporary solution, and at other times it may not. Envelope material also seems to play an important role here, and this problem will also be discussed under that subject.

The performance of a drainage system will highly depend on the care with which it is executed. Problems like depth control by means of laser equipment, soil conditions during execution and several other aspects will be discussed during the course of this symposium.

Effects of drainage on agriculture

Subsurface drainage is an important tool used to increase agricultural yields. In humid areas one has, however, to take in consideration that a soil can be overdrained with the consequence that drought damage occurs.

There is a tremendous amount of literature concerning the effect of drainage conditions on crop growth. A short review may be found in Wesseling (1974).

In a review on drainage problems, Van Schilfgaarde (1978) states that adequate analytical tools are available to describe the behaviour of the watertable, or even the time course of the water content in the rootzone. However, what is missing is an adequate data base to interprete such calculations for the economic return from a drainage system. In other words, given a certain drain depth, spacing and meteorological conditions, those watertables and soil water contents to be expected can be derived, but their effect on crop growth and yield is not yet known.

A considerable amount of field experiments are necessary to solve this problem. Fortunately, especially during the last decade, new possibilities arose in the form of so-called computer experiments. These experiments are based on the simulation of actual processes. Typical examples of models are given by Feddes and Van Wijk (1976), Skaggs (1978), and De Jong and Zentner (1985). Feddes and Van Wijk (1976) applied their model to Dutch conditions, while Hardjoamidjojo and Skaggs (1982) gave an example of determining the effect of drainage on maize yields in the USA.

Time is lacking to discuss these models in full. Therefore only the principles of the model of Feddes and Van Wijk are given here. For given soil and drainage parameters, the model computes watertables, discharges and soil water contents during the winter period. On the basis of the latter data, the time of sowing and planting is determined in terms of workability conditions. A crop growing model is then used to determine the crop growth during the growing season under prevailing meteorological and soil conditions. At the end of the growing season, workability demands can again be taken into account to determine the harvesting time.

A period of 30 sequential years is used to compute crop yields. By changing the drainage parameters in the model, different drainage conditions can be investigated in a very short time. Based on a statistical analysis the most effective depth and drain spacing can then be chosen. Moreover, the model results offer the possibility to translate drainage into additional crop yield, and hence offer the possibility of an economic evaluation.

It should be noted here that realization of such models calls for a number of data on e.g. workability of the soil, crop growth parameters, such as rooting pattern, Leaf Area Index, etc.

Under humid conditions, like those in Western Europe, there are two aspects to be considered, namely damage to the crops because of waterlogging/flooding of the soil and the workability of the land.

Soon as drainage reaches a certain level, the first aspect will be of little importance. In The Netherlands for instance, the advantages of drainage are thought to be found in an early workability (trafficability) of the land, rather than in preventing waterlogging. This is especially true for arable land. For permanent grassland the problem of poaching by grazing cattle forms an as yet unsolved problem. This aspect has not been considered in the model of Feddes and Van Wijk, although in principle the problem can be approached in the same way. A lot of research, however, has to be carried out before sufficient data are available to derive boundaries for poaching.

The above-mentioned models offer good possibilities to derive drainage criteria for design purposes. The most efficient combination of depth and spacing expressed in terms of crop yields adapted from the models leads directly to the required criterion.

Drainage and environment

In irrigated regions there is the problem of salinity of drainage water that may influence water quality in downstream areas.
In humid regions there is the problem of eutrophication of surface waters as a result of drainage activities. Moreover, drainage of agricultural land may lower the groundwater in adjoining natural areas, thus affecting wildlife habitat. In the third place drainage may influence stream flow from catchment areas (Ryder and Ward 1985).

Leaching of nutrients by drainage is a well-known phenomenon itself. Increase of this leaching has primarily to be sought in a more intensive use of fertilizers caused by an intensification of agriculture due to better drainage conditions. In certain cases this leaching has lead to pollution of groundwater aquifers, especially with nitrate, but pollution of surface water can also occur. In the intensive agriculture of Western Europe another problem is arising, namely the spreading of cow slurry. Due to lack of storage capacity, farmers want to spread slurry throughout the winter period. For this purpose they need a good trafficability of their parcels and hence good drainage conditions. Spreading in winter, however, increases the danger of run-off of slurry, especially when it is applied in large quantities under poor soil conditions, where soil structure is damaged. Agriculture is therefore faced by governmental regulation prescribing the terms and amounts of application of slurry, but also of the maximum amount of fertilizers to be applied. This in turn could reduce the economic benefits of drainage.

On the other hand, not much is known yet about the demands wildlife habitat imposes on drainage conditions. With the improvement of drainage conditions in many countries, maintaining poorly drained wet areas for preserving wildlife habitat seems to become a more important issue in this respect.

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