The study of effects of drainage on agriculture

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Introduction

Of the world's arable land, roughly 155 million ha have been drained (NOSENKO and ZONN 1976). FAO (1977) estimates that in irrigated regions alone 52 million ha need to be drained in the near future. With such large investments at stake it is necessary to continuously review our knowledge of drainage and of the effects it may have on soil, plant, agricultural practices, and hydrology. In this way, we can locate the possible gaps in our knowledge and try to bridge them. Recent attempts to understand the drainage-situation in the world and to determine the research needs were made by Dieleman, van Schilfgaarde, and Zaslavsky (WESSELING ed. 1979). A similar attempt will be made in this article. It is not my intention to review exhaustively all research efforts of the past, but rather to indicate the lines along which research has developed and to illustrate this with some examples.

Research on the effects of drainage can be done in two ways:

- by conducting experiments under controlled conditions, e.g. in the laboratory, in lysimeters, on experimental fields or with analog and simulation models
- by making observations in the fields, on the farms, i.e. under a wide variety of conditions.

The first kind of research identifies which factors are relevant in drainage design and evaluation. With this identification one is better able to perform the second kind of research. But, because of the wide variety of field conditions and the many interactions between them, it is possible that field observations, farm surveys, and the like lead to conclusions that differ from those found under controlled conditions. Hence, for the study of practical drainage problems, one should not rely only on the results of studies made in a uniform environment, but should check these results in a pluriform environment. In this way one can, additionally, detect relationships that cannot be discovered 'in the laboratory', or identify bottlenecks that might not have been found by a straightforward application of theory.

Research on the effects of drainage serves a dual purpose: it can show whether the installation of a drainage system is yielding the desired results, and it can lead to the development of appropriate drainage criteria so that good new drainage designs can be made.

There are many different types of drainage; for example:

- internal or field drainage versus external drainage (which mainly refers to disposal drains and outlets)
- surface drainage (which is done by land shaping) versus subsurface drainage (which is done by subsoiling or moling, or by installing pipe drains, ditches, or tubewells)
- gravity versus lift or pump drainage (which

entails important operational differences)
- interception versus relief drainage or dewatering (which entails important differences in discharge capacity)
- temporary drainage (i.e. the drainage system operates only on certain occasions) versus permanent drainage.

Any drainage system can be characterized by the alternatives in these five categories, thereby offering a large number of possible combinations. Some drainage systems have double functions.

Surface drainage is most common in areas with high rainfall intensities or where soils have a low infiltration capacity, but is also applied in irrigated lands. Subsurface drainage is common both in the temperate zone and in irrigated lands. Temporary drainage systems are found in paddy fields, where rice is grown in basins of ponded water. Here drainage is normally undesirable, but on certain occasions (e.g. after exceptionally high rainfall or before harvest operations) the drainage system is put to work. To describe such a system by the five categories mentioned above, we would call it a temporary surface relief drainage system, whose internal (and possibly also external) component is based on gravity flow.

The different types of drainage systems all require their own set of design criteria and a separate research approach as to their effects. But it often happens that the same kind of system is used in different situations (we can think of drainage of tropical lands or lands in the temperate zones, drainage of arable land, grassland, clay soils, peat soils, polderland) so we may expect similarities and differences at the same time.

In irrigated lands in arid zones, for example, a subsurface drainage system helps to control salinity, whereas in humid regions salinity constitutes no problem. Also, the drainage water in irrigated lands may have a high salt concentration, which can prove detrimental to the environment. Otherwise, drainage is not much different in the two situations, serving as it does in both to maintain a well-aerated soil. In both situations, the drain discharge depends on the recharge and it is immaterial whether this recharge is produced by rainfall or irrigation, though the latter can be better controlled. Soil salinity control in irrigated land is rather a matter of correct irrigation, with drainage as a complementary factor. The expression 'drainage for salinity control' is misleading.

Methods of analysis

A simple and direct method of analysing the effects of a drainage system is to consider the influence that the drainage system's engineering variables have on crop productivity. In the following diagram, this influence is expressed as Relation A.

$$\text{drainage system's engineering variables} \xrightarrow{A} \text{crop productivity}$$

The engineering variables depend on the kind of drainage system. For example, in a subsurface field drainage system by pipes, the variables can be depth, spacing, and diameter of the pipes.

The effects of different engineering variables can be studied step by step, e.g. by using a range of drain spacings (see Figure 3), or by simply considering the 'with' and 'without' case, i.e. by comparing crop productivity in drained and undrained land. SCHWAB et al. (1966), for instance, reported that maize production in drained land was 4000 kg/ha whereas in undrained land it was 2500 kg/ha.

Relation A, when established for a certain region, has no validity for application elsewhere because it depends on the type of soil, the climate, the crop, the hydrological conditions, and the topography of that region. However, a more universal applicability of empirical results can be promoted by introducing into Relation A more variables than just engineering and productivity. For example:

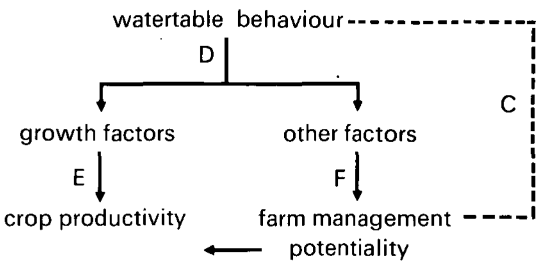
$$\begin{tikzcd}
\text{drainage system's engineering variables} \arrow[r, "B"] \arrow[rr, dashed, no head, bend left, "A"] & \text{water table behaviour} \arrow[r, "C"] & \text{crop productivity.}
\end{tikzcd}$$

Here, Relation A has been broken up into two other relations (B and C). The intermediate variable watertable behaviour was first introduced in about 1940, for two reasons:

- the change in watertable behaviour (or in more general terms the change in the amount of water present on or in the soil) can be considered a direct effect of a drainage system; in other words it is the first thing that happens before any other effect (like a change in crop growth or soil conditions) takes place.
- Relation B (often expressed in a form known as a drainage formula) is entirely a hydraulic relation and lends itself to the development of theroretical models; in other words one conceives certain idealized conditions and then predicts the watertable response to variations in engineering variables.

Drainage formulas have more than local value because they include variables representing natural conditions like recharge and hydraulic conductivity. With a correct assessment of the values of these variables in a certain area, the formulas can be applied under widely different conditions. These values, however, are not always easy to assess because of their generally wide variability. Besides, the more variables included in the formula, the costlier their determination becomes. The literature on surface and groundwater hydraulics and on Relation B is extensive. In fact, our knowledge of drainage formules is so vast that at the International Drainage Workshop (WESSELING ed. 1979) it was concluded that the high priority that had earlier been given to research on this subject is no longer required.

Theoretical models for Relation C (watertable-crop productivity) are practically non-existent. The relation is so complex that we must still rely on local, empirical data. Hence, Relation C, if developed in a particular region, is transferable to other regions only if the agricultural conditions are comparable. To enhance more general validity, Relation C can be broken up as follows:



The 'other factors' may, for example, be soil stability factors (workability, bearing capacity, subsidence), irrigation and leaching potentiality (important for salinity control), and hydrologic changes (seepage, runoff). In fact, growth and other factors are not entirely separable because many soil properties influence both crop productivity and farm management potentiality. Moreover, farm management influences crop productivity through the growth factors again. Hence, the above diagram simplifies the state of affairs.

Changes in growth (and other) factors are secondary effects of a drainage system. Their number is large. Restricting ourselves to the growth factors, we can summarize the secondary effects as in Figure 1.

Relations A, C, D, E, and F will be discussed further in the following sections. Relation B will not be treated as it is outside the scope of this article. Nor will the influence of drainage on the whole farming system be discussed, although, as can be seen in Figure 2, this influence can be significant. Research on the subject, however, is scarce (FOUND et al. 1976).

Direct production functions

Literature on crop production as a function of engineering variables (Relation A) is not very extensive. Investigators seem to prefer an analysis

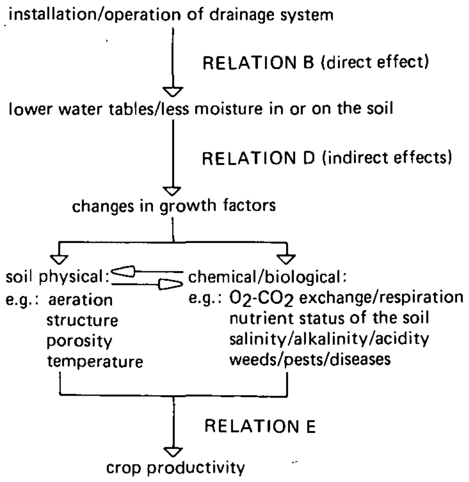


Figure 1.
Effects of a drainage system on plant growth.

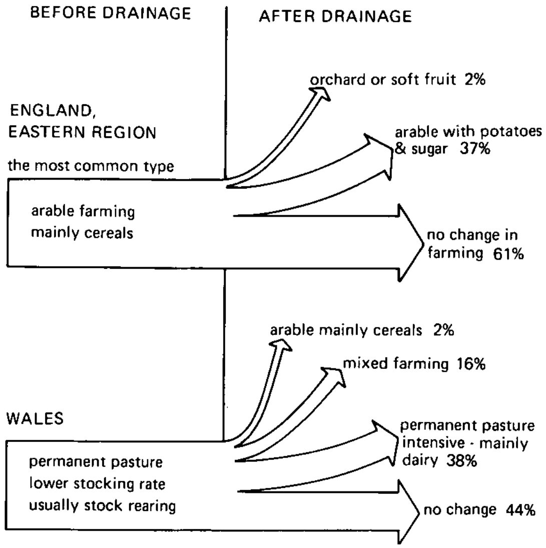


Figure 2.
Changes in farming system (FDEU 1972).

of 'with – without' cases or a study on the relation between watertable and crop production (Relation C).

An outstanding study of crop response to variations in one engineering variable (viz. drain spacing) is that reported by ERIKSSON (1979), concerning data obtained from 125 drain test fields over a period of 30 years. This kind of extensive research is not very common in the world of drainage. An example of this work is reproduced in Figure 3.

Figure 3 shows that in the range of drain spacings of 16–30 m the net benefit is practically constant. One thus has a wide range of design options. In the Swedish situation it is apparently not necessary to determine the drain spacing with any great accuracy.

TRAFFORD (1972) reviewed a number of situations in which different drainage intensities produced no significant differences in yield although the yields were clearly better than on the undrained control. DISETER and van SCHILFGAARDE (1958) found that yields of maize did not essentially differ when drain depths were 2, 3, or 4 ft with a spacing of 160 ft. These studies also indicate that no great precision in the determination of the engineering variables is required. DIELEMAN (1979) stressed that the cause of failure in drainage design is more often a lack of understanding of the broad interrelations between drainage and other farm or water management matters than the lack of precise data. The examples given above are a good illustration of his viewpoint. Drainage, evidently, is more than the determination of the correct dimensions of the system. Optimum depths and spacings of drains are probably strongly dependent on local conditions; general guides are difficult to conceive.

Another illustration of broad interrelations being more important than accurate design is given by FOUND et al. (1976). These authors analysed the benefit/cost ratio of a large number of external drains (outfalls) in Ontario, and found the ratios to vary from 0 to over 20. Except for some drains that appeared much too elaborate (over-engineering), the ratios were largely determined by the productivity of the environment and the local initiative to make use of the drainage potential.

Watertable and plant productivity

In a review article, WILLIAMSON and KRIZ (1970) reported that most of the early work in detecting relations between crop yields and the depth to the watertable (Relation C) was done in field experiments where the elements of nature could not be controlled. Thus, according to the authors, conflicting results were obtained. Since about 1940, the experiments have been conducted mainly in growth chambers, lysimeters, and controlled experimental fields. Very little work has been done on the response of crops to fluctuating watertables (WESSELING 1974). SIEBEN (1964) was one of the first to express fluctuating watertable behaviour with a single index and to relate this index to crop production (Figure 4). The value of the index SEW_{30} is found by taking the Sum of the daily Exceedances (in cm) of the Winter watertable above a level of 30 cm below the soil surface. Figure 4 shows that for SEW_{30} values of up to 500 little yield reduction occurs. For values above 500, yield depressions depend very much on the kind of crop and the year of observation.

Sieben limited the SEW values to the winter season, because his work was done in The Netherlands, where winter is the drainage season. In summertime the relation between watertable and yield would not produce information on how to drain but possibly on how to subirrigate, because in the Dutch summer evaporation exceeds rainfall.

It would seem likely that in fields with naturally fluctuating watertables the frequency of excep-

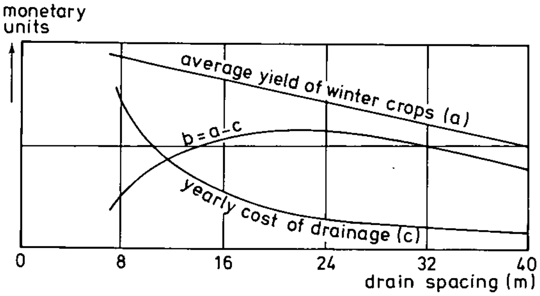


Figure 3.
Net benefit of winter crops as a function of drain spacing in a 60% clay soil in Sweden (adapted from ERIKSSON 1979).

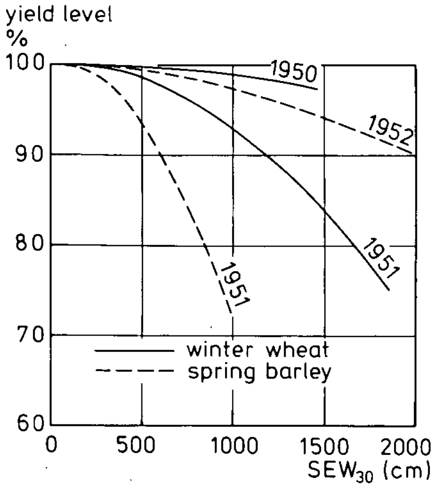


Figure 4.
Yields in relation to SEW values in The Netherlands (adapted from SIEBEN 1964).

tionally high watertables is strongly related to the average depth of the watertable: the lower the average level, the less frequently will high levels occur (FEDDES and van WIJK 1977). It may therefore be worthwhile to study plant production in relation to average watertable depths.

As is obvious from Figure 4, yields plotted against SEW values over a period of many years would produce a large scatter of points. It is unlikely that plotting the yields against average watertables would reduce the scatter (Figure 5). Nevertheless, the use of averages offers advantages over the use of extreme values in that the collection of the data and the application of drainage formulas is easier with averages.

It is regrettable that production functions are so often represented by smooth lines in a graph, with no reference to possible deviations from these lines, which might otherwise provide an extra insight into the problem. Relations showing a large scatter of data are seldom published, though there are probably more data of the kind depicted in Figure 5 than have ever been reported in our journals. True, it is hard to predict a yield from Figure 5, but this is not unrealistic because the watertable is, of course, not the only production variable involved. Moreover, the figure has interesting features.

It shows that the maximum yields (i.e. yields obtained under optimum cultivation conditions other than watertable) are less sensitive to shallow watertables than minimum yields (i.e yields obtained under adverse cultivation conditions other than watertable). All yields however, are depressed at watertables shallower than 30 cm. In the range of 30–60 cm, maximum yields are not influenced by depth, but minimum yields react sharply. This means that in this range good cultivation conditions can compensate for unfavourable groundwater conditions or good groundwater conditions can compensate for poor cultivation conditions. Beyond a depth of 60 cm yields are no longer influenced by changes in depth. In other words, in areas similar to the experimental area, drainage systems that maintain average watertables at 60 cm will be satisfactory.

In the past decades, the effects of the watertable on crop productivity have been studied mainly in small-scale experiments, which have not provided clear-cut indications for large-scale application. The experiments have, however, led to the recognition of important growth factors, as will be demonstrated in the next section.

Watertable and growth factors

The study of the physical growth factors in Relation D (figure 1) has been reviewed by WESSELING (1974), van de GOOR (1972) and FEDDES (1971). It appears that the bulk of research on this subject took place concurrently with the development of drainage formulas, i.e. after about 1940, and that it emphasizes the interactions between air content of the soil, gas exchange, and temperature. Gas exchange determines the amount of oxygen in the soil, and this triggers off an enormous amount of chemical and biological reactions, in the form of oxidation and reduction of chemical compounds, plant root respiration, changes in the quality of the organic matter, etc. Soil temperature has been found to exert a great influence on seedling emergence and early frost damage.

The influence of watertable on soil structure is likewise determined by a large number of intermediate factors, while soil structure in its turn influences the aeration and aeration-dependent soil properties. WESSELING ed. (1979) presents a number of articles on the relation between drainage and soil structure. All these articles refer to

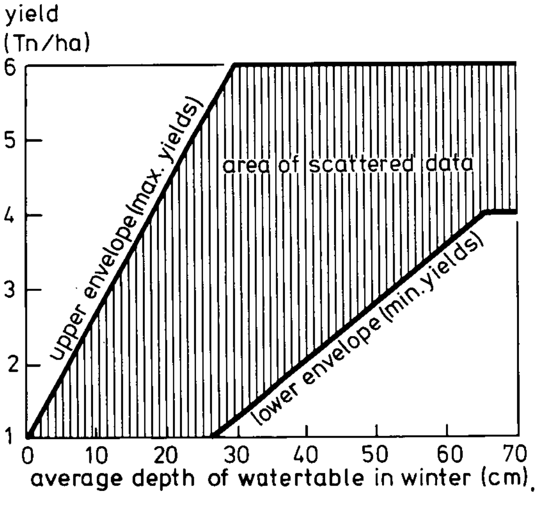


Figure 5.
The yield of grains (mainly winter wheat) on a heavy soil in England as a function of watertable depth (based on unpublished data from Drayton experiment, FDEU).

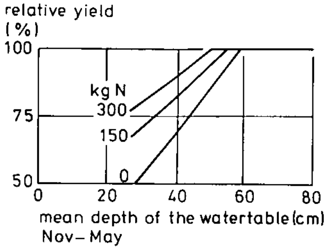


Figure 6.
Yield of 1st and 2nd cut of grass on peat soil in The Netherlands (FEDDES and van WIJK 1977).

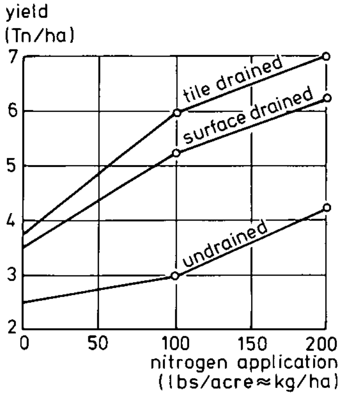


Figure 7.
Effect of drainage and N on corn yield – 3 year average (SCHWAB et al. 1966).

heavy clay soils, where the structure problem is most pronounced. The general conclusion is that drainage can produce considerable structure improvements, which in turn enhance the functioning of the drainage system.

So far it has not been possible to formulate an integral picture of all the indirect effects that drainage has on the physical or chemical properties of the soil. However, it has become clear that the indirect effects should not be investigated for isolated growth factors, but rather as a coherent complex of factors with numerous interactions. Figure 6, which refers to grassland on peat soil, an illustration of an indirect chemical effect of drainage. As seen here, nitrogen dressing can compensate for poor drainage. One can also say that the soil itself releases more nitrogen for the plant as the watertable is lower (down to a depth of about 60 cm), because with increasing depth the need for nitrogen application reduces. Van HOORN (1958) obtained a similar result for cereals on a clay soil; here the maximum nitrogen release by the soil was reached at a watertable depth of 150 cm.

SCHWAB et al. (1966) found a different result. The same amount of fertilizer produced greater yield increases in drained plots than in undrained plots (Figure 7). It seems that the relation between drainage and nitrogen status of the soil depends much on local conditions.

These examples show that drainage can make nitrogen application either unnecessary or more efficient. Indeed, drainage can influence agriculture in many respects, both through natural growth factors and through farm management potentialities. An example is the salinity control in arid lands under irrigation, where drainage serves two purposes: to maintain a well aerated soil and to permit leaching.

For salinity control only, the depth of the watertable is relatively unimportant because the salt content of the soil is mainly determined by the prevailing direction of water movement through the soil rather than on the height of the watertable, although there can be a certain mutual influence. Table 1 is a sample of unpublished data on this subject which came to my knowledge.

As can be seen from some of the observations in this table, even though the watertable is deep, salinity can be high. Apparently, a scarcity of irrigation water, or another constraint, makes salinity control not feasible in these situations.

The growth factor salinity has received enormous attention in the last decades. The literature on the subject has been reviewed by BERNSTEIN (1974), who gives ample information on crop tolerance to salinity. Soils with ECe values of 4–8 are considered saline because the yields of most crops become negatively affected in this range. ECe values of 8–16 are so high that only salt tolerant crops yield satisfactorily (see article by van

Table 1.
22 Random observations of soil salinity in relation to watertable depth (based on unpublished data from Khairpur Demonstration Plots, Pakistan).

	watertable depth (ft)				
EC_e*	<4	4–5	5–6	6–7	> 7
<4		1		1	7
4–6			2		3
6–8					2
8–10				1	1
10–12		1			
12–14					
14–16					1
16–18					
> 18			1		1

*electric conductivity of an extract of a saturated soil paste in mmho/cm; a value representing salt concentration proportionally.

Hoorn and van Aart in this book).

Nearly all the information available stems from experiments under controlled conditions, which means that it is not advisable to apply the research results directly to areas with management limitations. One cannot always predict yield increases merely on the basis of initial salinity figures and those one expects to obtain with a drainage cum-leaching program; one must also measure yields. This is illustrated in Figure 8, which shows yields obtained in the Khairpur Demonstration Plots.

Figure 8 reveals that yields in soils considered saline are not consistently less than yields in non-saline soils. Admittedly, so few data are available for EC values > 10 that no firm conclusion can be drawn. ALVA et al. (1976) reported that in Peru rice yields as high as 6400 kg/ha were observed on a soil with EC values of 16 mmho/cm in the top layer and even higher salinity values in the deeper layers.

Apparently crop response to salinity under controlled conditions differs from that under conditions where other farm management constraints are also present. The explanation must be the interactions between different growth factors and perhaps compensating circumstances. If one had had only the salinity figures of Table 1 and not the corresponding yields of Figure 8, one probably would have concluded that the soils needed leaching. But, because the low yields occur in non-saline soils, it is clear that other farm management deficiencies must first be tackled.

To detect farm management problems field surveys of production functions are necessary. Theoretical deductions and rules of thumb are not enough. Nor should one consider isolated growth factors, but rather the complex of factors, including the possibilities of improving farm management.

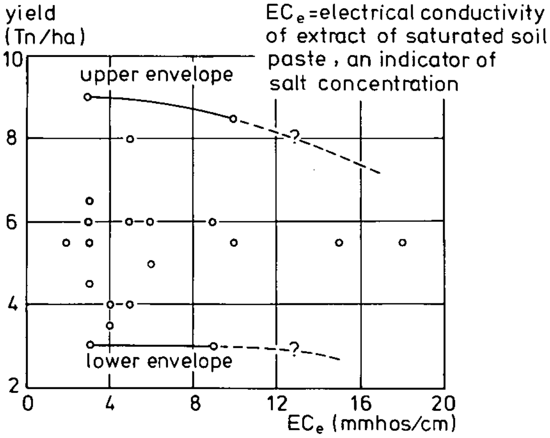


Figure 8.
Wheat production as a function of soil salinity (based on unpublished data from Khaipur Demonstration Plots, Pakistan).

Drainage and other factors

The relation between drainage and factors other than growth factors can be described very well on the basis of average water levels during certain (critical) periods. Exceptionally high levels appear to have limited influence, as will be seen in the following examples.

Soil stability

The increasing mechanization of farming, the desire to have more head of cattle per ha or to ensure timely farm operations such as sowing and harvesting have roused interest in the effect of drainage on the stability of the topsoil (its bearing capacity and workability). Most of the research on this subject has been done in the last decade (REEVE and FAUSEY 1974).

With a modification of the relations presented by WIND and BUITENDIJK (1979), Figure 9 shows the influence of watertable depth on workability. As the figure shows, the average depth of the watertable has a great impact on workability, especially in the range of 100–150 cm. It also shows that the q/h ratio (used in The Netherlands as a drainage criterion) exerts only a minor influence. From the point of view of workability it would appear that the average depth of the watertable is an excellent indicator and could serve as a good basis for a drainage criterion, the more so because it has proved to be a good indicator for plant growth too.

In pasture lands it is not the workability of the soil that is important but rather its resistance to poaching (trampling of the soil by the hoofs). It has been proved that drainage (both surface and subsurface) can prolong the number of grazing days and considerably reduce the damage caused by poaching (BERRYMAN 1975).

FAUSEY and SCHWAB (1969) studied the influence of drainage on timely farm operations. They found that the moisture content in the upper layer of a clay soil drained by surface drainage was 4–5 per cent higher throughout spring than that in a similar soil drained by subsurface drainage. Planting operations on the latter soil could start seventeen days earlier, which had important consequences for operation costs and yield levels.

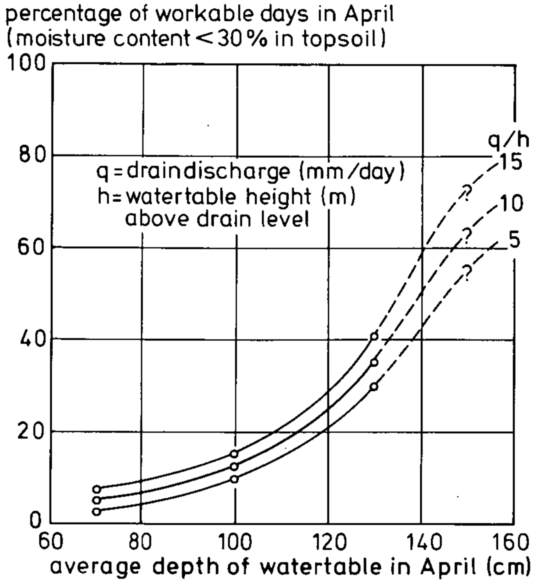


Figure 9.
Drainage and workability of a uniform silt loam soil under Dutch climatic conditions. Data obtained with a simulation model covering a period of 35 years (adapted from WIND and BUITENDIJK 1979).

It is to be expected that the influence of drainage on farm management potentiality will receive increasing attention in the years to come.

Subsidence
If groundwater is mined on a large scale e.g. for irrigation or for industrial or domestic water supplies, land may subside (BOUWER 1978). This will rarely happen as a result of drainage, except in peat soils or swamp land (SEGEREN and SMITS 1974). The results of a recent investigation on the shrinkage of peat soils are presented in Figure 10.
Although deep watertables may increase crop production on peat soils (cf. Figure 6) the adverse effect of shrinkage may lead to the decision that shallow watertables are preferable. Otherwise bridges, houses, or other structures may collapse. In tropical coastal lowlands, the disappearance of peat by oxidation and decomposition may lead to the appearance of underlying cat clays (potentially acid soils).

Hydrologic effects
Figure 11 depicts the different hydrological factors that may act on a piece of land. Here we can distinguish various interconnected reservoirs. As a result of drainage, the amount of water normally present in one or more of the reservoirs will reduce, thereby enlarging their storage capacity for additional water.
As is well known in hydrology, the buffering effect of larger storage capacities reduces outflows, especially peak outflows. Inflows, on the other hand, can increase. Therefore it is obvious that:
- with surface drainage, infiltration will reduce and the watertable will fall, although evapotranspiration may also reduce, which can lead to yield reductions (see article by Slabbers in this book)
- with subsurface drainage, infiltration and percolation can be more, hence surface drainage can be less (RYCROFT 1975)

The dependence of peak surface runoffs on the depth of the watertable has found recognition in The Netherlands in the equation of Blauw. This equation expresses runoff in terms of catchment area, frequency of exceedance, and a proportionality factor (F). For regions with a watertable below 1.7 m Blauw found that F = 1, whereas for regions where the watertable fluctuates between 0.0–0.4 m, F = 4. In the second case peak runoffs are four times higher than in the first.
Figure 12 illustrates another hydrologic influence that a small (20 ha) drainage project can exert on the surrounding land. After subsurface drainage had lowered the watertable in the pilot area, the net subsurface inflow (W–U, Figure 11, 12) increased and subsurface outflow (U) reduced (W is constant). In fact, the pilot area intercepted so much groundwater that the land between the pilot area and the sea changed from marshy land into well-drained land, which was promptly brought under cultivation by the local farmers.
The influence of drainage on the hydrology of a region is very much locally determined so no general guidelines can be presented. The development of calculation methods, however, is in full swing.

Conclusions

Despite the considerable research on the effects of drainage on agriculture, there exists a general feeling of dissatisfaction with the results of many drainage projects.
Van SCHILFGAARDE (1979) states that drainage criteria should be better defined, that the data base for crop response should be expanded and that drainage problems should be regarded as part of a total management scheme.
FOUND et al. (1976) conclude that a significant

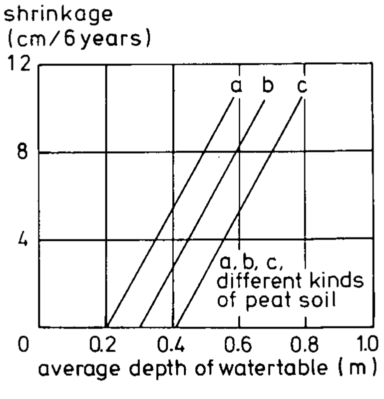


Figure 10.
Shrinkage of peat soils in The Netherlands can be related to average groundwater depth (SCHOTHORST 1978).

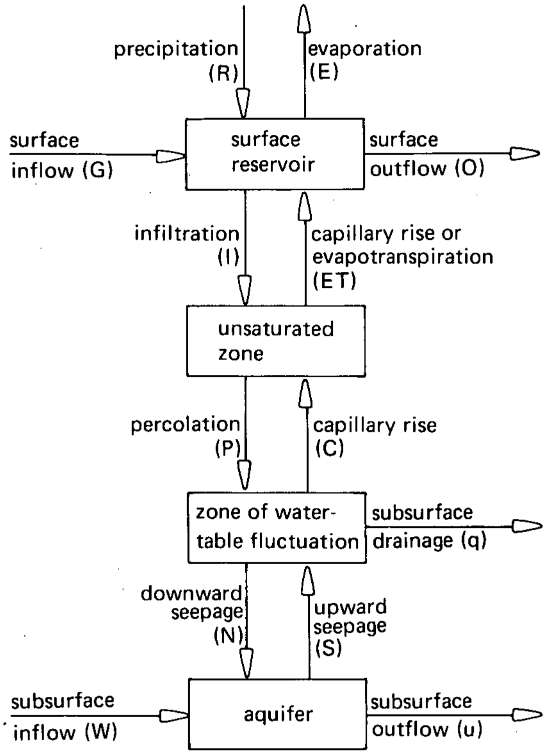


Figure 11.
Water balance factors in agriculture.

minority of drainage projects have failed to generate enough agricultural benefits to justify their construction. Further they consider that, despite the significance of drainage, little scientific analysis of the full effects has been undertaken. ZASLAVSKY (1979) calls for a new engineering approach. Otherwise the design of drainage projects will often be based on habits, superstitions, and prejudices, rather than on really measured and checked experiences.

When drainage design is based on a formula, with no consideration given to the environmental changes that can be brought about, failure may result. Figure 13 illustrates that an outfall drain, designed with the Manning formula, proved to be disastrous, not because Manning's equation is in correct, but because the drain drastically changed the hydrologic situation.

In most commercial, industrial, or public enterprises it is customary to make regular evaluations of past results. This rarely happens in agricultural water management projects, let alone in drainage projects. The lack of evaluation means that it is not known whether what was done was rightly done and that no information exists on how to do better.

The economic evaluation of a drainage system should include a great number of items such as:

- cost of the system
- increase in crop yields
- reduction of costs of farm operations and inputs
- gains obtained from timely farm operations
- profit, or damage, as a result of hydrologic side effects
- advantages of new cropping patterns
- social benefits accruing from intensified agriculture

This evaluation is no simple matter and can, of course, not be realised in the laboratory or in experimental fields, but requires regional surveys.

It has been shown in this article that our knowledge of drainage is detailed but fragmented, and that we have no integrated models with which to predict the beneficial and adverse effects of a drainage system. Drainage, therefore, is still a matter of trial and error, which means that monitoring of projects is indispensable. As drainage effects vary from place to place and form an intricate complex with other farm management practices, it is vital that theoretical considerations, book knowledge, and designs based on experience elsewhere be verified by extensive field observations and a proper statistical interpretation of the facts.

Reversely, only with sufficient evaluation data to hand will it be possible to improve existing theory and to extend our knowledge on the many

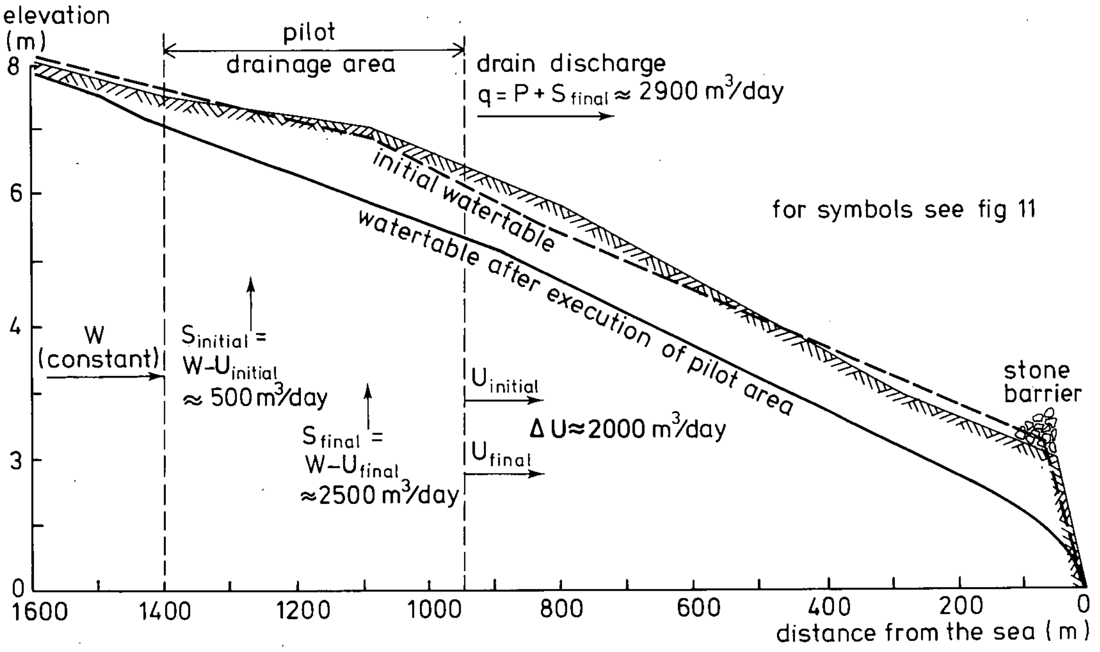


Figure 12.
A 20 ha pilot project area in a coastal valley in southern Peru (OOSTERBAAN 1975).

Figure 13.
What can happen to a drain if installed in an area prone to inundations.

interrelations between drainage and agriculture. Despite the need for them, monitoring programs will probably meet with a certain resistance before being established on a routine basis because:

- they are expensive, time-consuming, and labour-intensive
- the faith we have in our present design procedures is so great that the possibility of failure is considered a problem of second order
- monitoring programs may lead to the discovery of errors that can have serious political consequences
- there is a tendency to confine scientific work to the office premises, with its laboratories, experimental stations, and computer facilities.

However, with the world's growing demand for food, the evaluation of projects and a more intensive collection of data on the farm will soon be unavoidable. Examples of such evaluation projects in developing countries are the cooperative programs of the Colorado State University (U.S.A.) and the Water and Power Development Authority in Pakistan and of the interinstitutional Panel of Dutch and Egyptian organisations which are assisting the Drainage Research Institute (Ministry of Irrigation) in Egypt.
After all, it is likely that the cost of a monitoring program is much less than the damage afflicted by a wrong project, which might have been avoided with a proper survey of past experiences.

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