A DECADE RESEARCH IN LAND AND WATER MANAGEMENT

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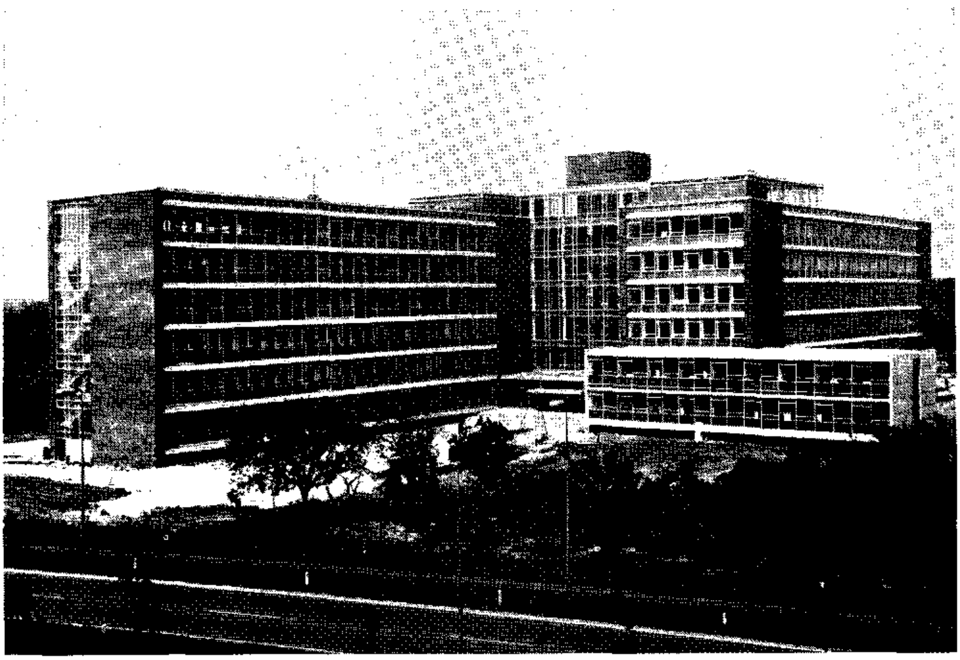

The Staringbuilding at Wageningen, The Netherlands. The high wing at the right is occupied by the Institute

Preface

The papers presented here are intended to give a general idea of the kind of investigations carried out during the past ten years by the 'Instituut voor Cultuurtechniek en Waterhuishouding', Wageningen, The Netherlands.

Although the Institute was founded by the Netherlands Government in the last months of 1955, our research activities did give their first results in the beginning of 1957. The period considered therefore practically spans the life of our Institute.

Our moving in December 1967 to a new building, of which one wing was specially constructed to meet our research requirements, did seem to us the right time not only to look back but also to give an inkling of the research on hydrology, plant-soil-water relationships, soil improvement and land consolidation to be carried out in the near future.

It is typical for our kind of research that it always has had a close relationship with the practical problems of organizations executing land and water management works. The investigations are intended to give reliable solutions to the problems they encounter, bringing with it, however, that the research in many cases has to be extended to fundamental principles.

It is also interesting to see how our research even within such a short period as ten years, did shift to a fair extent to problems of overall improvement of agricultural areas and how the solving of non-agricultural problems within such areas had to be incorporated in it.

We express the hope that the following pages will give a better insight into the work done by the Institute and that they will further our many good relations with other organizations and scientists, elsewhere engaged in the improvement of agriculture.

DR. IR. C. VAN DEN BERG
Director of the Institute

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C. VAN DEN BERG

INTRODUCTION

In the Netherlands land improvement works, either on a small or a larger scale, have been continuously executed throughout the past centuries. In every period, however, there have been particular impulses for such measures. Although every such an impulse was apparently an economic one, the basic causes were either of a more physical or a more social nature. Generally speaking, mostly a growth in population and the ensuing increase in the demand for food were responsible for periods of increased land improvement activities.

Due to the physical environment of the Low Countries – situated in the Rhine-Meuse delta and having a climate with a fairly high rainfall – the measures, beginning as far back as the Middle Ages, took initially the form of land drainage and reclamation of coastal land. In those early days the variation in the extent of drainage and reclamation works was directly connected with the change in population growth. Since this impulse built up slowly, the adaptation to the new conditions was also only gradually achieved.

Today and in the future a variety of improvements of the rural areas in the Netherlands is still required, since by no means an optimum condition exists. The land is still in danger by floods and droughts, still suffers from fragmented holdings, an inheritance from the past, and still the many only moderately fertile soils have limitations in their use. At the present time, however, economic and social changes occur much more rapidly than was formerly the case and much swifter reactions are therefore necessary.

The supply of food has in our country become a less important problem than the efficient use of labour and capital, to which more attention is now to be paid. Moreover, the interrelation between land use for agricultural and non-agricultural purposes has become considerably stronger in this densely populated country. As a result, drainage and reclamation alone have not been able to meet any longer the requirements, a much more intricate program of land improvement measures must now be used.

The Netherlands Government has, particularly after the Second World War, stimulated and supported such programs of 'rural reconstruction'. The first example of this was the complete physical reconstruction of the isle of Walcheren, having been flooded by the sea at the end of the war.

However complicated land improvement has become, unchanged is the fact that impulses of an economic or social nature still influence the definite form of improvement or reconstruction that is executed in a certain period. The same impetuses that influenced the agencies carrying out land improvement works, gave a momentum to certain research activities at our Institute. In fact this reflects the close relationship that exists between our research and the practice of land improvement. This is as it should be, for the existence of an agricultural research institute must find its justification in the possibility to apply its results.

In this chapter a general survey will be given of the kind of research carried out at the Institute for Land and Water Management Research, but seen against the background of stimulating economic, social and climatologic influences. For even in the first decade of its existence, one can point to many connections between research projects of the Institute and developments in the national or international sphere.

The outside influences that have had the most impact on recent land and water management research in the Netherlands have been:
- the changes in economic and social development;
- the changes in agricultural economy;
- the flood disaster of 1953;
- the change in annual rainfall in the last decennia.

Some of these developments started before the foundation of the Institute in 1955. For a clear understanding the following will in such cases cover the period from 1945 to 1955 as well.

CHANGES IN ECONOMIC AND SOCIAL DEVELOPMENT

In the first years after the Second World War the Netherlands were in a poor economic condition as a result of:
- a standstill, respectively slowdown, of economic development after 1930;
- the heavy war damage;
- a fast growing population, resulting in considerable unemployment, hidden unemployment in farm families included.

An extensive Government program for industrialization was so successful that unemployment disappeared within six years after the war. For agriculture, industrialization meant an exodus of farm workers and a need for substitution of hand labour by machinery, this in its turn gave a sharp increase in the requests of farmers for land consolidation projects, in which now about two-thirds of the cultivated area in the Netherlands is involved.

The impact of these factors on research in land and water management will be described under the headings 'influences of industrialization' and 'influences of increased population and prosperity'.

a. *Influences of industrialization*

The increasing scarcety in labour immediately led to the need for larger land units and the consolidation of fragmented holdings, as only in this way an increase in farm mechanization could economically be achieved. Because of this, research was particularly directed towards the effects of lot size and farm layout on labour requirements. Investigations were also aimed at determining border losses and transport requirements, as a reduction of these factors is one of the principal benefits of the reallotment of the scattered lots belonging to one farm. Next, with the aid of traffic count and analyses of the composition of rural traffic and its relation to farm activities, valuable indications were obtained on the efficient layout of a road network in rural areas.

Since for drainage purposes the small existing lots are often surrounded by ditches, the problem of obtaining earth to fill them is directly connected with the execution of lot enlargements. Preferably the earth has to be taken from the subsoil without disturbing the existing productivity level. Several methods came into use, in which heavy machinery like draglines, deep-plows and bulldozers play an important role. It has been the task of the division of soil improvement in the Institute to study the results of such work, always with the view of maintaining or preferably improving soil fertility. The latter may for instance be achieved when topsoils have unfavourable properties. Deep-plowing then has an improving effect while at the same time the subsoil will become available for ditch-filling. In this context close attention has also been given to the soil compaction effect of heavy machinery.

The results of these investigations have led to the formulation of a set of conditions, required for work of high quality.

The filling of ditches disturbs the existing drainage systems and it therefore has to be complemented by tile drainage of the newly formed lots. Consequently also research-work on tile drainage has greatly been stimulated by this type of soil improvement measures.

As industry developed plastic pipes for drainage, research in the Institute is now concerned with the hydrological effects and hydraulic properties of plastic tiles too. The many existing types are tested as well in the laboratory as in trials under different field conditions.

The increased industrialization in all countries in Western Europe did have a profound influence on the pollution of the river Rhine. Among the waste products discharged in this river belongs also a huge amount of salts. In the Netherlands, Rhine water is used for domestic purposes, but also serves to flush canals and ditches in the glasshouse districts of the western part of the country. Here salt water intrusion from the North Sea causes a 'natural' salt content in the open water which is used for irrigation of horticultural crops as legumes and fruit grown in glasshouses. As long as the Rhine water was of good quality it could fulfil satisfactorily the task of pushing back the brackish water in canals and ditches. But 15 years after the war, the salt content of the river water had in summer periods increased to 1000 mg per liter (of which about 300 mg Cl), thus making it less effective in freshening the brackish water in the glasshouse districts.

Apart from international deliberation, leading to a certain limitation of salt discharges in countries along the river Rhine, in the Institute renewed investigations of salt-effects on the main garden crops were started.

The danger for salinization of surface water did not only arise from pollution by other European countries but could also be increased by extensive harbour developments in and near Rotterdam. Therefore, recently a regional research project on water and salt movement in the central western part of the Netherlands has been started to analyze precisely the sources of salinization and to find means to reduce their activity.

b. *Influences of increased population and prosperity*

The Netherlands not only belong to the most densely populated countries of the world, but for a modern country its growth in population after the Second World War has been relatively rapid. The building of living quarters, industries and main traffic roads, necessarily leads to a considerable loss in agricultural land, which up to now could be compensated by reclamation of sea bottom land in the former Zuiderzee (IJssel Lake). On the 'old land', however, the allotting of land for the different uses has become quite a problem. The solution for agriculture is often found in a land consolidation scheme and transfer of a number of farmers to the new land in the polders of the IJssel Lake. The interrelations between agricultural and non-agricultural use are many, the layout of fields and farms often influences non-agricultural development and vice versa. Physical planning is therefore an important item in the Netherlands and a section in the Institute has devoted itself to studies intended to throw light on the question how a land consolidation scheme can also serve non-agricultural developments in rural districts.

Due to the success of industrialization in the Netherlands not only sufficient job opportunities for the growing population were created, but the national income per head increased considerably. This prosperity, together with a reduction in the number of working hours, promoted enormously the demand for recreational opportunities. This demand has been answered with for example the creation of artificial lakes in several land consolidation schemes. To fill ditches, earth is then obtained by means of suction dredgers, and the resulting lake is shaped in such a way that it can be used for swimming, boating and fishing.

In 1966 it was decided that the Institute should take part in investigations in the recreational requirements as far as they are influenced by land improvement schemes. The investigations will cover a survey of existing recreation projects, the optimum site of the projects within rural areas, the required road system and the recreational facilities as far as they are related to soil, water and plant cover.

CHANGES IN AGRICULTURAL ECONOMY

In the first years after the Second World War agriculture did strive to increase production to end the food shortage. As already said, labour saving methods in agriculture were needed at that time to compensate for an external influence: the exodus of farm workers to the flourishing industry. But gradually food supply began to surpass demand, resulting in a serious fall in prices. At that moment internal circumstances made it a must to lower agricultural production costs. Instead of production per unit of land, production per man became the criterion for efficient farming. This transition again stimulated the demand for land consolidation schemes. At the same time economists evaluated more critically the land improvement plans, as they require high Government investments.

These tendencies led, already before the Institute started its work, to a general survey of the overall requirement for land consolidation in the Netherlands. An inventory was made of the imperfections related to soil, water and land of about 700 districts and the benefits and costs of improvement of each district were estimated.

The research of the Institute also reflects these economic considerations, the more so as it became clear that agriculture had definitely reached a structurally weak position.

As one of the studies, supplying a background for the planning of complex consolidation schemes, the research into future farm sizes should be mentioned first. With the aid of linear programming, extensive investigations are carried out in order to fix the desirable future size of different types of holdings on which the most modern type of machinery will be used. From elaborate models it has been found that in some arable areas farm sizes of 120 ha (1 ha = 2.47 acre) with 3 farm workers (or a combination of 3 one-man farms of 40 ha) can use modern machinery most efficiently. In grassland districts it has been found that the size to be tended by one man should be about 30 ha with about 30 to 40 cows. In the actual situation farm sizes are much smaller and have only about one half to one third of the desirable size. Studies like these learn, that land consolidation schemes should account for a future growth in farm size and that in the layout of roads, water courses and farmbuildings future developments should as much as possible be reckoned with.

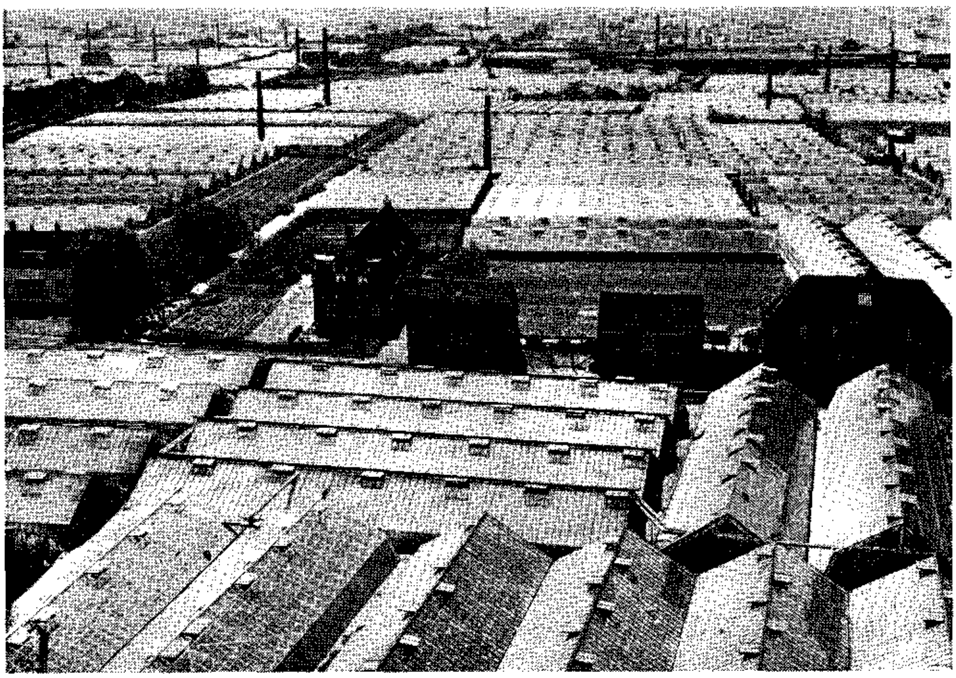
The need to limit labour requirement and transport has led to research for the need of re-siting farmbuildings, now often concentrated in villages. Theoretical elaborations, applied to actual situations, make it possible to show the saving of labour in dependence of the number of re-sited farmbuildings, as well as giving the most suitable site for each of these buildings. Comparison of costs and benefits then permits to select the most efficient re-siting scheme.

The more stringent requirements to keep the costs of consolidation schemes as low as possible has greatly stimulated the comparing of alternative solutions. In most research projects, whether related to water management, to soil improvement or other parts of consolidation projects, this comparison is now common practice. It has found its culmination in integrated studies of specific consolidation schemes considered for execution by the Government Service for Land and Water Use. In such regional research projects, in most cases representative for considerable areas, it is tried to find the optimum solution for the whole project, including the layout of roads and water courses, the water management system, the re-siting of farmbuildings, the sizes of new lots and the methods of soil improvement.

During these regional investigations it soon became apparent that detailed data on the parcellation of land were needed in order to characterize the prevailing conditions, to convey research results and to decide on the type of improvement. As many of such data are also valuable in planning land consolidation schemes in practice, it was decided to make for the whole of the Netherlands a survey and inventory of all facets of the division of an area that are of importance to farming. With the aid of computer techniques it is possible to get quick information about the district, about every village area, as well as on the characteristic data of individual farms. It is highly probably that these data will as well be useful as a background for regional physical planning and economic evaluations.

As a consequence of the need to evaluate economic short and long term effects of consolidation projects, general economics, as far as related to land improvement, has been included in the Institute's research program. Models of economic growth in improved and non-improved regions have been developed and are now tested in some areas. Factors considered are savings, investments, migration of farm workers and farm income as influenced by land improvement schemes.

The regression in agriculture did not affect all types of farming to the same degree. In particular high quality vegetables and flowers did profit from the increasing prosper-



Glasshouse district 'Het Westland' in a polder near the sea coast ity in Europe and showed a regularly growing demand. This resulted among other things in a continuous enlargement of the area covered with glasshouses, mainly heated ones. The area of glasshouses in the Netherlands is now at least 6000 ha, the annual production value amounts to more than 500 million guilders. Also bulbgrowing and growing early horticultural crops in the open remained a paying business. The horticultural regions themselves, however, show many defects in the layout of fields, the drainage system and the transport facilities. In some cases the fields can only be reached by boat. Gradually, market gardeners asked for consolidation schemes and particularly for new road systems, for the improvement of drainage and for better workable soils. In connection with the economic importance of horticulture, the Institute devoted part of its research especially to it.

Several investigations on water supply of horticultural crops were carried out, together with the research on water quality which has been mentioned before. The reaction of several horticultural crops on different groundwater levels was investigated in an already existing experimental field.

As in most horticultural consolidation projects considerable quantities of earth will have to be moved for ditch-filling, the effects of moving earth, deep-plowing and deep-mixing on yield and quality of horticultural crops have become research projects. On clay soils experiments were carried out to improve the workability of the topsoil by mixing the heavy toplayer with sand. Planned are investigations for the improvement of soils for flower growing in glasshouses.

Finally, integrated regional studies were also undertaken in horticultural districts in order to develop a systematic planning of land consolidation schemes for horticulture. To this end, more detailed investigations were devoted to labour requirements under different conditions of farm layout, means of transport and sizes of horticultural farms.

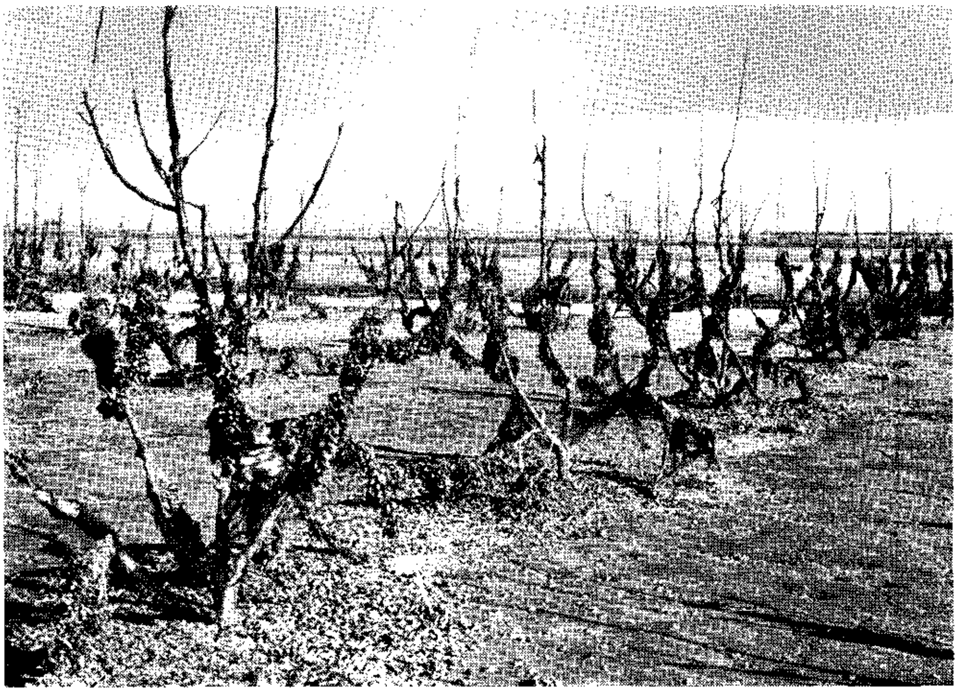
This horticulturally oriented research is carried out in close co-operation with specialized horticultural experimental stations, all situated in the West-Netherlands.

Three scientists of the Institute have been seconded to these stations to carry out research and to promote a quick flow of the obtained results to the horticultural extension services and to organizations involved in land consolidation and improvement in these regions.

THE FLOOD DISASTER OF 1953

In the night of January 31 on February 1 1953, a gale as heavy as never experienced here before hit, at the time of high water, the coast of the southwestern Netherlands. The toll of that night was: 187 km of seadikes destroyed or heavily damaged, area encroached by the sea 150,000 ha, 1835 people killed or missing, 100,000 people to be evacuated, estimated total material damage 1000 million Dutch guilders.

The abrupt interruption of normal life led to a number of decisions by the Government, which in the end greatly influenced the research of the Institute.



After the flood

The first decision was to reconstruct the broken dikes, to drain the flooded land and to restore land and buildings. Secondly, it was decided to combine land consolidation plans with the reclamation of the land. Thirdly, the decision was taken to protect these areas against any flood in the future. In this well-known Delta-plan the main estuaries between the islands in the southwest will be closed by large dams.

In this same region, the isle of Walcheren had already been flooded in the last year of the war and favourable experience had been gained with such a consolidation scheme, in which reallotment of land, soil improvement, road construction, farmbuilding re-siting and new drainage systems were all combined. The investigations accompanying the execution of this work were a stimulus to organize in the new Institute a division for soil improvement and a division for integrated land improvement project studies. Further, the Institute immediately after its foundation started in close co-operation with the Ministry of Public Works, with investigations in the Delta-area.

The research was concentrated on the salt and water balances of the 'Lake Zeeland', to be formed after closing the estuaries. This led among other things to a comparison of several methods to determine the salt water intrusion into the land under the existing conditions, as well as the fresh water intrusion from the lake in the future situation. Of particular interest became the geo-hydrological investigations of specific parts of the delta and the statistical analyses of groundwater levels, by means of which a water balance could be formulated. Later these investigations were completed by analyses of discharges of pumping stations.

CHANGE IN ANNUAL RAINFALL IN THE LAST DECADES

Climatic conditions in the Netherlands are fairly stable, but there are periodical variations which have considerable influence on agriculture. So for instance the rainfall from April to September during 1940 to 1950 averaged 350 mm, whereas the average reached 455 mm from 1957 to 1966.

In the period 1940 to 1950 the dry summers of 1947 and 1949 in particular underlined the existence of a water shortage on the sandy soils of the Netherlands, which cover about half of the total cultivated area. Ideas on water supply were developed and several scientists investigated problems of plant water use and soil conditions as influenced by a limited availability of water and a limited water supply.

When these research workers were brought together in 1956 in our Institute, the work of the water management division still reflected the 'dry' aspect of plant-water-soil relationships. In this connection the water in the non-saturated zone of the soil became an important subject of research. In the laboratory determinations of moisture characteristics of different soils were correlated with other soil physical properties like texture and humus content. In the field gypsum blocks and particularly nylon elements, were used to check soil moisture tension. For experiments in glasshouses, where water supply is fully artificial and a high soil moisture condition must be maintained, tensiometers came into use. In normal practice the instrument has now become quite popular among market gardeners. In later years, moisture measurements in our research were also made with neutron and gamma radiation equipment.

The reaction of plants on available soil moisture continues to be an important research item. In pot experiments in glasshouses several important horticultural crops were tested on their productivity in relation to soil moisture conditions.

Since the meteorological conditons play often a decisive role in plant production, the study of evapotranspiration and the probability of a given precipitation deficit became research projects, meeting considerable interest, both in and outside the Institute.

In several regions of the country sprinkler experiments were carried out on the main crops grown on sandy soils. Where regional conditions seemed promising for supplemental irrigation soon the question arose where the water needed had to come from. River water could be made available, but its transport costs seemed prohibitive in many cases. Groundwater could be pumped up easily enough but might lead to a lowering of the groundwater table in land where hitherto this water had by capillary rise contributed to plant growth.

To solve such questions, one of our first regional geo-hydrological investigations was devoted to the study of a watershed on sandy soils with a high transmissibility. The movement of groundwater in such soils and the changes in level as a result of eventual groundwater withdrawal were the subject of elaborate investigations.

In this context the rising research interest in unsaturated flow, particularly capillary rise, can also be mentioned. It seemed surprising that this field of research had almost been neglected in the Netherlands, as an estimate learns that at least one third of our cultivated area consists of low lying grasslands, where a high water table gives considerable capillary rise in dry periods. Moreover, on most of these lands, systems to maintain a high water level in ditches throughout the year have been in operation for centuries. The experience gained must have been satisfying, since on the average no serious problems arose with this form of subsurface irrigation.

In addition to the determination of suction characteristics, unsaturated flow measurements were included in the Institute's program. The capillary conductivity, in undisturbed soil samples up to a length of one meter, can now be determined in the laboratory in the wet range of unsaturated soils, whereas its determination in the dry range is expected to be successful before long. From the relation of this capillary conductivity to soil water suction, the delivery of capillary water to the root zone can be calculated.

Another research project, greatly stimulated by the above mentioned relatively dry period, is the evolving of evaporation formulas. In lysimeter studies the relation between meteorological conditions and evapotranspiration of short crops as found by Penman was confirmed for the Netherlands. Later, however, the plant resistance and the crop roughness were added to the existing formula, factors important when dealing with long crops. A formula based on a combined water and energy balance approach was tested on grass in the Netherlands as well as on alfalfa growing in Tunisia and it is hoped that it will be of value when designing irrigation projects under any given climatological condition.

As regards the 'wet' side of plant-water relationships, the Netherlands have always been famous for its age-old drainage systems. Research on this subject, however, only started after 1930, when the well-known hydrologist Hooghoudt started to develop his drainage formulas and the field method of hydraulic conductivity determination. Later, investigations followed on the desirable depth of the groundwater table. But till up to around 1950 the subject of drainage, although the earlier research findings were applied to tile drainage on a routine scale, did not get a share of research equivalent with its importance.

The long period of wet years starting in 1950 and even lasting now, only interrupted by the dry summer and autumn of the year 1959, gave an intensification of investigations on the desirable groundwater level in specially conducted field experiments and the renewed interest of research in problems of excess water in the soil and of drainage manifested itself in several ways in the Institute.

In the first place the attention was focussed on watershed hydrology in the slightly sloping and undulating sandy regions of the country. The mutual relations between precipitation surplus, drainage flow and groundwater table depth, the validity of hydraulic flow formulae, the development of new equipment for flow measurements and the economics of different methods of cleaning water courses did receive attention in our research projects. A factor of importance in watershed hydrology is the accuracy with which rainfall distribution is measured. Mathematical studies of rainfall distribution data have therefore become a complemental research project.

In the second place more research has gradually been devoted to aeration of the soil and its consequences for plant growth. Investigations on the components of soil air under varying conditions of aeration have been introduced and air supply to plant roots as related to groundwater level is being studied.

In the third place the influence of excess water on farm management became an important item. These studies gave an insight in the damage done and at the same time in the benefits to be expected from drainage improvement of the watershed.

A particular harmful aspect of excess water on farm management became gradually apparent in extensive areas of permanent grasslands on peat soil: the trampling of the grass sod by cattle under conditions of heavy rainfall and high water tables, the latter being normal for these peatlands.

The first investigations dealing with these problems were carried out on shallow peat soils overlying sandy layers. The solution against trampling could be found here in deep-plowing, thus covering the peat with subsoil sand in a layer of 10 to 15 cm. Later, soils with thick peat layers where no sand could be plowed to the surface, were studied. After determining the relation between humus content, density of the top-layer and water content, it was possible to indicate the correct water table depth for any given peaty soil. As, however, a deep water table in peatland may cause a lowering of the surface of the land, field experiments are now conducted to find the accurate management of the water table during the course of the year to prevent this.

Taken all together, it is believed that now not only all components of the water balance, but also their repercussions on agriculture receive an adequate attention in the Institute.

THE FINAL GOAL OF LAND IMPROVEMENT RESEARCH

The gradual growth of the number of research projects, as stimulated by the changes in agricultural conditions, has led to a conglomerate of activities, permitting the 30 scientists of the Institute to go deeply into a variety of physical and economic problems.

Practical improvement work, however, no longer concentrates on the single tile drainage case, the soil profile improvement of an individual farm or the reconstruction of a single rural road, but it aims at the integrated improvement of the physical structure of rural areas.

In the first place attention is focussed on the improvement of agricultural economy which, as land drainage, soil improvement, re-siting of farmbuildings, road construction, etc. are involved, leads in itself already to multipurpose projects.

But the complexity of the projects still increases by the need to take general physical planning into account, in the way it arises from the expansion of towns, the construction of highways, the exploitation of groundwater for domestic purposes and so on. It goes without saying that including recreational constructions further complicates the planning.

Research will have to adapt itself to these demands and must look for solutions in which the results of a variety of detailed investigations are integrated and economic optima are approximated. This must be considered as the most difficult problem to solve and its solution is far from being complete.

In some cases solutions are available for the integration of problems of a more limited nature. This is for instance the case with the water balance. Written as an equation, the unknown component may be found after detailed investigations of the other components. Another example is the calculation of optimum farm layout, when some data like farm size, labour units and main crops are given, but farm labour, transport, border losses, etc. are variables to be found by investigations and elaborate calculations. Usually, however, solutions only refer to parts of the project and their further integration remains necessary.

The approach of such problems, gradually developing in the research of the Institute, is to concentrate several specialized investigations on a number of case studies in different regions of the country. Within larger regions, generally a representative area is chosen for elaborate investigations by a team of specialized research workers, who are aware of the required integration of their results into the whole of the project and who have to adapt their research to this purpose.

An example is the investigation of a watershed in a sandy region of the East-Netherlands, where watersupply companies and industries are much interested in groundwater withdrawal, but a lowering of the groundwater table may considerably diminish the groundwater contribution to the moisture available for crops during summer. It is characteristic for this type of research that the optimum solution mostly must be found in the comparison of alternatives, whether by varying the intensity of one type of solution or by comparing different types of solution. In the case of the given example, one might try to spread withdrawal of groundwater as much as possible, think of possibilities of storing water from winter rains or infiltrate river water into the area.

Another example concerns the investigations in a clayey region in the northern Netherlands, where some land consolidation schemes are underway or in preparation. The region is characterized by winding roads and by irregular lots of about 1 ha, surrounded by ditches and sloping on all sides to the ditches. The site of the farm-buildings is fairly favourable. One of the main problems is, how to fill ditches in order to enlarge lot sizes. The degree of filling, the type of machinery to be used and the sites for obtaining earth are some of the variables. Moreover, farm size and recreational opportunities have to be considered. A close co-operation of soil improvement specialists with planning engineers and economists is needed here to arrive at a result close to the optimum.

The complications in such studies are many and it is often necessary to simplify matters by using models, whether physical, mathematical or economic, depending on the type of problem. The use of computer techniques makes it possible to investigate with such models the effects of the many variations and makes it easier to find the optimum solution.

Whereas much research on detailed problems remains needed, the Institute's work has a tendency to move in the direction of investigations of a more complex nature and to the integration of research results of different disciplines. This seems to be in accordance with the development of society, where the interdependence of activities related to land use is ever increasing, particularly in a densely populated country like the Netherlands.

Some research techniques for multivariate land improvement problems

W. C. VISSER

THE PROBLEMS

In the preceding ten years, research of different types has been carried out in the Institute. In the first place a number of specific practical problems as drainage or consumptive use have been tackled, methods of assessment of plant and soil properties have been developed and their results, of direct practical applicability, have attracted much interest. In the second place, however, the problem of setting up multivariate land improvement models has also been gone into, although this has met with less direct interest. It is, however, of equal importance to obtain reliable design results.

Land and water management problems require a comprehensive type of research, which differs from the classic type of investigation mainly shaped for problems where all factors can be kept constant save the one to be studied. This classic type of research also requires that the factor to be studied has been previously indicated. Comprehensive research deals with a number of factors, known and unknown, which are largely varying without the possibility to keep them constant. Neither are the factors to be studied previously known. Part of the problem to be solved is to indicate which factors are limiting.

The ultimate land improvement problem is, in what order of profitability practical measures can be taken to improve an insufficient level of land management. It is required to specify not only the nature but also the intensity of the measures. The complexity of the investigation not only arises from the large number of factors which may be involved, but also from the fact that practical measures affect a number of them generally in a complex way, in a range from beneficial to injurious. The results of the measures taken may furthermore easily transgress the realm of land improvement techniques and touch upon problems as the kind of farming, the crop selection or fertilization.

As will be discussed, for the solution of these multivariate problems some research techniques are particularly suited.

REQUIREMENTS OF COMPREHENSIVE RESEARCH TECHNIQUES

Classic research, by its specific nature, has not endeavoured to formulate a technique for multidimensional comprehensive research. It may, however, be assumed that within its line of thought such a technique would have embraced the determination of every detail and the combination in some way of the results. The number of details would have been very large, but adding them up would not have constituted a difficulty now that computers are available. The costs, however, of such an exhaustive investigation would have been prohibitive. Since, however, the theory of classic research techniques has not worked out a basis for comprehensive research, fitting research rules had to be used or evolved with which efficient comprehensive research techniques could be constructed.

Comprehensive research makes at first sight contradictory demands. It should be complete but not intricate, accurate but without unnecessary details. It should be manageable but not superficial. Above all it should not be costly but the results should still give sufficient information to solve intricate practical problems.

A major difference with classic research is, that the shape and extension of the investigations to be carried out depends to a large extent not on the importance of the results but also on the costs and the possible outcome of the research technique. The methods of comprehensive research depend not only on the problem to be solved but also on the availability of many specialists, the research facilities and the economic effectiveness of the scientific methods used. The manner of the investigations will depend on the required intensity of the research to be done.

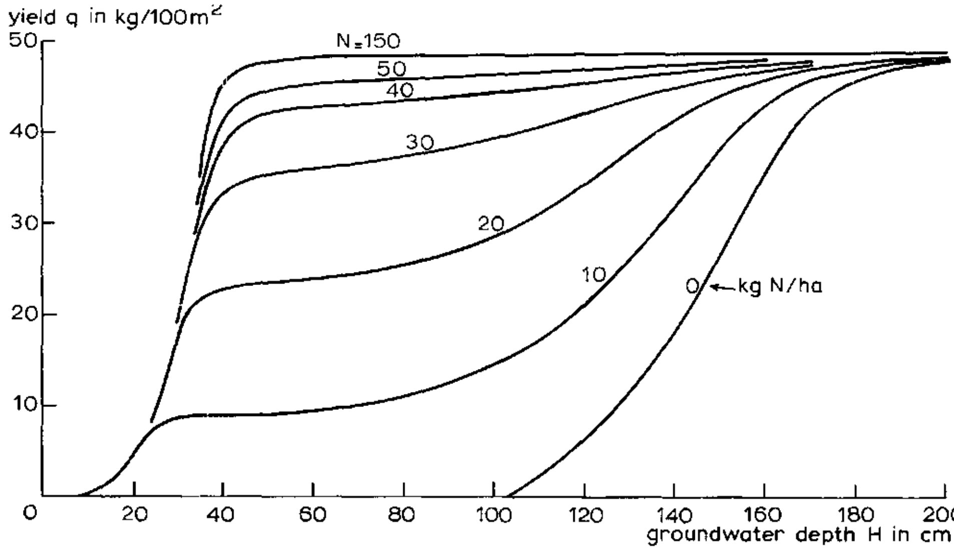
In the following pages a few techniques, used during the last ten years, will be discussed.

USE OF MODELS OF GENERAL VALIDITY

In comprehensive research the use of models is of well-known value. It precludes the need of evolving time-consuming ad hoc solutions and makes it possible to compute the constants which produce the best fit of the model to the observations. In hydrology using models is becoming standard procedure, but it will be of importance to evolve such general concepts in every branch of land improvement research. It is in the description of plant production that models were most conspiciously lacking and had to be constructed. The development of a crop production function will therefore be discussed as an example of this model approach.

The production function is based on three hypotheses. First, the uptake of nutrients works in accordance with a linear flow or diffusion function. Secondly, a healthy growing plant takes up its nutrients in a certain optimal ratio. Thirdly, in suboptimal growing conditions the sum of the relative deviations in uptake of the various factors from this optimal reference ratio, is zero. This third concept in fact states, that the level of production is such that an optimum use is made of all available nutrients.

These three concepts lead directly to a relatively simple mathematical equation for the rate of crop growth, identical with the law of limiting factors or the growth relations according to Blackman. Comparison of the results of the obtained formula with data of field experiments, taken from literature, did show that the concepts of diffusion and minimum deviation provided a correct background, not only for simple



$$\left(1-\frac{q}{51.1}\right)\left(1-\frac{10^5 q}{0.82\,H^{4.35}}\right)\left(1-\frac{q}{1.61\{N+0.76\;10^{-8}\,H^{4.35}-4.21\}}\right)=0.0394$$

FIG. 1. *Graphical and mathematical representation of a crop production model for the depth of the groundwater and the application of nitrogen as an instance of a rather complex growth model*

cases but also for more complex ones as co-operation, substitution or antagonism of growth factors.

An illustration of how plant and soil aspects can be dealt with – in this case the interrelation of nitrogen application and groundwater depth – is given in fig. 1. The yield depends in the first place on the limit set by the maximum yield, which in our case is 51 kg/100 m^2, given in the first term of the formula. The second term describes the influence of aeration – defined as an exponential function of groundwater depth – on the growth of the crop. The third term shows how the same aeration will influence the amount of nitrogen made available by micro-organisms, to which the amount of N applied as fertilizer is added. The negative quantity of 4.2 kg represents the nitrogen lost by leaching or in some other way.

The example shows how with a model the effect of a complex process as aeration can be solved and how with the aid of the model the constants can be assessed. The models should be shaped in such a way that they can be used not only as a biological growth relation but also as an economic production function. In the mentioned case it will be clear that by writing the groundwater depth and the nitrogen application as a function of costs and expressing the yield as a function of benefits, such a model can be used to decide under which conditions supplemental drainage or nitrogen application is the most profitable way to counteract insufficient drainage.

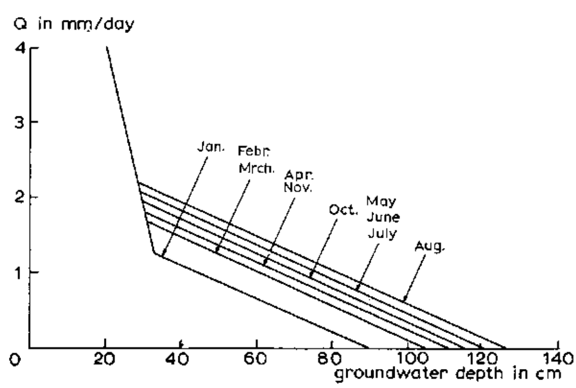
REDUCTION TO ONE COMMON VARIABLE

In a multivariate problem the ultimate result often depends on a number of properties which can be measured independently, but which are linked by some mutual relation. Elaboration of the effect of such properties is hazardous, because the interrelated property may be accounted for more than once. But even if this danger has been overcome it is possible that, by using the relation as basis of a design, new conditions are assumed which are physically impossible or improbable. This difficulty can be eluded by reducing such properties to their mutual variable and define the improvements to be contemplated not as a change of the property itself, but as a change of the constants relating the property to the common variable.

As example can be mentioned a problem dealing with the question whether land drainage had to be based on improving the main water courses, on improving the minor ditches or on a specific combination of both.

When making groundwater depth – discharge curves, results as given in fig. 2 are generally found, indicating that at high groundwater tables the drainage flow is directed to nearby shallow water courses. At low groundwater tables, however, the residual drainage directs itself to deeper water courses farther away. The variation in level of zero flow over the months shows that the water level in the main channel forces the water back into the minor water courses.

The groundwater level, which in fig. 2 is clearly affected by drainage to two different water course systems, can be expressed as the result of the water level in the main channel by expressing the water level in the secondary system in terms of the level in the primary system. The water levels in the minor system can be calculated from the level in the main system. The groundwater level can in this way be related to the water



$$\left\{1-\frac{Q}{\frac{8k_1D_1}{L_1^2}\left(W-a_1H-b_1\right)}\right\}\left\{1-\frac{Q}{\frac{8k_2D_2}{L_2^2}\left(W-a_2H-b_2\right)}\right\}=F$$

$$a_1H+b_1=S_1 \qquad a_2H+b_2=S_2$$

FIG. 2. *A drain discharge model that accounts for the influence of the water level H in the main water course on the groundwater level W and water levels S_1 and S_2 in the minor open drainage systems. Four water levels in the area to be drained, related to the discharge, provide an insight into which drainage system is the most in need of improvement*

level in two or more systems of water courses which provides the basis to assess the effect of improving each of these systems, on the level of the groundwater and therefore on the related crop yields. This will show whether the minor or principal drainage system is most in need of improvement.

Such an expression for the water level in systems of water courses of various order shows clearly the advantages of the reduction to a common variable. The original variables – the water level in the minor ditches – can be recalculated afterwards. The reduced equation, which only contains the water table in the main channel, provides an expression with which to solve the practical problem where improvement is most urgent. It simplifies the solution and eliminates the source of errors arising from the assumption of values for the water level in the minor system which cannot be realized in the design, because these latter water levels are not in accordance with the levels in the main water course.

THE PROBABILITY DISTRIBUTION TECHNIQUE

For the assessment of the optimum design one of the methods in use is to make up a number of alternative plans in all detail and select the optimum one. If carried out accurately this is a very time consuming method. Using random sampling and probability distributions can often provide a more manageable solution. An example of this, dealing with the assessment of the damage of flooding due to high river levels, can explain this.

In an inundated area, on a number of randomly selected farms the financial loss was estimated by means of an inquiry. The decrease in sold product, the costs of countermeasures as artificial drying of grain, extra spraying against diseases, hiring of additional labour were determined on each farm and compared with the excess of rain which fell on the land of that farm.

This provided curves for each crop, giving the relation between the excess of rain and the decrease in farm income. The influence of the cropping pattern was accounted for by determination of the frequency distribution of each crop in relation to the type of soil. In fig. 3 the magnitude of the damage per ha to farm income is given by curve A. From the data on rainfall, the probability distribution of a certain rain duration was constructed, represented by curve C. Multiplication of the probability of this rain frequency with the damage done by such a storm, will give an amount which represents the average financial loss to be expected when a storm with a certain rain intensity and the given duration will happen within the specified period (curve B).

Wet periods, however, may occur all over the year and the sensitivity of farming for excess of water was brought into the calculation by estimating the sensitivity to damage over the months of the year, as given by curve F. Multiplication of the relation between damage and rainfall with this sensitivity factor, accounting for the rainfall frequency in the successive months of the year, produced curve D for the damage over the years to be expected to occur as an average in each month, while in curve E the monthly

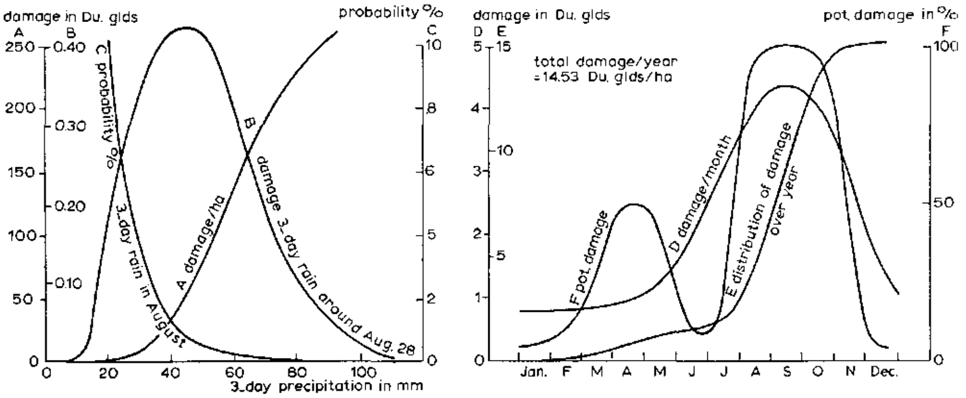


FIG. 3. *Damage done to farm in come by 3-day storms in a specific area in the Netherlands. Left: for 3-day storms around August 28; Right: for 3-day storms integrated over the year. Example of the use of probability distribution techniques when determining the need for drainage*

damage is integrated. A fund providing a yearly rent of 14.50 Dutch guilders per ha would in this case in the long run be enough to compensate for the damage done by flooding. The effect of the improvement of drainage is then brought in by reducing the scale of curve A by means of the ratio of the discharge capacity in the improved condition over the discharge capacity in the existing condition.

The example may show how rather unmanageable quantities as height of the soil surface, depth of the groundwater table, the irregularities of the climate, or variations in cropping pattern, can be treated by probability distribution techniques. One may take for certain that practically no comprehensive problem dealing with farming returns, can be solved without using such techniques at some point in the sequence of reasoning.

PROPAGATION OF ERRORS

As the purpose of an integrated project often is to point out what measures can be taken to improve financial farm results, the accuracy of such a prognosis is of considerable importance. Often it appears that the accuracy of scientific as well as practical forecasts are overrated and that the need for accurate data is underrated.

Supposing that a comprehensive problem is dependent on 25 independent parameters with equal influence and with an error of determination of 5%, then the result will have an error proportional to this determination error and to the square root of the number of parameters and it will amount to 25%. Results with an error of this magnitude will generally be useless for land improvement work. Errors in comprehensive models can therefore not be neglected.

Because there is a large danger that in multivariate problems with many only superficially known factors and parameters, the results will prove to be disappointing, it is of utmost importance to locate the errors, to devise error-insensitive procedures and to account for the remaining errors in the conclusions to be drawn. On the other hand a conviction of the importance of the effect of errors must not lead to unnecessary work. In the following some of this is discussed.

In cases where the relations between the basic factors and the ultimate result are known in formulae, the influence of the error of each parameter can be ascertained by for instance calculating the result with two slightly different values of the parameter. Such calculations often show that the sensitivity of the result for such an error differs considerably for the various parameters, and for the separate parameters when using different values for the variables. This means that it may be appropriate to give close attention to the determination of some of the parameters, but that other parameters can without risk be determined by visual estimation or any other simple technique. It must therefore be born in mind that subjective appraisals in a scientifically acceptable way can give promising methods to collect data. Where for instance the number of unknowns exceeds the number of equations, the use of a subjective estimate of relations which are known to be error-insensitive compensates for the lacking equations.

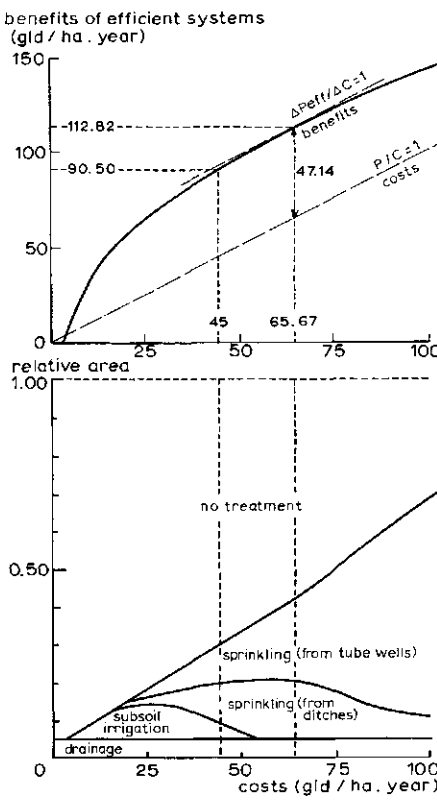
An impression of the influence of deviations caused by errors on a water management plan can be given by the result of a cost-benefit calculation which, because of the sensitivity to shift of the point of contact of tangent lines with curves possibly slightly varying in position and shape, furnishes an interesting example.

In a relatively dry area five methods of water management were compared with respect to their contribution to the improvement of farm income and with respect to their share in total area. The effect of additional water was studied as well for an average field itself as for the adjacent fields where lateral effects of seepage or extraction could occur.

A production function provided for each level of investment the optimum ratio for the different treatments as given in the lower graph of fig. 4. The first investment should go to subsoil irrigation by reason of its loss of water to adjacent fields receiving no treatment, where the seepage water will have a beneficial effect. Larger investments and larger areas of irrigation will diminish the area of soils which are not to be treated and will therefore diminish the benefit-cost ratio of subsoil irrigation and will make a less costly sprinkling irrigation method more profitable. The change from one method to another is largely due to its effect on the non-treated areas, which are profitable ones because they require no additional cost.

Optimization produced the cost-benefit relation of the upper graph of fig. 4, showing that the optimum investment would be 65 Dutch guilders. At an investment of 45 Dutch guilders, however, the difference between costs and benefits will, according to the curve, only decrease by 2%. This degree of inaccuracy in the investment prognosis, although quite reasonable when looking at the shape and position of the cost and benefit lines, would mean for the design that subirrigation would enter into it, that the area to be sprinkled from wells would become halved and that the plan of the project would change materially (bottom graph).

FIG. 4. *The benefits in relation to the costs for different combinations of water management practices for an undulating sandy area in the Netherlands. An example of the importance to account for the propagation of errors*



The example is given to show that in multivariate problems it is quite difficult to attain an accuracy which is high enough to determine which one of considerably different designs is the most economical. A fair chance exists that without careful appraisal of the propagation of errors, the choice of a specific design alternative will be more based on accidental deviations than on real differences in the effect of the physical relations.

SOME FINAL REMARKS

The approach to be used when undertaking comprehensive land and water management research, should be selected while bearing in mind that this type of research requires its own consistent methodology. Classic research is in most cases not able to provide the necessary research theories. Mathematical models and for example multidimensional non-linear curve fitting techniques are often essential, but then a close attention should be given to the practical accuracy of the final results.

Up to recently, models for agricultural productivity were failing and still many have to be elaborated or evolved. It has become clear that these models are to be shaped in such a way, that they not only accurately describe the multivariate relations by means of a correct physical expression, but that they also have to be closely linked with practical problems and design purposes.

The most difficult points in comprehensive investigations are the lack of success that the researcher and the technician experience in translating the practical problem into scientifically correct research models, or that they do not succeed in interpreting the model back into practical measures.

Comparing the development in knowledge of the technical solutions of practical problems with the methodological progress of finding the right way to arrive at solutions in general, the first mentioned results often seem to have spoken more to the imagination than the second. When perusing world literature, one finds less examples concerning the special requirements of comprehensive land and water management research than agrees with the importance of research methodology in this field. More attention should be given to methods with which to achieve completeness without complexity and to preventing, and accounting for, the propagation of errors without unduly increasing the research efforts. In the first ten years of our Institute these aspects of land improvement research have made a fair progress.

Water management

J. WESSELING

GENERAL HYDROLOGICAL SITUATION OF THE NETHERLANDS

The Netherlands have a humid temperate climate with an annual rainfall of about 720 mm more or less evenly distributed throughout the year. In winter evaporation rates are very low, but in summer they considerably exceed rainfall rates. The water balance is therefore in principle a scheme as represented by fig. 5. During winter periods there is generally an excess of rain. Early in spring when evapotranspiration begins to exceed rainfall, drainage will stop and crops are partially dependent on water supply from moisture present in the soil. In autumn the recharge of groundwater starts, followed by drainage.

The agricultural soils in the Netherlands are mainly flat alluvial soils. About 45% of them are situated below mean sea level, which makes drainage one of the main requirements for agriculture.

In the low lying and flat western part of the country drainage originally was realized by a rather dense system of man-made open furrows, ditches and channels from which water is removed by pumping. Except that the open channels have to some extent been replaced by subsurface systems, the situation is there basically still the same.

In the higher eastern part of the country drainage occurred originally by means of natural water courses removing water by gravity. Due to the ever increasing reclamation of waste lands in this region during the last part of the 19th and first part of the 20th century, regulation and improvement of this channel system became necessary. The drainage system during that time was also extended by new man-made channels and subsurface systems.

To make up for the water shortage in summer, in the western part water is let in

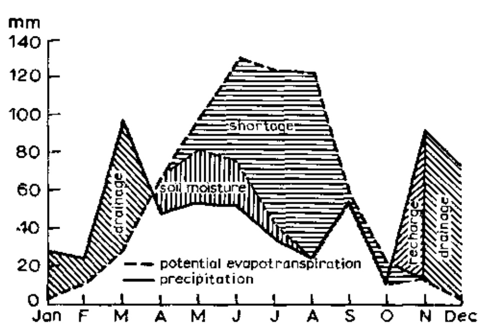


FIG. 5. *Example of the water balance of soils in the Netherlands (sandy soil in 1947)*

into the polder regions where the water level in the open ditch system is maintained at a constant level. In the eastern part water is dammed up by means of weirs in the small rivers and brooks to obtain a high groundwater level during summer.

Apart from supplementary water for crop growth in summer, a great deal of water is needed to push back the salt intrusion entering via the large sea harbours and to flush the channel and ditch system in order to keep low the salt intrusion via the subsoil. This is vitally important particularly for the large glasshouse areas, since this water must be used for irrigation purposes. For water supply in summer, the Netherlands relies on its most important fresh water source, the river Rhine.

A discussion of the influence of the fresh water reservoirs of the IJssel Lake and of the future 'Lake Zeeland' (both for the major part to be fed with increasingly polluted Rhine water) on the availability of water during summer is going beyond the scope of this chapter.

GROUNDWATER FLOW

From the situation described above, it is clear that a great deal of crop growth in the Netherlands is influenced by groundwater and it is therefore not surprising that much research has been done on groundwater flow. This research does not only deal with agricultural drainage but perhaps even more with general groundwater flow problems.

Theories on groundwater flow mostly originate from civil engineering science and are based on rather simple physical laws. Their practical application is, however, rather difficult due to the complicated boundary conditions and the wide variety of hydrological properties occurring in nature. Apart from this, introduction of the theories of groundwater hydrology into agriculture is made more difficult by the fact that, generally speaking, agriculturists are not familiar with the necessary mathematics.

Agriculture in the Netherlands has in this regard the advantage that the study leading to the master of science degree of agricultural engineer in land and water management, is rather heavily oriented in a mathematical direction, and that in the solving of practical problems in this field there is always a close co-operation between civil and agricultural engineers.

Despite the complications met in practice, research in the past 10 to 15 years did not only lead to a variety of solutions for various problems, but also to their practical application. This was partly caused by the fact that in various solutions use could be made of hydrological constants determined by means of rather simple field measurements of piezometric pressures. In addition to this, new techniques made it possible to collect undisturbed samples from deep borings and to measure their water transmitting capacity in the laboratory.

An example of the use of simple measuring techniques is the analysis of the transmission of tidal waves in aquifers along open water. The theoretical solution of this problem is analoguous to the transmission of the daily temperature wave into the soil.

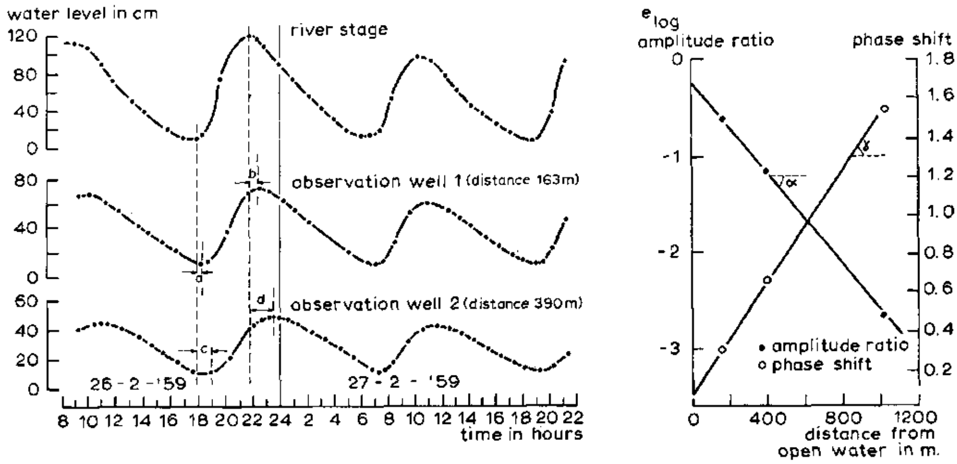


FIG. 6. *Left: observations of the stages of a tidal river and of two piezometric wells, showing the phase shifts a, b, c and d. Right: the relation between the amplitude ratio and the phase shift, with the distance from the tidal river*

The mathematical solution for groundwater flow was given by Steggewentz as early as 1933. In 1959 and 1962 at the Institute solutions were found which account for the elasticity of the aquifer. Despite the rather complicated equations there appeared to be a simple relation between the reduction in amplitude and the phase shift, and the hydrological constants. This offered the possibility to find the aquifer constants from simple piezometric observations. An example of such data is given in fig. 6.

By means of the developed theory it proved to be possible to reconstruct rather accurately piezometric heads at various distances from a river. The reproducing computations can be programmed on a digital computer. This is an important aspect when initial conditions must be known to determine for instance the source of the effects which have occurred after pumping for building purposes as the construction of dams or tunnels.

There are many other methods to determine hydrological constants. A well-known method to find the hydraulic conductivity of soils, at least for sandy material, is using the so-called Kozeny-type equations which rely on a certain relationship between grain size of the soil particles and soil permeability. The system is based on a texture analysis of the soil.

Another method uses a new apparatus to take undisturbed samples from deep borings. Special laboratory equipment, also developed in the Institute, offers the possibility to measure the hydraulic conductivity in both vertical and horizontal direction for a large number of samples simultaneously (fig. 7).

Table 1 gives the results of two laboratory methods, together with the transmissibility values obtained from pumping tests.

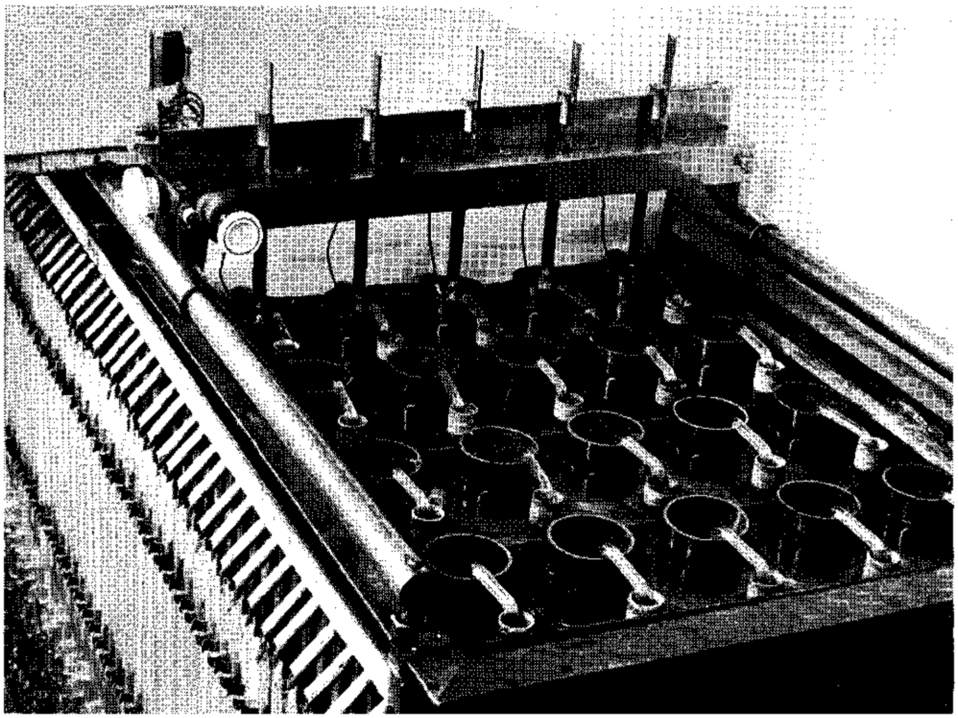


FIG. 7. *Apparatus to determine the vertical and horizontal hydraulic conductivity of undisturbed saturated soil samples*

Table 1. Transmissibility values for the upper aquifer of a polder in the south-western part of the Netherlands obtained by different methods

Boring No.	Pumping test	Texture analysis	Lab. measurement undist. samples
H_2	285	310	270
H_{32}	560	480	532
H_{24}	290	320	310

A new method not only to check solutions of theoretical flow, but also to compute flow intensities in soils, is a three dimensional statistical analysis of groundwater observations and rainfall data. The method needs observations over a long time and takes into account the distribution of rainfall and of discharge, the latter being dependent on the observed piezometric height, a storage effect of the soil, the evaporation and a non-steady state effect of groundwater flow.

The availability of many methods offers a possibility to check the results of one with the results from others. Such a comparison is given in table 2.

Table 2. Results of seepage computations for two polder areas in the south-western part of the Netherlands. Data im mm/day

Method	Polder area	
	Prunje	Oude Korendijk
1. Groundwater contour maps combined with transmissibilities from pumping tests	0.70–0.75	0.22
2. Transmission of tidal waves	1.5	1–0
3. Discharges and salt content of water discharged from pumping plants	0.95–1.3	0.20–0.24
4. Statistical analysis of groundwater observations	1.2	
5. Direct measurement of seepage into ditches and drains	0.7–1.0	0.28

FIELD DRAINAGE

One research which showed a very rapid development during the past 10 to 15 years is that in field drainage. Mathematical solutions for this problem were first developed by Hooghoudt (1936, 1940). The practical application of these solutions started after World War II when there was an increased demand for food and a necessity of reclaiming large inundated areas in the country. Since then, various new drainage formulas both for steady and non-steady state flow have been developed, but in practice it became common use to base the design of drainage schemes on simple drainage formulas, with the hydraulic conductivity determined by means of the augerhole method.

In 1955 the Netherlands Government ended subsidies on field drainage with the exception of drainage in reallocation areas. Still, about 20,000 ha per year are with private means provided with a subsurface drainage system.

Except for very small horticultural plots all tile drainage work is nowadays performed mechanically (fig. 8). This is a logical consequence of increasing wages. Since, however, the working speed could be greatly increased with such machines, this asked for new pipe material. In the Netherlands, the first experiments with plastic pipes were carried out in 1957 and within a few years this material was used for thirtyfive per cent of all drainage projects and this percentage has so remained.

Besides plastic pipe materials, new filter materials for drainage were introduced instead of the normally applied dry peat. Here the development also was towards rapid installation methods by using materials wrapped or folded around the pipes.

A good deal of the investigations of the Institute in this field has been concerned with the hydrological and hydraulic properties of pipes and filter materials. Plastic pipes prove to be economical only when having small diameters and wall thicknesses. For the normally used 4 and 5 cm pipes, a wall thickness of 0.8 and 1.0 mm respectively was found to give sufficient mechanical strength to the pipes, provided that the perforations are correctly made. The amount of perforations is again related with the

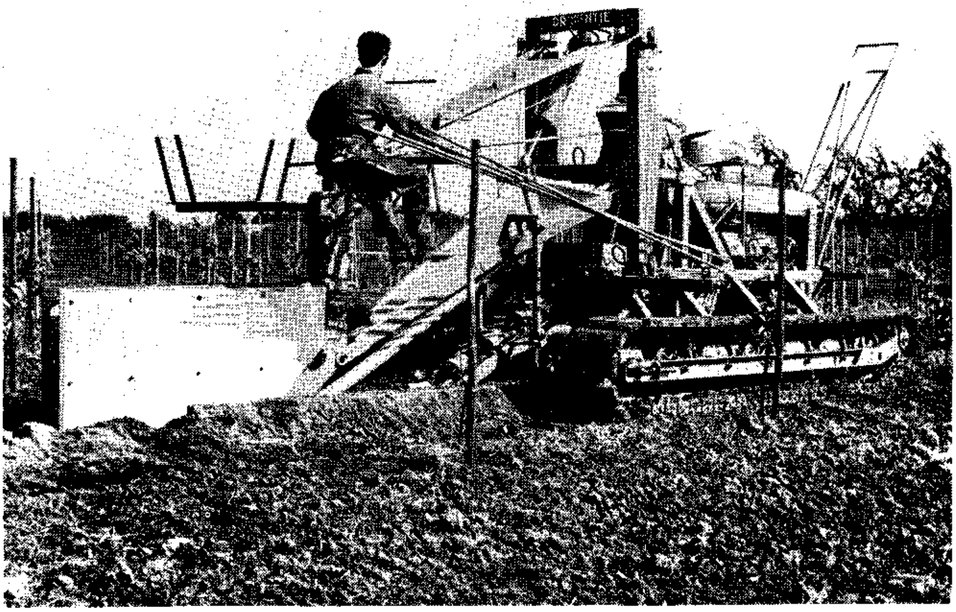


FIG. 8. *Modern drainage machine*

diameter since the perforations influence the entrance resistance for water. Experiments in model tanks (fig. 9) proved that the most important factor on which this depends is, however, the filter material. A thin filter like glassfibre may be very efficient to prevent the pipe from silting up, but from a hydrological point of view it does not form a sufficiently thick permeable layer around the pipe Particularly in soils with a non-stable structure (loamy sand, sandy loam or peat) a thicker filter is required and the originally widely used glassfibre filter now has been superseded almost completely by thicker blankets of peat or flax-straw which proved to be much more effective.

Since only small diameter pipes are used in the Netherlands the flow resistance in the pipes is of importance. Hydraulic experiments resulted into new formulas for the flow resistance in pipes, with which the area that can be drained with a given pipe diameter can be calculated.

Further research in field drainage will be done, although the criteria presently applied for the design are sufficient to prevent the occurrence of high groundwater levels during a long period in the growing season, provided of course that the system remains in good working order. At the moment special attention is given to checking in the field the hydrological resistances found in the laboratory.

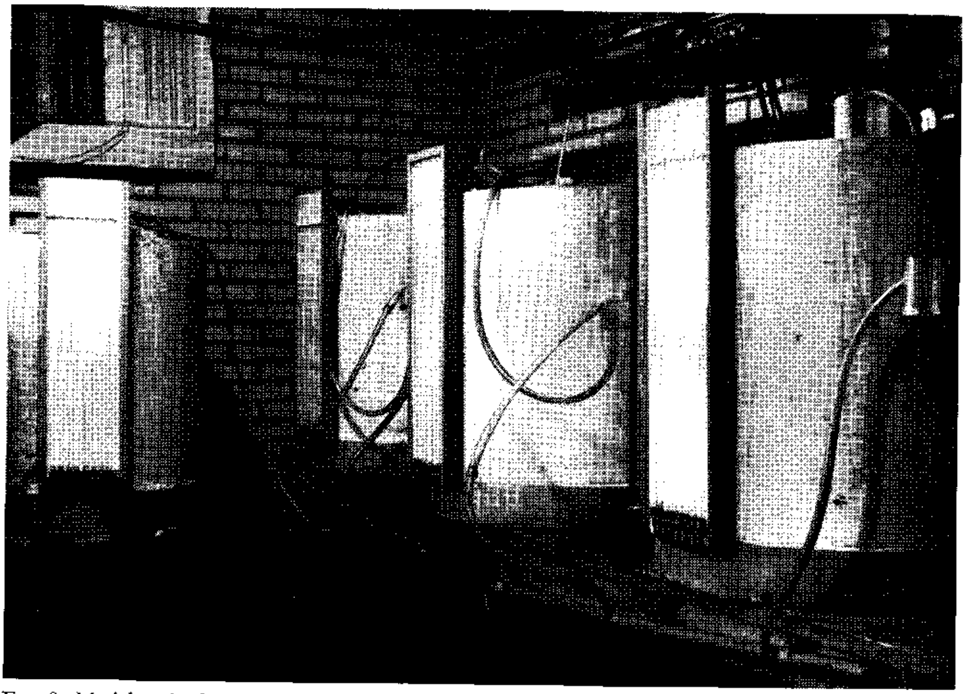


FIG. 9. *Model tanks for the determination of the hydrological properties of drainage materials*

WATER AND AIR IN THE UNSATURATED ZONE

The available non-steady state solutions of the drainage flow problem offer the possibility to compute not only the discharge but also the depth of the water table for any given drainage system. Despite this fact only the less correct steady state solutions are used for design purposes. The reason for this is, that the effect of the water table depth on crop yield is not exactly known. Fig. 10 gives the relation between mean yield depression and mean depth of the water table for seven groups of soil types, taken from the countrywide survey which the then existing COLN (Commission on Agricultural Water Management Research of the Netherlands) carried out in the years 1952 to 1955. Particularly the curves for the lighter soils have a clearly defined maximum. To the left of this maximum the yield depressions must be ascribed to an excess of water and therefore to a lack of aeration of the soil. The yield depressions at greater depths of the water table must be ascribed to a water shortage in the root zone. Since climatological conditions (rainfall and evaporation) change from year to year, it is clear that the optimum water table depth will not be exactly the same each year.

During the past ten years a good deal of the water management research has occupied itself with the reaction of the crop on the depth of the groundwater table and therefore with the reaction of the crop on the availability of water in the root zone. The progress made in this field of research was mainly due to an increase in knowledge of the physical properties of soils.

Starting with the wetter left side of the curves of fig. 10, research has been carried out on the exchange of air in the soil. This phenomenon can be described by rather simple diffusion equations, known from other branches of physics. The solution of such equations is rather complicated, however, since the diffusion coefficient depends on the moisture content of the soil.

Generally this moisture content will change with time and depth. Moreover, the activity – i.e. the uptake of oxygen and the production of carbondioxide – is not only a function of the depth of the rooted profile, but will change with temperature, fertility of the soil, etc. Choosing certain functions for diffusion coefficient and activity offers the possibility of obtaining solutions for a steady state diffusion process. Although still complicated, these solutions can be handled when use is made of digital computers. The interpretation of the results, expressed in either oxygen or carbondioxide concentrations in the soil, remains difficult since it is not exactly known what the effect of certain concentrations is on the final crop production.

Results of groundwater experimental fields did learn that an important share of the air in the soil is required for the mobilization of nitrogen and not directly for root growth. Present research is directed towards the development of simple methods to determine the diffusion coefficient of soils and to measure the real activity in the soil.

UNSATURATED FLOW

For the explanation of the 'dry' (right) part of the curves of fig. 10, the most important aspects are the water holding capacity of the soil and the possibilities for transport in the unsaturated zone of water coming from the groundwater. Regular

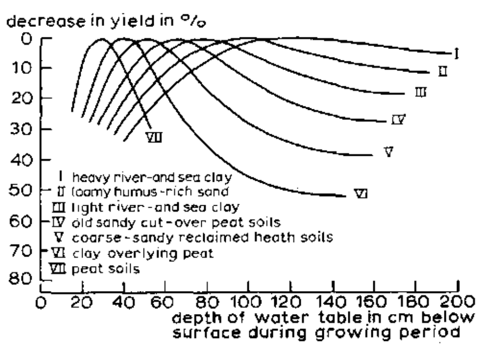


FIG. 10. *The effect of groundwater table depth on crop yield for seven groups of soil types in the Netherlands*

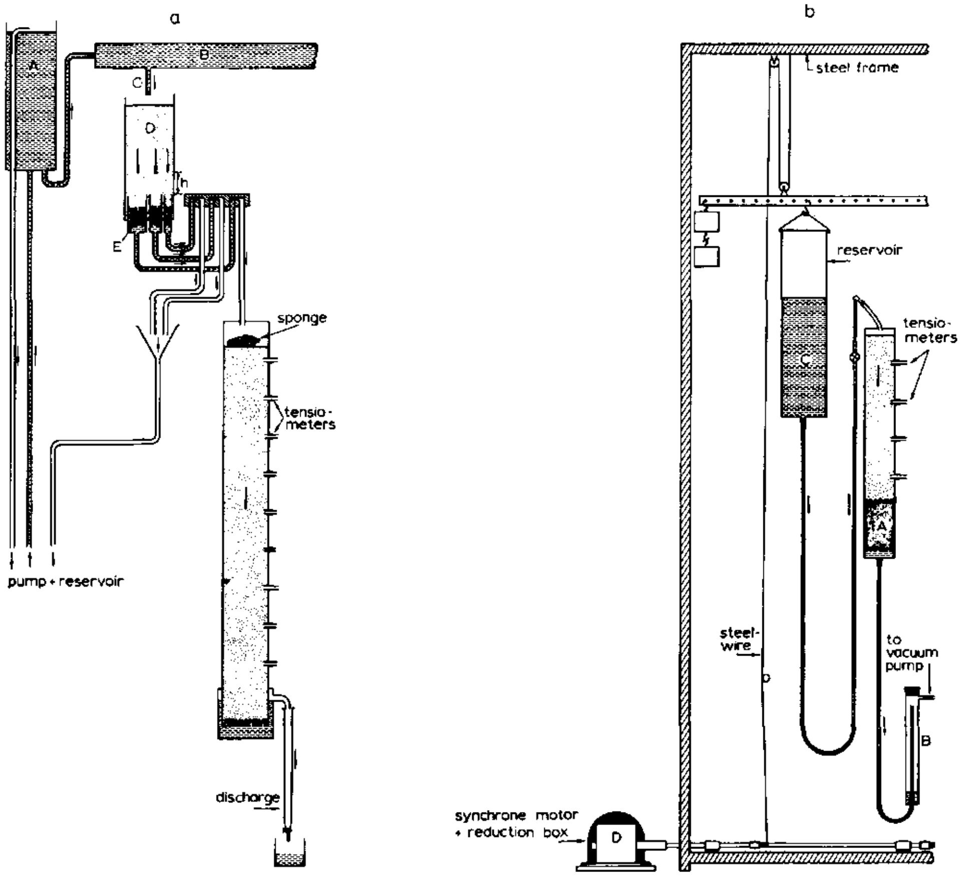


FIG. 11. *Two types of laboratory equipment for the determination of capillary conductivity in undisturbed unsaturated soil collumns*

determinations of the soil moisture content do not only give a good insight in the availability of moisture but also in the energy state of the water. Besides this, an insight in the magnitude of the unsaturated conductivity is required. For this purpose a laboratory apparatus has been developed (fig. 11), which makes it possible to determine the capillary conductivity of undisturbed soil cores with a length of 0.5 to 1.0 meter.

Knowledge of the capillary conductivity offers the possibility to compute the energy state of the soil moisture under various conditions of water table depths and evaporation rates. A relation between energy state and crop production is then needed. To determine this, monolyth lysimeters, in combination with neutron-scattering and gamma-ray methods of soil moisture measurement, have been put into use (fig. 12).

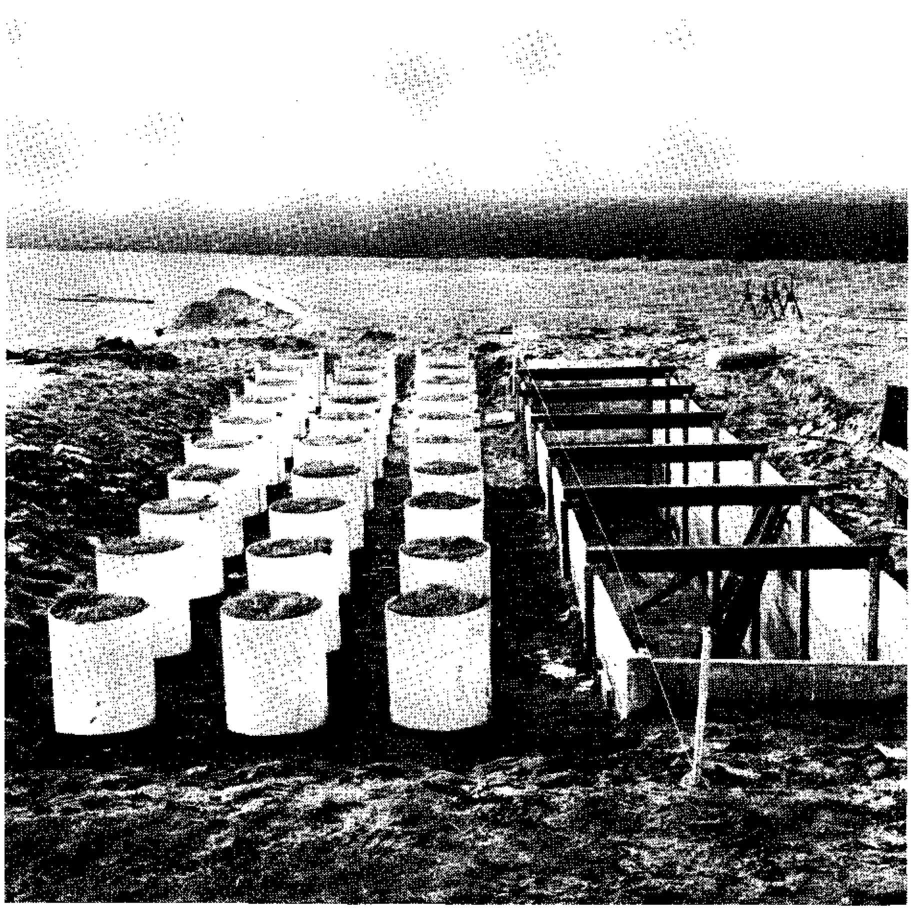


FIG. 12. *Installing monolyth lysimeters (diameter 50 cm, length 120 cm) containing various undisturbed soils taken elsewhere*

POLDERS AND CATCHMENT AREAS

For the drainage of larger regions, apart from the height of the water table and the discharge capacity of the drainage system, the storage capacity both in the soil and in the open water system, and, when present, the capacity of the pumping plant, are of importance. In the Netherlands pumping plants normally are designed with a capacity of 10 to 12 mm/day or 1.2 to 1.4 l/sec. ha, depending on area, type of plant, lift and type of engine used. For ditches and brooks the same capacities are applied, depending on topography, vegetation, slope of the terrain, etc.

Frequency analyses of actual discharges have shown that the used design discharge generally equals the maximum real discharge occurring once in a winter period. For discharges that occur once in 10 years one has then to expect 1.5 times the design discharge. Discharges occurring with a frequency of once per 100 years will be about twice as high as the ones to be expected once a year. The freeboard, required to maintain a certain depth of groundwater table for crop growth, should at the same time prevent flooding. The design of the system is therefore based on a given discharge and corresponding freeboard, just as is the case for subsurface drainage where the drainage criterion depends on discharge and drainage depth. Research should therefore occupy itself not only with the depth of the water table necessary for good crop growth, but also with the occurring discharges in relation to the properties of the catchment area. The often necessary routing of water through a system of open channels is one of the things that can complicate matters.

Correlative methods made it possible to predict the maximum discharge intensity of various parts of a large catchment area from a small number of simultaneous discharge or stage measurements.

The hydraulic flow resistance of open channels and the factors influencing it are of importance not only for the reproduction of discharges from stage discharge curves, but also to know the variations in flow capacity that will occur. Weed growth can considerably reduce the capacity of a channel, as is shown by fig. 13, where the conductivity of the channel (expressed in the Manning-coefficient) drops as soon as weed growth starts. To keep the channel up to its design capacity frequent cleaning is necessary. From an economic point of view not only the investment for construction of the conduits have to be taken into account, but also the yearly maintenance costs. Whereas small conduits have to be cleaned more often than large ones, the latter

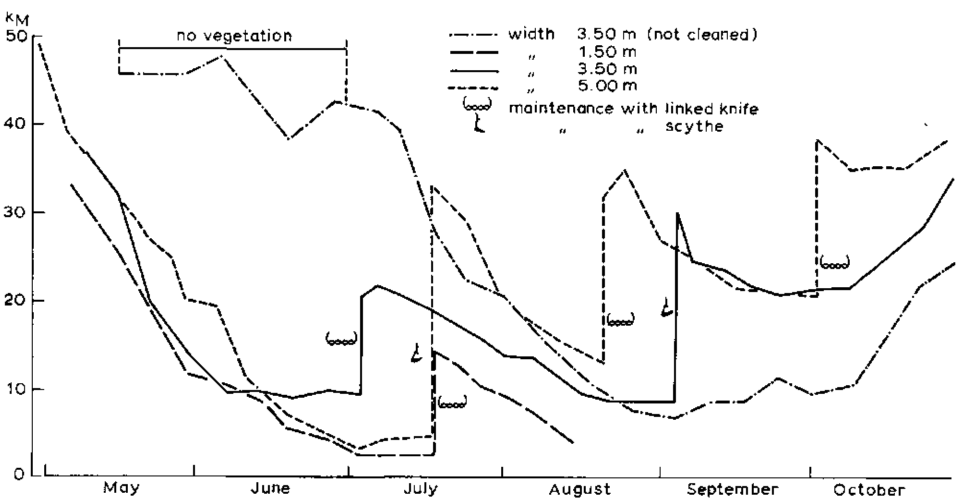


FIG. 13. *Changes in the Manning-coefficient during the growing season in some water courses*

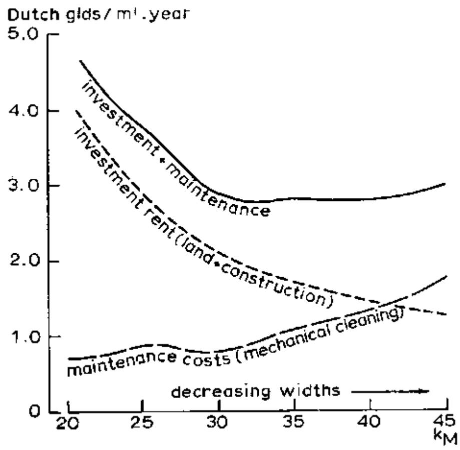


FIG. 14. *Yearly cost level of an open water course with a drainage capacity of 1 m³/sec in relation with the choice in Manning-coefficient*

require higher investments. There is therefore a direct relation of the investment and the maintenance cost with the Manning-coefficient (fig 14), from which the optimum choice of it, to be used in the design, can be derived.

A factor to be taken into account when planning drainage of agricultural land in the higher, sloping catchment areas in the eastern part of the country is, that in these regions water of good quality can be extracted from the soil for domestic and industrial purposes. With a rapidly expanding demand, the danger of overpumping, resulting in a lowering of the groundwater table, is quite near and water conservation measures should be built into the design.

As regards the still remaining damages originating from periods with high water tables or temporary flooding, these depend highly on the flexibility of farm management. Farms with for example both low and high lying sites have a possibility to prevent at least part of these damages by a change in farm management.

FUTURE DEVELOPMENTS

Modern agriculture asks for well-drained large fields. Subsurface drainage systems will therefore be needed in a great deal of farm lands. Since installation by mechanical means is the only economical possibility, the research of new materials both for pipes as for filters suited for mechanical installation must be promoted.

The knowledge of groundwater flow will have to be applied to determine the effect of water management measures in larger regions. A further development of model tests and analogues may be expected. Further research in this field will be directed to a better overall view and to the interpretation of the interrelationship between energy state of soil moisture and crop growth. A better insight into the properties and laws governing the movement of water and its effect on plant environment will open the way to change the problem of drainage from a measure to remove excess water from the soil to complete water control. Drainage of catchment areas in the eastern part of the country soon will be no longer a problem of brook regulation or enlargement of the capacity of the drainage system, but will become a rather complicated system of withdrawal and supply of water dependent on both time of the year and topographical conditions.

Water for agricultural use

J. F. BIERHUIZEN

QUALITY

In the Netherlands the main sources of water supply for agricultural purposes are rainfall, surface water and groundwater. The average rainfall in the Netherlands is 700 mm per year or in total 25×10^9 m^3 of water. The inflow of the two main rivers, the river Rhine and the river Meuse is 70 respectively 8 times 10^9 m^3 per year. Approximately 30% of the incoming river water goes to the groundwater in the subsoil of the Netherlands. It is evident that the contamination of our largest source of fresh water, the river Rhine, is of special importance in the general hydrology of the Netherlands.

In the western part of the Netherlands the groundwater, particularly in the somewhat deeper layers, is too salt, because of seepage of sea water towards the polders below sea level. In this area, apart from rainfall, surface water is the most important source of water supply either for sprinkling or sub-irrigation purposes. In the latter case a relative shallow layer of fresh water is kept above the deeper saline groundwater. In the dunes, the fresh water layer is much thicker and used mainly for industrial and domestic purposes. As this consumptive use increases, upstreams Rhine water is pumped into the dunes to recharge the storage. Horticultural holdings along these dunes, howewer, often use the groundwater directly.

In the eastern part, groundwater supply is the most important source, and it is fresh to a great depth. Quality problems in this area are of minor importance except in cases where the iron content is too high. Sprinkling irrigation then will damage the leaves and will lower the quality of fruits. At the Institute a simple and relatively cheap device has been developed to reduce the iron content of sprinkling water.

Contamination with inorganic material of surface water in the western part of the Netherlands has increased heavily during the last twenty years. The Rhine, being the main source for flushing the water course systems in the polders, did show an increase in chloride concentration of 10 to 60 mg/l from 1875 till 1915. The concentration remained relative constant for some time, but showed after the Second World War a steep rise to 150 mg/l due to the explosive increase of industry in France and Germany. Moreover, the salt intrusion did increase by the rise in shipping. Our own salt water sources are mainly the sluices of the North Sea Canal near Amsterdam, the open harbour near Rotterdam and, to some extent, artificial wells in the coastal area. Local industry also produces an additional amount of salt. Rainfall in the last few years has been well above average, but in dry years the salinity effect is, particularly in horticulture, outspoken yield decreasing.

It is therefore clear that at the Institute experiments on plant growth in relation to salinity are carried out. Studies of salt balances of polders and researches in flushing and network planning are made, often in co-operation with local waterboards, county water authorities and the Ministry of Traffic and Waterways.

In literature, a vast amount of experience is already available on plant growth – salinity relations, mainly based on the total salt concentration. In the Netherlands, however, the chloride anion is a particular important component in the irrigation water. In the Rhine the ratio of chloride to total salts is approximately 1 to 3.5. Due to seepage of seawater, this ratio shifts in the coastal areas to 1 to 2.0 with increasing total salt concentrations. Experiments with saline irrigation water are therefore based on mixtures of Rhine and seawater, in such a way that the final composition at each concentration closely resembles that of the surface waters in our polders.

In order to establish the relation between a gift of saline irrigation water and the increase of salts in the soil solution at field capacity certain parameters have to be known, such as total water use, the amount of rainfall relative to the amount of the additional water supply, the salt concentration and the total amount of water available at field capacity, which depends on soil type, rooting depth and the amount of leaching. From such data a salt balance can be made and the average salt concentration of the soil solution at field capacity during a certain growing period can then be calculated.

Taken over the year, the surplus of rainfall during the winter period (approximately 200 mm) is sufficient to leach the salts that accumulated in the preceding period. For most agricultural crops and for some horticultural crops grown in the open, no dangerous salinity problems will arise, since often the level of salt tolerance is high and the increase in salt in the soil solution at field capacity is low. In bulb growing (tulips for example) saline hazards are to be expected because the shallow rooting depth makes a more frequent additional water supply necessary. Moreover, in the sandy type soils used for this purpose the increase in soil salinity is much more rapid. Calculations have shown that then irrigation water with a concentration not exceeding 400 mg Cl/l should be available.

In glasshouse cultures saline hazards are greater, since there is no rainfall nor is rainwater applied via storage tanks. The marketable yearly value of lettuce, cucumbers and tomatoes is approximately 80, 100 and 230 million Dutch guilders respectively, yielding approximately 90% of the total vegetable glasshouse production in the Netherlands. In our research the yield response versus soil salinity was established for these crops and the results were compared with data available in literature.

Usually, the soil in glasshouses is leached with 100 to 200 mm of water in September or October. Then, mainly lettuce is grown during the winter period, with a total water use of 50 to 100 mm. Although lettuce is rather salt sensitive, salinity effects need not be expected since the increase of salts in the soil is small. Moreover, salinity effects depend to a large extent on the rate of growth. At the low light intensity levels existing in the winter period, the growth rate is small. This means that lettuce is much more salt tolerant in winter than in summer.

In fig. 15, the effect of chloride concentration of the soil solution at field capacity

Erratum

page 46: change figs. 15 and 16, keeping captions at their present place

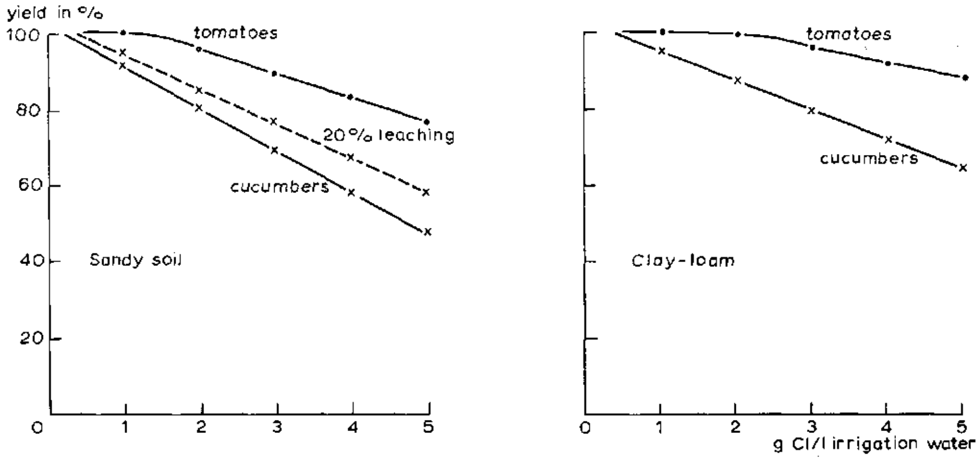


FIG. 15. *Effect of the salinity of the solution in soils at fieldcapacity on the yield of tomatoesand cucumbers*

is represented versus yield of cucumbers and tomatoes as a percentage of the control. It is evident that the yield decreases linearly with an increase in chloride concentration, tomatoes being more tolerant than cucumbers. Taking into consideration total water use, water availability and leaching, the yield depressions that will occur when irrigating with water of different chloride concentrations could be calculated (fig. 16). In this way, it could be established that the surface water in the 'Westland' glasshouse district, between The Hague, Rotterdam and Hook of Holland, should not exceed 200 mg Cl/l. Such water should be available in other glasshouse regions as well, as also in those areas which might develop in this direction.

Flowers usually are less tolerant than cucumbers, whereas the increase of salts might be more rapid due to the small rooting depth especially in potcultures. An

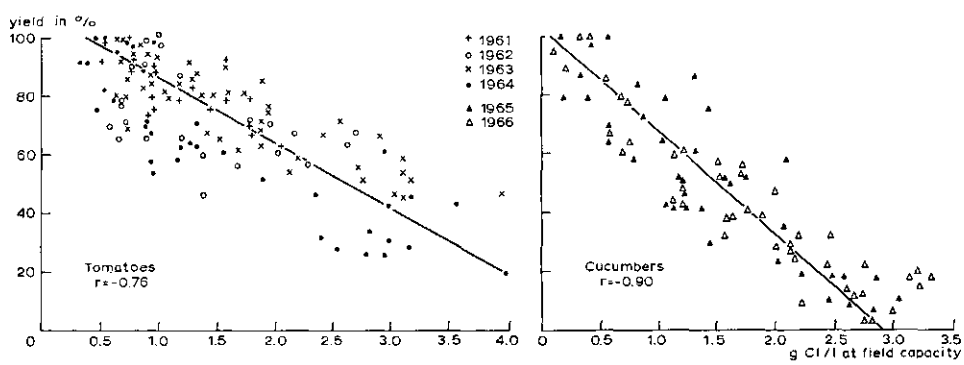


FIG. 16. *Effect of Cl-content in the irrigation water on the yield of tomatoes and cucumbers grown in a sandy soil and in a clay-loam*

upper limit of less than 200 mg Cl/l should therefore not be exceeded in floriculture.

Although progress has been made in the preceding years regarding the evaluation of the effect of saline water on plant growth, various problems remain to be solved. Studies are continued on subjects such as the leaching requirements of different soil types and the effect of sulphates, carbonates, chlorides and total salt on plant growth. All this seen in the larger framework of the hydrology of the western part of the Netherlands.

It should be mentioned here, that various means of decreasing the salt input into the Netherlands will be carried out in the near future. A decrease in chloride content of the Rhine is discussed on an international level. Evacuation of salt water in sluices by means of pumping devices are planned, as also the use of air bubble screens. Studies are made to make a deepening of the open harbours possible without increasing salt infiltration. The IJssel Lake and the future 'Lake Zeeland' will be important sources of fresh water supply when in the near future the demand is expected to rise sharply.

For agricultural purposes the quantity and quality of water will remain essential parameters for the attainable yield, their relative importance will depend on the area under study. The general results of research carried out in these fields will have a much wider application, however, even in completely different climatological regions.

QUANTITY

From evapotranspiration data and rainfall distribution, the frequency of water shortage or water surplus can be determined for any period. In case its effect on plant growth is known as well, cost–benefit calculations can be made of technical devices such as water supply or drainage systems, calculations needed to evaluate land consolidation plans.

On weighable lysimeters, the evapotranspiration of grass (in which lies approximately 30% of the total area of the Netherlands) has been studied for different soil types and groundwater levels. The rate of evapotranspiration could be obtained from a water balance equation when knowing the change in weight and the amount of rainfall, of drainage and of infiltration in 3-day intervals. Soil moisture was also regularly measured, so the transport of water below and within the root zone could be calculated as well. From a combined energy balance and vapour transport approach, meteorological data could be fitted in an evapotranspiration formula, taking into account also plant parameters such as roughness of the canopy, stomatal opening and root distribution, and soil characteristics such as unsaturated conductivity in relation to soil moisture content. The general application of such a formula is shown in fig. 17, where calculated and actual evapotranspiration of alfalfa in the Medjerda valley in Tunisia is plotted versus each other. Experiments for other crops are in progress, particularly to obtain data on roughness, stomates, root distribution and leaf-water potential in relation to climate and soil moisture conditions. As well weighable as non-weighable lysimeters with fluctuating groundwater levels, in which the soil moisture

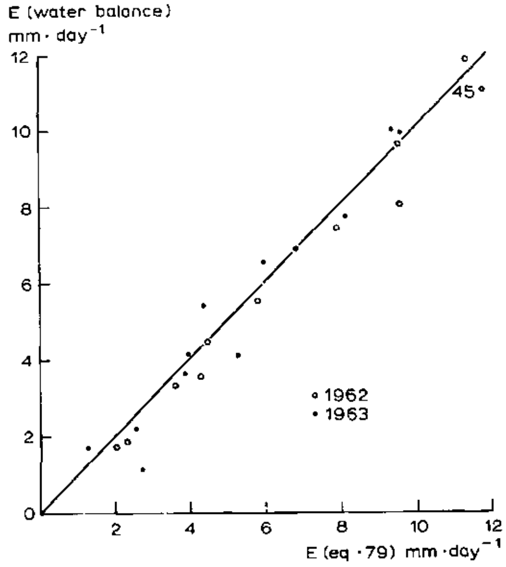


FIG. 17. *Relation between the measured potential evapotranspiration from alfalfa and the values calculated with an evapotranspiration formula (equation 79) for the climatological conditions in Tunisia*

profile is measured by means of neutron or gamma-ray equipment, are used for this purpose.

Rainfall intensity and distribution have been analyzed in relation to storage capacity for small but also for larger areas. From these results frequencies of as well water surplus as water shortage could be calculated, taking into account the evapotranspiration.

The effect of a water surplus on plant growth has been studied by means of inundation, high groundwater tables and varying mixtures of oxygen, carbondioxide and nitrogen in the air of the soil. In cases of high rainfall intensity and low water storage capacity, it is important to know the length of the inundation period which causes no decrease in growth. It is evident that in those areas where constant groundwater tables can be maintained, optimum levels for different soil types can be established. A too high groundwater level may lead to inundation and a too low level to water shortage. A high water table can, as has been shown in another chapter in this publication, often be compensated by increased nitrogen fertilization.

Grass is relatively insensitive towards inundation, although the oxygen content falls towards zero within one day. Vegetables such as lettuce, beans and tomatoes show a much higher sensitivity, whereas endive is more comparable with grass (fig. 18).

The number of days that plants can withstand inundation depends, apart from crop tolerance, also on the depth of inundation, the growth rate and the fertility status of the soil. At conditions of high light intensity and high temperature, resulting in a rapid growth, the effect of inundation is more pronounced. It is in this respect important not only to establish threshold values at which growth reduction does not occur but also those limits which lead to irriversible damage.

Experiments in which the soil was continuously flushed with predetermined mixtures of N_2, CO_2 and O_2 have been carried out as well, and the effect on transpiration and plant growth was studied. Values of oxygen content limiting to plant growth shift to higher ones when the carbon-dioxide content increases. Concentration measurements and diffusion measurements are made in soil columns in order to obtain a more complete picture of drainage requirements.

Studies on the effect of water shortage on growth and yield of agricultural and horticultural crops have been performed on an experimental farm as well as in pot experiments in glasshouses. The amount of water available between field capacity and wilting point could be obtained from soil moisture retention curves determined in the laboratory. The total amount available for the plant depends on rooting depth and capillary transport from below the root zone. In the experiments four moisture regimes in the range of 0 to 25, 0 to 50, 0 to 75 and 0 to 100% of the total amount of available water were usually used. In this way, moisture limits below which decreases in yield occur could be established. The limits depended on climatic conditions, the tolerance of the crop and on whether dry or fresh products are to be marketed.

Often a linear relation between total water use and yield, and between evapo-

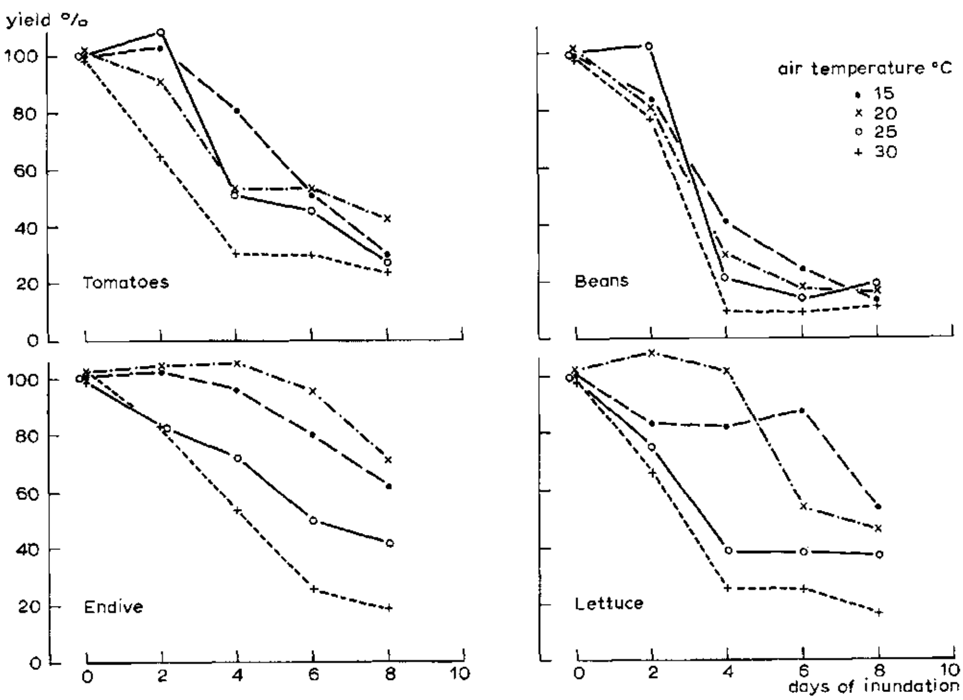


FIG. 18. *Effect of the length of inundation on the yield of various crops at different air temperatures*

transpiration deficit and yield increase, was obtained. Calculations of deficits in 10-day intervals were summated from March till the end of the growing period. After the winter rains, the soil was in March assumed to be at field capacity. The line through the deficits intersects the ordinate some distance from the origin, this indicating the amount of available soil moisture, which of course depends on soil type. From such data, the cost and benefits of water supply can be calculated as well as the total amount of water supply necessary for a certain area. For areas where the topography is relatively flat, economic evaluations have been made of water supply, via sprinkling versus sub-irrigation through the drainage system.

The transport of water in the liquid and in the vapour state through the plant in relation to carbondioxide uptake has been studied. Fluxes and gradients were measured and resistances calculated. The resistance of the boundary layer in relation to stomatal and mesophyll resistance and its consequences for growth were determined, as also the effect of external factors on transpiration-production ratios. Apart from experiments with agricultural and horticultural crops grown in the Netherlands, experiments with tropicals such as cotton and coffee were made. For such studies a conditioned glasshouse is available, with four compartments in each of which the air temperature, humidity and CO_2-content can be regulated separately. In the future, in four cells in our new building, also the light intensity can be controlled with the aid of daylight tubes and high mercury vapour lamps.

Apart from research on water surplus and shortage and other specific plant-water relations, water management in relation to horticultural requirements in certain regions is studied.

In the glasshouse district 'Westland', the percentage of glasscover is extremely high, approximately 80%. The surface runoff during rain is large, which means that to prevent flooding, the storage capacity of the open water system of the polder in which it is situated has to be sufficiently large. Calculations have been made of the relation between frequency of rainfall intensity, percentage of glasscover, open water storage capacity and rise of the water level in the canals. The results are of importance for the calculation of the necessary pumping capacity, to design in- and outlet devices and also for the planning of supply and discharge systems in future glasshouse areas.

The usability of arable soil for glasshouses and soil improvement measures as the application of organic matter and particular cultivation methods have been studied. Since the cultivation methods in a glasshouse are in many respects different from those in the open, special growth and evapotranspiration studies under practical circumstances are made in close co-operation with the Experimental Station for Glasshouse Crops in the 'Westland' at Naaldwijk.

Problems in bulb cultivation in winter are different from those in summer. Lack of aeration, frost damage, bad structure of the topsoil and a high groundwater table are threats during winter. In summer, however, water shortage may occur. Due to the relatively shallow rooting of bulbs and their sensitivity with regard to soil moisture, the range of optimum soil moisture conditions is small. When bad soil structures prevail, a water shortage has been observed only a few days after conditions of water surplus. At present a constant water table of approximately 60 cm below surface is maintained. Research is carried out to see if a deeper groundwater table, which will increase the storage capacity of the soil, and a more frequent artificial water supply by means of sprinkling is more efficient. In bulb growing a rapid evaluation of unfavourable wheather conditions is important, because the main productive period for new bulbs occurs, after the flowering, from May till June. Unfavourable moisture conditions can lead to an earlier yellowing of the leaves which is an irreversible process and reduces the production to a large extent. Research on bulb crops is carried out in close co-operation with the Bulb Research Laboratory at Lisse, near the dunes along the coast.

Extensive cultivation of vegetables grown in the open is practiced in the northwest of the Netherlands, where various land consolidation projects have to be carried out. Optimum groundwater levels have been established for various vegetables grown in different soil types. Studies with lysimeters are continued, to obtain a more detailed information on water transport through the soil via the plant into the atmosphere, in relation to various soil types. This research is carried out in co-operation with the Horticultural Experimental Station at Alkmaar, North of Amsterdam.

Soil improvement

G. P. WIND

INTRODUCTION

Dutch farmers have seldom been content with the natural condition of their soils. Nearly every soil needs artificial drainage by ditches or tiles and many of them by pumping stations as well. Therefore the farmers, used to control this drainage aspect, since long have tried to control other soil conditions too. Many sandy soils had a poor fertility, which they improved with fairly large amounts of heath sods and manure.

In low lying areas ditches were made very wide in order to get material with which the remaining land could be raised sufficiently above the water table. Nowadays, these ditches as wide as canals have to be filled again to get parcels of a reasonable size.

Many other forms of soil improvement have been practiced since long, as bringing a sand or clay cover on peat soils to increase bearing capacity and fertility, digging-off sandy soils to decrease drought risks, loosening of soils and levelling of land, and so on. In the Netherlands such kinds of works are called soil improvement works. In general soil improvement is defined here as an investment which aims at a lasting increase of soil productivity by alteration of the soil itself.

Such improvements were formerly only based on empirical knowledge. This was possible as for a very long time the mutual relations between the prices of labour, land and agricultural products remained unchanged and fertilizers were not known. So empirical knowledge could be collected and remained valid.

When the application of fertilizers became common practice, increasing chemical soil fertility was not a problem of soil improvement any more. After the Second World War the wages showed a sharp increase as compared with those of agricultural products. The former handwork changed to work for bulldozers and draglines. But the empirical knowledge remained the same as it could not rapidly enough follow the developments in prices and mechanization. In the years around 1950 heavy machinery did the same work as the unemployed did in relief works between 1930 and 1940, even the same degree of perfection was pursued. It was then understood that empirical knowledge alone is not sufficient in a period of rapidly changing economic and technical conditions and that it can even cause big mistakes. The only solution was to start with research in this field. When our Institute was founded in 1955, a department of soil improvement research was therefore included.

ROOTABILITY

In our climate the mean difference between evapotranspiration and rainfall in the growing season is for grains about 150 mm. For sugar beets and potatoes this is about the same, although with a larger scatter of the actual values. So a good agricultural soil has to be able to supply at least 150 mm of moisture. A part of this moisture can be furnished by the unrooted subsoil by means of capillary rise. This part is the greater the more moisture is present in the subsoil and it is directly influenced by the height of the groundwater table. Table 3 gives an example of the distribution of available moisture in top and subsoil of clay-cover soils with different groundwater depths

Table 3. Amounts of available and accessible moisture (in mm) in root zone and subsoil in two clay-cover soils for different depths of the groundwater table at the beginning of the growing season

Clay cover (cm)	30				50			
Depth groundwater (cm below surface)	60	90	120	150	60	90	120	150
Moisture in root zone	69	63	60	60	120	108	102	100
Moisture in subsoil	84	74	37	23	86	81	62	32
Total accessible moisture	153	137	97	83	206	189	164	132

Formerly, with shallow drainage, the poorest soil (30 cm clay cover) was able to provide 153 mm of moisture. Nowadays there is less moisture as the drainage depth was increased. The richer soil (50 cm clay cover) possesses enough available moisture even when the drainage depth is 120 cm. So only the poorer soil needs improvement of its water holding capacity. This improvement can be attained by loosening the sandy subsoil, that on account of its density cannot be penetrated by roots. If one does succeed in deepening the root system there are two effects. In the first place the amount of available moisture increases with the amount present in the newly opened layers. Since they consist of sand, this amount is only 0.5 to 1.0 mm of water per cm of soil. The second effect is that the roots come closer to the groundwater; which means that they come nearer to layers rich in moisture. Therefore the amount of accessible moisture in the non-rooted undisturbed subsoil increases too.

So, generally speaking, by increasing the rooting depth one can compensate for the loss of available moisture which is often caused by economic and natural changes in agricultural use of the soil. Up to now, three kinds of impediments have been found which limit an efficient rooting depth.

Most plant roots can exert a force of penetration between 15 and 20 kg/cm². Most sandy soils without organic matter have a penetration resistance of more than 20 kg/cm², which can be read with a penetrometer. It was found that plant roots did not penetrate into sands with less than 40% pores. This porosity limit for root growth is accompanied by the 15 to 20 kg/cm² penetration resistance limit.

Loosening the soil provides no solution, however, when the original sandy layers are too dense for root penetration. After a short time, after one year or even within that period, the root limiting density returns. There are some exceptions: in experimental drums a soil can be kept loose for years and in dry sand dunes loosening measures appeared to last several years.

The pressure of heavy agricultural machinery hardly ever exceeds 1 kg/cm². It is scarcely to be expected that these pressures can cause compaction to such a degree that the penetration resistance becomes 20 kg/cm² and more. The penetration resistance of the top layer of meadows trodden by cattle with a 4 kg/cm² hoof-pressure exceeds this value only when the soil is very dry. We observed, however, that vibration is a very strong compacting agent which acts to an appreciable depth (see fig. 19). Caterpillar tractors transmit motor vibrations better to the soil than tractors with rubber tire wheels; although the soil pressure of a track is much smaller than that of a tractor tire, the compacting action of the former is much greater.

The resistance of sand against compaction by vibrations is fairly great for medium moisture contents, which is possibly due to capillary forces. If these are lacking, as in very wet and in very dry conditions, a very high density will come into being even without vibrations and pressure, simply by the soils own weight.

So loosening a sandy soil alone is not sufficient to get a lasting better rootability. The low density has to be stabilized. This can be done by mixing the sand with peat, clay or humous layers. This restricts the improvement possibilities to places where such materials are present.

Loosening and mixing occur on sandy subsoils with a clay cover (clay-cover soils)

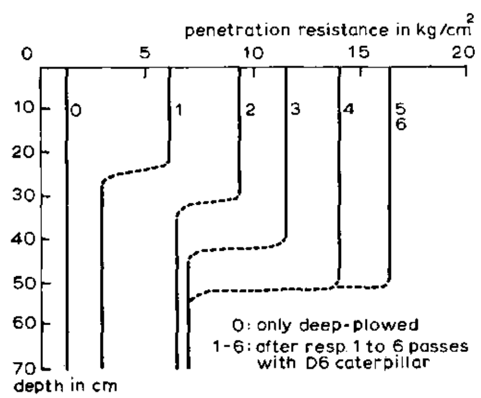


FIG. 19. *The penetration resistance and the depth of compaction of a loose soil is strongly dependent on the number of passes with a caterpillar*

or with a top layer of peat (peat-colony soils). The tools can be plows, mixing rooters or rotary-mixers. Most of these can work to a depth of about 110 cm; the biggest plow reaches to 220 cm depth.

CHEMICAL IMPEDIMENTS

In about 100,000 ha of 'peat-colony' soils (cut-over high moor peat soils) the rooting depth is limited by the high acidity of the moss peat. In field and pot experiments (fig. 20) a very sharp pH-limit appeared to exist. In layers with a pH-KCl below 3.4 not any root of wheat and oats was found. Above pH-KCl 3.6 the rooting density was high and independent of the acidity.

The pH of the moss peat below the sandy top soil in the 'peat-colonies' varies between 2.7 and 3.7, so it is mostly below the rooting limit. As the topsoil (with pH about 5.0) has a depth of not more than 20 cm, the rooting depth is very shallow. A large part of the moisture used by the crop has to be supplied by capillary rise from the non-rooted peat and the underlying sand. Capillary flow has only sufficient velocity if the moisture content of the soil is rather high. Formerly this was attained by a rather shallow drainage. Nowadays mechanized agriculture needs deep drainage, so there is not enough accessible moisture for the crop, although the peat contains a very high amount of moisture.

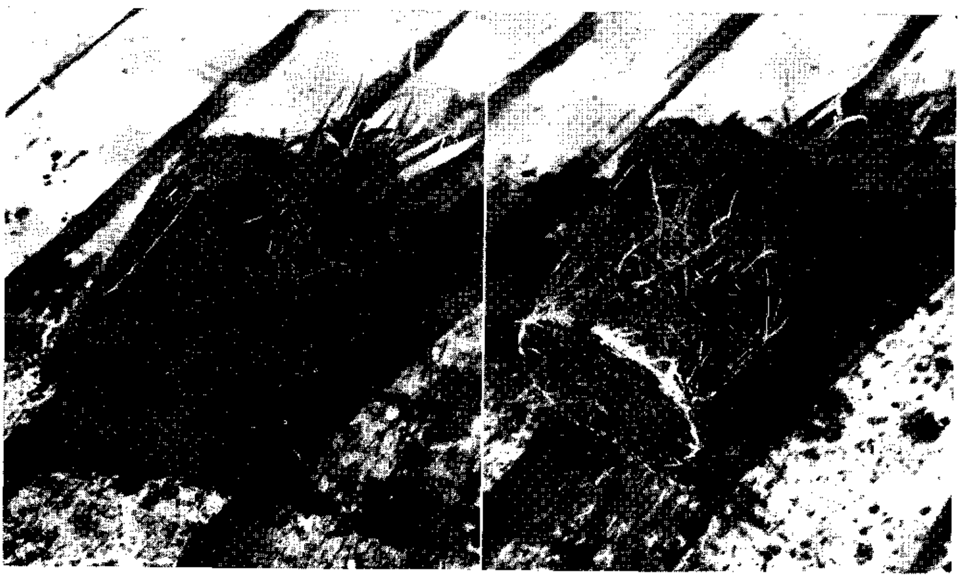


FIG. 20. *Moss peat generally is very acid, often with a pH as low as 3.0. When such an acid soil is put at the bottom of a pot, roots do not penetrate into it (left). When the acidity of the same peat is lowered to pH 4.5 an abundance of roots is present (right)*

FIG. 21. *Effect of soil improvement on oats in the 'peat colonies'. Left: control with 72 kg N/ha. Middle: mixed with wide rooter, 0 kg N/ha. Right: mixed with wide rooter, 48 N/ha*

One would expect that improvement of such drought sensitive soils would first have been achieved by liming the acid subsoil. As a matter of fact the improvement by mixing with deep-plows and rooters did already start before the real cause of the trouble was known. This work had remarkable success (see table 4 and fig. 21), since the pH of the mixture in most cases will exceed the critical value of 3.5.

Table 4. Yield increase in % (mean over 5 years) by increasing the rooting depth from 20 to 70 cm by deep-plowing. Experimental field Borgercompagnie

Rye	20.5
Oats	17.6
Wheat	22.7
Potatoes	9.3
Sugar beets	13.2

The results of this improvement are very good and these improvement measures are applied on a rather large scale, but it is uncertain whether the physical and chemical changes in the peat induced by the increase in pH will not give harmful effects.

PHYSICAL IMPEDIMENTS

Lack of aeration is the main impediment for deep root development. The supply of oxygen to deep layers is effected by diffusion from the surface. Therefore any deeper layer has a lower oxygen content than any higher layer. At which depth the oxygen content is too low for root growth, is dependent on pore volume and moisture content. In our low lying countries this condition is generally found at shallow depths, because there already a too high moisture content will be present.

The present knowledge on acration is not yet sufficient for quantitative application. Much more research will have to be done before the problems of heavy clay soils and soils with a dense structure can be solved. With the present tools for soil improvement there are few possibilities to increase aeration. The most important soil property, the air-filled pore space is mainly determined by the texture and structure of the soil. Loosening gives only relief for a short time, as the natural equilibrium in the soil-water-air relations will quickly return.

The natural conditions, however, can be disturbed by the ever increasing use of heavy and vibrating machinery in agriculture. Therefore a better understanding of the problems involved in aeration is a necessity. With the aid of this a technology for practical improvement of aeration will have to be developed.

BEARING CAPACITY OF GRASSLAND

In the Netherlands the productivity of grassland is not less than of arable land. There is therefore no difference in the value of both land types. With such high land prices as 8,000 to 10,000 Dutch guilders per ha (that is 1,000 U.S. dollars per acre) only intensive forms of agriculture are fitting.

The most inhibiting factor for the intensification of animal husbandry is the insufficient bearing capacity of most grasslands. Through that the stock density is limited to about 1.5 milking cow per ha. Especially the pastures on peat soils are very susceptible to trampling.

In those areas where there is a sandy subsoil at a depth of less than one meter, it is possible to make a firmer topsoil by deep-plowing. Even if the sandy subsoil is as

FIG. 22. *Sand screw (photo Kon. Ned. Heidemaatschappij)*

deep as 3 to 4 m below surface it is possible to raise a sand cover with a machine which screws up sand from the subsoil to the surface and spreads it (fig. 22).

Increasing the bearing capacity in one of these manners has proved to be of great value. Transport of sand over a horizontal distance is generally too expensive, however. So this kind of improvement can only be used for soils which have a sandy subsoil within a reasonable depth.

The bearing capacity of a soil is above all determined by its density (fig. 23). The pressure of a cows hoof, 4 to 5 kg/cm², will act as a compacting agent. Compactions can, however, not exceed the density at which the soil becomes fully saturated with moisture. If the soil is saturated before a counter pressure of 4 to 5 kg/cm² is reached, the hoofs will make deep holes in the soil, destroying the sward. Another improvement method is therefore to decrease the moisture content of the soil by increasing the drainage depth. It was calculated that for most peat soils a groundwater depth of 60 to 70 cm below surface can prevent trampling. This was proved experimentally on a number of sites.

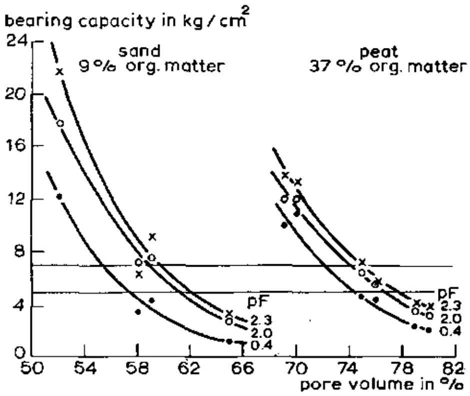


FIG. 23. *Bearing capacity of two soils in relation to pore volume*

Deeper drainage of our peat soils is recommended now, in spite of the other factors involved. Especially the subsidence of deep peat soils is a great problem and also a topic of research. The high density of the topsoil required for a good bearing capacity causes a bad aeration which confines the roots of permanent grasslands to the surface layer. This is another problem on which research is carried out.

FILLING OF DITCHES AND LAND LEVELLING

Changes in natural, economic and technological conditions not only gave a greater need for research on soil improvement, but also influenced the objectives of the improvement work. From the earlier aims, the increasing of chemical and physical fertility, the first has been achieved and only the latter has remained. A new aim is the increase of labour productivity by making the soil and the parcellation more suitable for mechanical cultivation. Small sites are not fit for large combine harvesters and many other machines. As in our country a parcel is often surrounded by, sometimes wide, ditches, filling them is a prerequisite for mechanization.

It is one of the tasks of the soil improver to find from where the material can come and how the ditch is to be filled. To prevent high transport costs, earth from the adjacent parcels will often have to be used. The topsoil, however, has in most cases too good agricultural properties, so the use of subsoil is indicated. This means the topsoil has to be removed first and has then to be returned afterwards. The old handwork system was superseded by work carried out by draglines and bulldozers, but this also has grown too expensive. A new, cheap method has been found, called: ploughing and shoving. With a special plow (fig. 24) with two mould boards the topsoil is turned under and the subsoil is brought to the surface. After that the new subsoil cover is shoved by bulldozers into the ditch and the topsoil is again at the top of the profile. This method considerably reduced the costs of ditch filling.

Another used method to obtain sand, particularly in very extensive areas with ditches to be filled, is by means of a suction dredger. It is then practice to leave a shallow artificial lake at the cut, to be used for swimming, boating and fishing.

A separate problem when enlarging parcels is often the unevenness of the land surface. Hardly any parcel is flat and the ditches are in the lowest places. A newly form-

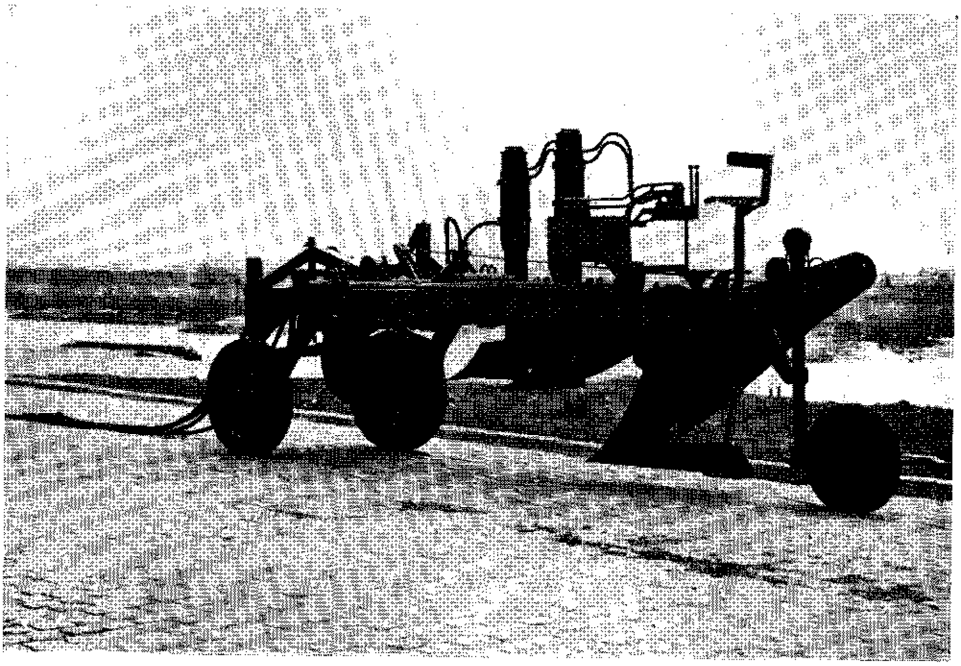


FIG. 24. *Deepplow for soil improvement (photo Kon. Ned. Heidemaatschappij)*

ed large parcel may therefore have some low spots without any possibility of open discharge, in other words, have enclosed depressions.

Used as they were to highly subvented levelling works, it was common opinion among farmers that unevenness is a great failing of a parcel. The question if this was really the case was the first problem to be studied by the soil improvement department. The results were that generally the harmful effects of depressions only existed with unsufficient drainage.
Deeper drainage could solve most problems. The main disadvantage of wet conditions in the depressions is that it handicaps tillage and other field work, not only in the depression itself but for the parcel as a whole. This results for instance in too late sowing dates, which can considerably reduce yields.

The harmful effect of enclosed depressions is only present when the infiltration capacity of the topsoil or the permeability of a subsoil layer is too small compared with rainfall intensity. In the latter case, occurring in places in our western clay district, the problem can be solved by a special drainage of the depressions. The lower part of the tile drain groove in the depression has to be filled with coarse material as gravel or shells, while the upper 20 cm of the groove can be filled with normal topsoil. Where water accumulation in the depressions is caused by a small infiltration capacity of the topsoil other measures will have to be taken, but this problem is still under investigation.

FUTURE DEVELOPMENTS

In the above it was argued that the new circumstances which now start to control agriculture have created new soil property demands. It remains the task of soil improvement to arrange the soil profile and the soil surface in such a way that it is fit for modern agriculture. This can only be done if the right machinery for this work is available. In this country where soil improvement has a rather long history there are many machines specially developed to alter the soil profile. In the last years many new machines were built: sharp and wide rooters, mixing rooters, rotamixers, deepplows in many constructions, as well with as without appliances for conservation of the topsoil, and soil fraises.

Every new machine has new properties and gives another type of work. Some can turn the soil totally, other do only raise a new cover on the soil. Many of them are mixing machines; the mixing can be more or less homogeneous, it can partly conserve the profile or build an entirely new one. It is one of the tasks of soil improvement research to indicate what can be expected of these machines and where, why and how they have to be used. The old practical experience cannot be the basis anymore of modern soil improvement. Nearly all production circumstances have changed and they will continue to change before sufficient practical experience can have been obtained. Research will also in this case have to give an ever growing insight in all interrelations between soil, water, plants and the machinery that is used.

Rural reconstruction and development

C. BIJKERK

INTRODUCTION

Whereas research in water management and soil improvement basicly deals with studies of vertical cross sections of agricultural land, the research on rural reconstruction is principally a study of the man-made division of the land surface as connected with agriculture.

The problems adhering to the layout of land are as old as agriculture itself. In all the solutions that have been found, the arising pattern of occupation was the result of two main aspects of the period in question: the available technical means and the economic, social and legal circumstances. In the Netherlands these factors have let emerge three main types of occupation of the land:

a. central villages with the farmhouses mainly situated in them, with the holdings fragmented in relatively small lots often at large distances from the farmhouse pertaining to them, and a dense and irregular road system. This so-called mosaic parcelling mainly concerns old settlements on the higher sandy soils, but also occurs in the older sea clay areas;
b. ribbon-shaped villages of great length and very small width in which almost all the farmbuildings are situated, the lots of the holdings much less scattered, but having an extremely small width and very great length. The very thinly spread system of roads as well as the whole pattern is in most cases regular. This strip parcelling occurs in the old peat-districts and in the younger colonisation areas on low lying peat and clay soils ('peat colonies' and some polders);
c. farmhouses fairly evenly spread along a regular mostly rectangular system of roads, each farmhouse situated on one block of land which comprises the entire holding. This modern or block parcelling is found in the latest occupied regions (IJssellake polders) and in reconstructed areas.

The types a and b are not adapted for modern agriculture, resulting in losses in yield and in manpower. Reconstruction of such areas is necessary, involving also non-agricultural interests. It was found that the elements playing the most important role in reconstructions are:

a. size and shape of lots and parcels;
b. topographical features bounding the parcels or lots, as ditches, earthen banks and hedges, as also vertical drops and steep slopes;
c. roads and canals;
d. farmbuildings;

e. size and layout of the holdings;
f. utility works (electricity, drinking water supply, telephone);
g. structure of the villages and of the region as a whole;
h. facilities for outdoor recreation;
i. scenic elements and present or future nature conservancies.

To supply the necessary scientific background for regional reconstruction plans, the effect of change and rearrangement of these elements as well as the socio-economic consequences of it, are studied at the Institute.

Although the physical and economic conditions upon which this research is based are typical for the Netherlands, it is thought that the basic results may also be applied elsewhere. The degree in which this can be the case will depend to a large extent on the economic development and the national policy of the country concerned.

The research on land reconstruction in combination with economic studies has received much attention in the Netherlands. The two main reasons for this interest are:

a. the relative overproduction in agriculture with at the same time an increasing prosperity of non-agricultural activities, has shifted the accent of the national structural policy more and more away from measures to increase agricultural production and towards measures decreasing the production cost in agriculture. The already existing imbalance between demand and supply of agricultural products is then prevented to grow, while the same measures give the farmers an opportunity to keep an income at parity with that of industrial workers;
b. the land consolidation schemes have gradually changed from rather simple reallocations to complete regional reconstructions. Land consolidation schemes in the Netherlands are nowadays not only dealing with agricultural problems, but also with problems of traffic, country planning, recreation facilities, scenery, etc.

Since the purpose of land consolidation schemes is now to stimulate the economic growth of a whole region, the Institute has incorporated other disciplines than agriculture in its research. The scientific team engaged in rural reconstruction research includes also a farm economist, a regional economist, a geodetical engineer, a civil engineer specialized in physical planning and an agricultural engineer specialized in outdoor recreation facilities.

It will be tried to give an insight in the diversified studies by treating them more or less in the order of the earlier mentioned elements of major importance for reconstruction of rural areas. It must be emphasized that this is an artificial division, which in our actual research is often not practised.

LOTS AND PARCELS

A large number of disconnected lots per holding and the parcels per lot of too small a size and of irregular shape, are a serious drawback when trying to reach maximum mechanization and rationalization in farm management. One of the research objects is therefore to determine, for each degree of mechanization, for various cropping patterns and therefore for various labour requirements, the optimum size and shape of parcels and lots.

These studies have given quantitative information on the benefits to be acquired after improving the size and shape of lots and parcels. An example is given in fig. 25.

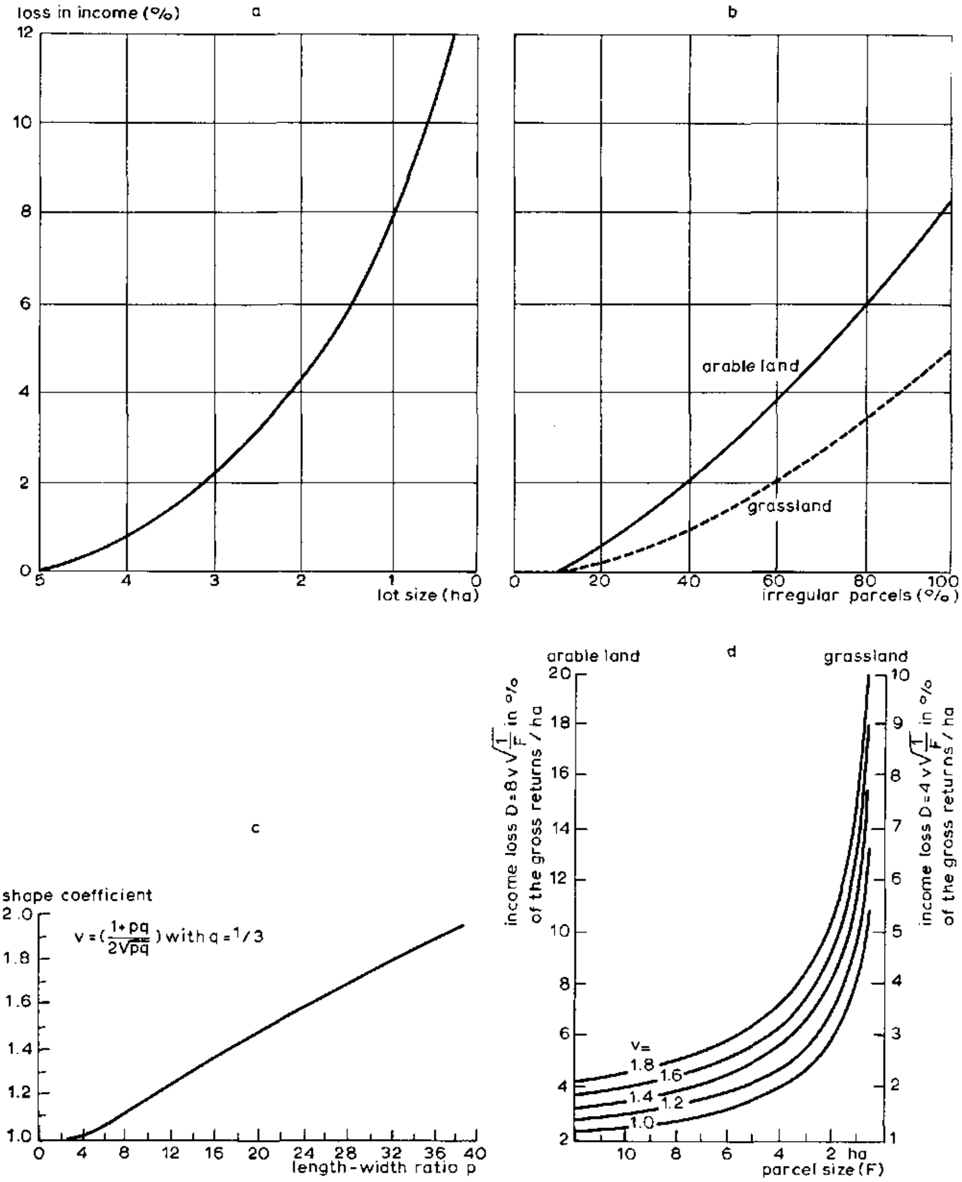


FIG. 25. *Relation between lot size (a), per cent irregular parcels (b) and loss in labour-income. Determination of the shape coefficient from the length-width ratio of irregular parcels (c). Determination of the benefits of increasing the parcel size or improving its shape for arable land and grassland (d)*

TOPOGRAPHY

In many cases topographical features as ditches, earthen walls or hedges mark the boundary of parcels. Aside from the lost agricultural area and the impossibility to use large machines, even the used parts of the side borders and turning borders give lower yields than the centre of the parcel. An example of this is given in table 5.

Table 5. Yield losses on turning borders and side borders on parcels with arable crops in the area 'Oost- en Westdongeradeel' (clay area with ditches surrounding the parcels)

Site and crop	Part of cropping pattern in %	Gross returns in Du. gld/ha	Yield depression in Du. gld/100 m'		
			1964	1965	1966
TURNING BORDER					
Winter wheat	23.3	1950	11.70	10.70	15.60
Spring wheat	11.2	1850	8.30	24.10	19.40
Spring rye	8.5	1450	10.90	16.00	14.50
Seed potatoes	30.9	4250	53.10	78.60	68.00
Sugar beets	12.9	3100	7.80	37.20	27.90
Mean		2880	25	41	36
SIDE BORDER					
Winter wheat	23.3	1950	7.80	12.70	10.70
Spring wheat	11.2	1850	6.50	13.00	12.00
Spring rye	8.5	1450	6.50	10.20	5.10
Seed potatoes	30.9	4250	19.10	12.80	10.60
Sugar beets	12.9	3100	12.40	23.30	23.30
Mean		2880	12	14	12

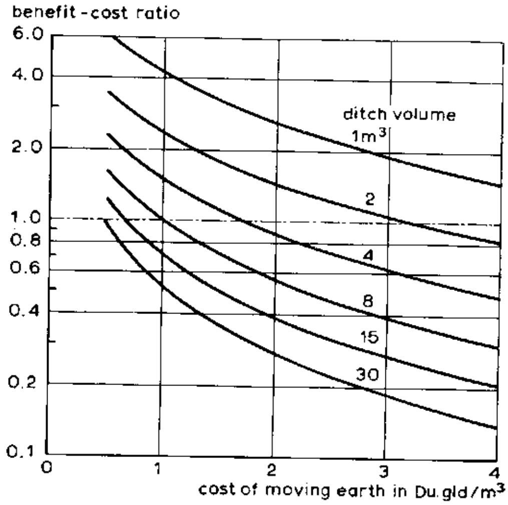
Knowing from this kind of research the benefits of removing topographical obstacles to modern farm management, it is possible to choose between alternative execution techniques with the aid of benefit-cost ratios. Fig. 26 gives these ratios for the filling of ditches.

In the last mentioned research it became apparent that the normally used surveying technique to determine the ditch volumes was rather expensive. Since aerial photographs gave too large a deviation from the actual volume of the fill, an apparatus was devised and constructed (fig. 27) which saves up to 70% of the surveying costs with an obtainable accuracy only some 5% less than is usual with a levelling instrument.

TRANSPORT SPEED AND DISTANCE

One of the most important aims in land consolidation schemes is lessening the transport time as well on the holding as in the area as a whole. The improvements

FIG. 26. *Influence of the ditch volume on the benefit-cost ratio in relation with the costs of moving earth*



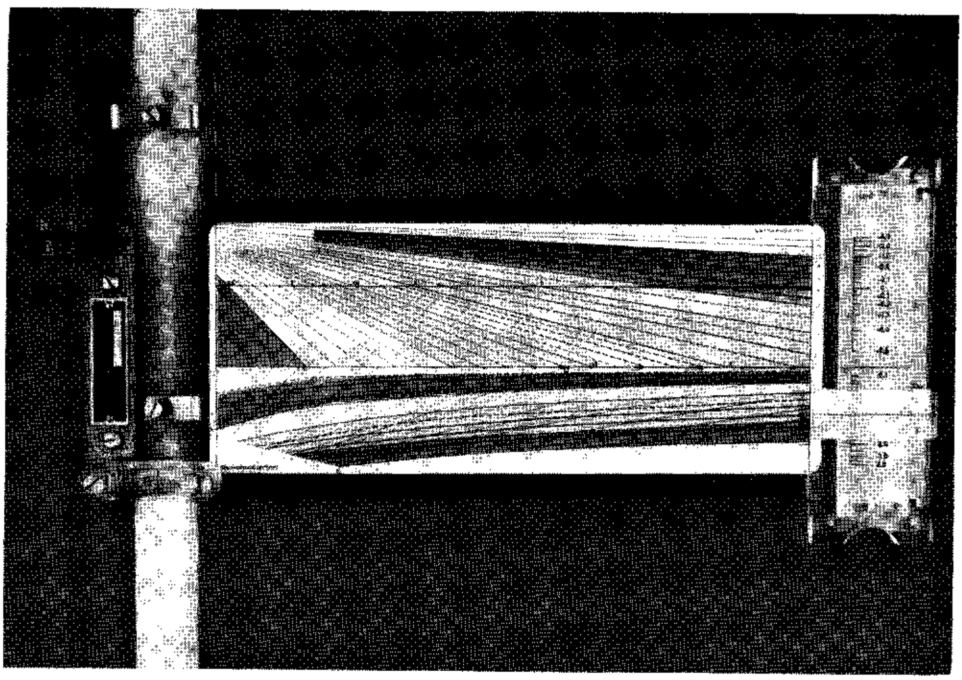


FIG. 27. *The ditch volume plotter consists of a measuring plate with two nomographs, a slide and an indicator (both with a sight), attached to a stick. Two sightings at only one side of the ditch and a plumbing give the volume of ditches up to 5 m in width*

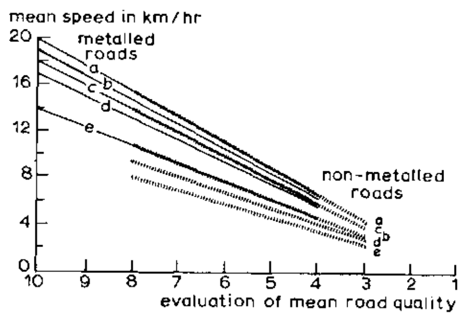


FIG. 28. *Relation between road quality (10 = completely smooth surface; 3 = unpassable for motor cars) and mean vehicle speed on metalled roads for a number of transport categories (all vehicles with pneumatic tires): a, single tractor or tractor with empty or lightly loaded two-wheeled wagon; b, tractor with heavily loaded two-wheeled wagon; c, tractor with empty or lightly loaded four-wheeled wagon(s) or with mounted implement; d, tractor with heavily loaded four-wheeled wagon(s) or wheeled implement; e, tractor with four-wheeled wagon(s) with bulky load*

can consist of one or more of the following measures; improvement of existing roads and paths, building of new roads, re-siting of the lots and re-siting of the farmbuildings. In this way one of the essential conditions for productive farming, short transport distances on roads that can be used under any weather conditions, can be achieved.

As well from the viewpoint of research as of economics, transportation speed and transport distance are basic parameters.

After a comprehensive research of vehicle speeds on metalled and non-metalled rural roads, taking into account the road qualities under various climatological circumstances it was possible to give for various forms of traction a relation between mean road quality and mean speed (see fig. 28). Such results together with data on transport frequencies of the various farm types did give an estimate of the saving of manhours that can be achieved by means of road improvement and by shortening the transport distance.

ROADS AND WATER COURSES

In most cases rural roads have several functions and for a rational design it is indicated to distinguish between them. The road pattern and the road itself should be designed in accordance with the traffic it should bear (see fig. 29).

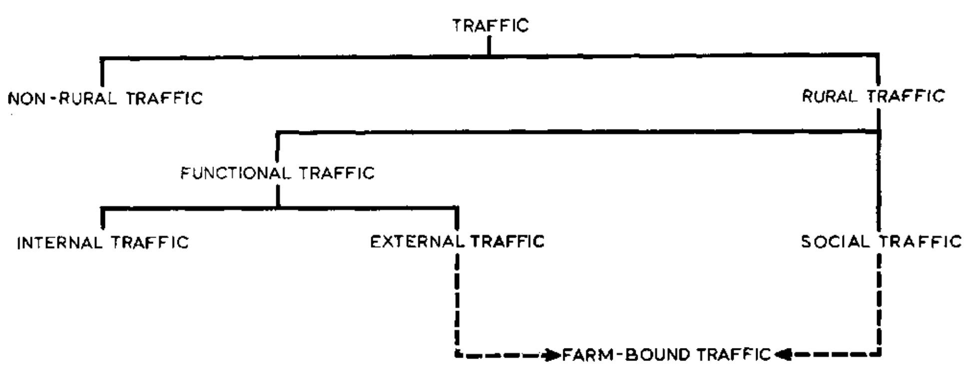


FIG. 29. *Schematic classification of traffic*

To get an insight in the various kinds of traffic several studies have been made, based on automatic and visual volume counts, origin and destination surveys and bookkeepings by individual farmers.

In the paragraph above something has already been said on the quality of the road itself, and it may be mentioned here that a systematic research on the problem of maintenance of rural roads and its economic repercussions is in progress.

Regarding the layout of roads in rural areas, not only the structure but even more the density of the system is of importance. Determining factors in this respect are: the size of the holdings, the type of agriculture or horticulture, the lot size distribution and the topography.

When making land consolidation schemes, the effect of these factors on road requirements must be known. As an example a relation between minimum road length, lot size and shape is given in fig. 30. It is evident that the higher the length-width ratio of the lots, the smaller the for accessibility necessary road length, but this means a larger transport length on the lots themselves. An optimum shape of the lots in this context can be calculated by taking into account transport volume and frequency, transport speed, costs of establishment and maintenance of a particular type of road, all for various farm and soil types.

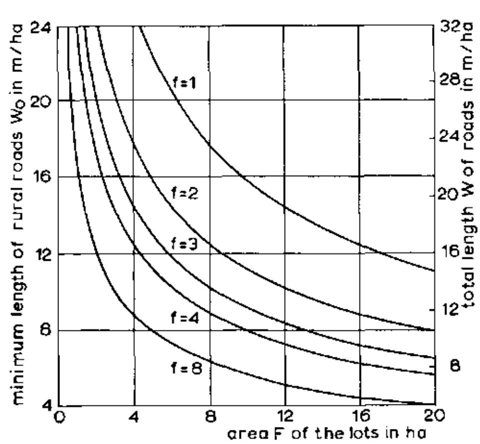


FIG. 30. *Relation between lot size F, lot shape f (length-width ratio) and minimum length W_0, of rural roads necessary for accessibility of the lots as well as necessary total length W of roads (including village interconnections) for a rectangular parcellation pattern and $W_0/W = 0.75$*

For water courses, which in our low lying areas are mostly situated at the back of the lots, similar relationships can be determined. The costs of establishment and maintenance of water courses for agricultural purposes have in particular been subject of study. Fig. 31 emphasizes the importance of lot size on the exploitation costs of canal systems.

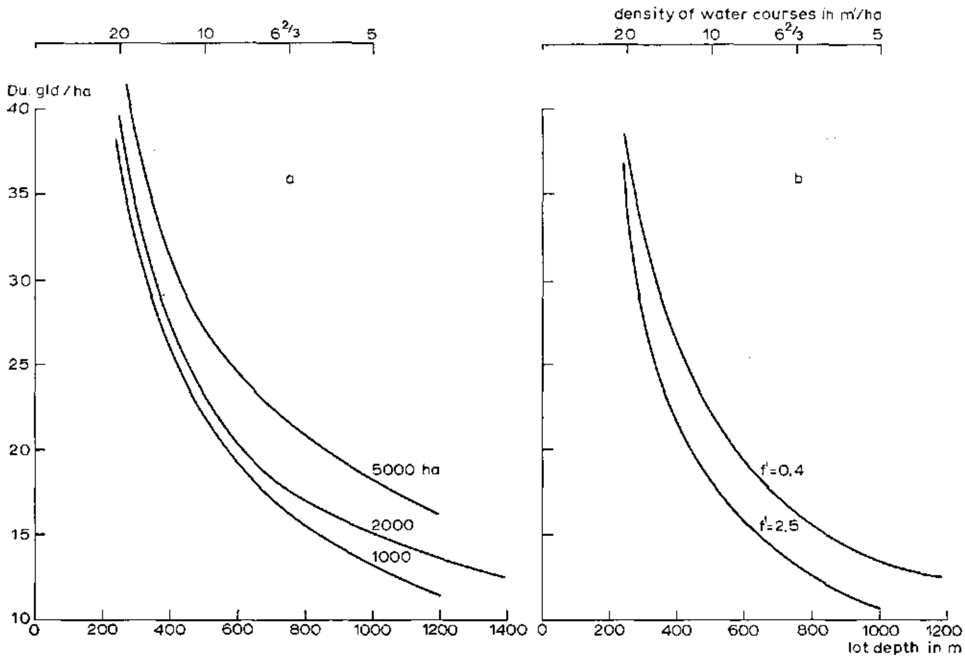


FIG. 31. *Influence of the depth of lots (indicative for the density of water courses for agricultural purposes) on the total yearly costs (investment plus maintenance) of open water courses for different drainage areas (a) and different shapes of the area (b). The discharge coefficient is taken as 1l/sec. ha; (a) is valid for a width-length ratio of the area f′ = 0.4; (b) holds for a drainage area of 1000 ha*

RE-SITING OF FARMBUILDINGS

The re-siting of farmbuildings is a measure which in land consolidation schemes in the Netherlands involves a fair amount of farms (up to 20% or more of the total area in reconstruction). The measure, although rather expensive, is often indicated because of its many advantages. Re-siting farmbuildings shortens the mean transport distance in the area, improves the possibilities to concentrate the scattered lots of holdings, may save on the necessary length of rural roads in the area, is an important factor when planning village reconstruction and increases the efficiency of farm management.

To evaluate the total economic effect many relations have to be investigated. So, for example, a method was developed with which the new site of each farmbuilding creating an optimum lessening of the transport distance in the area, can be determined. After the method had been computerized, it was ready for use in planning rural reconstruction schemes (see fig. 32).

It must be mentioned that although by re-siting of farmbuildings the volume of internal functional traffic diminishes, the volume of farm-bound traffic (external

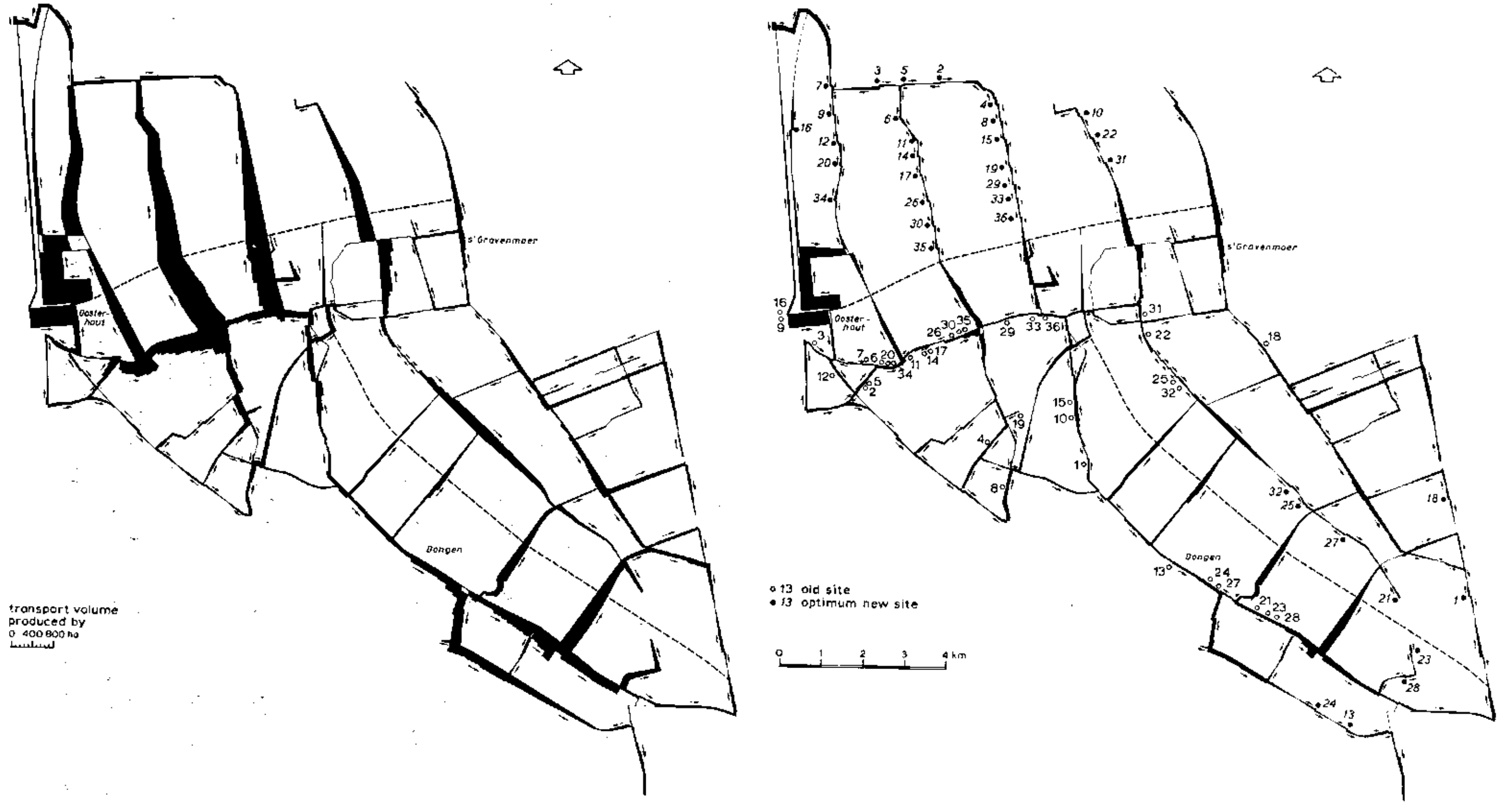


FIG. 32. *Transport volumes produced by agriculture in the rural reconstruction area 'Beneden Donge' as they would be after land consolidation without re-siting (left) and with re-siting of the indicated farmbuildings (right)*

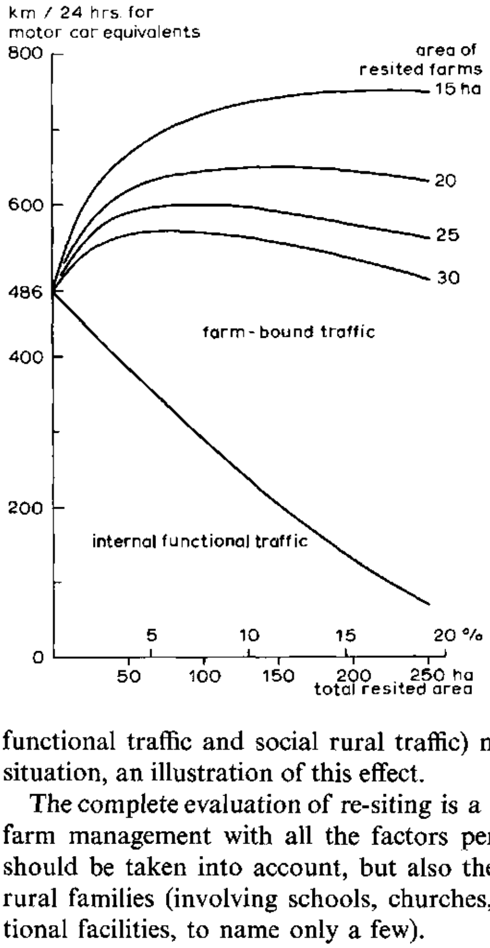


FIG. 33. *Decrease in internal functional traffic and increase in farm-bound traffic (see also fig. 29) on a certain farmroad in the rural reconstruction area 'Rolde', as affected by re-siting of farmbuildings and the holdings pertaining to it*

functional traffic and social rural traffic) may increase. Fig. 33 gives, for a certain situation, an illustration of this effect.

The complete evaluation of re-siting is a very intricate matter, in which not only farm management with all the factors pertaining to it and their economic effects should be taken into account, but also the changes then made in the social life of rural families (involving schools, churches, shopping centers, and sport and recreational facilities, to name only a few).

Nevertheless it is hoped that the research carried out on this subject may contribute to an optimum layout of rural reconstruction plans.

UTILITY WORKS

Inherent to the re-siting of farmbuildings is the layout of public utility works, as electricity, drinking water and telephone mains.

Construction and maintenance costs are heavily influenced by the number of farmbuildings to be connected and if they are situated in groups or not. Basic research on the costs as influenced by these factors was necessary since usable norms were not available for rural networks. This resulted, among other things, in the construction of some nomographs, of which the one for drinking water supply is given in fig. 34,

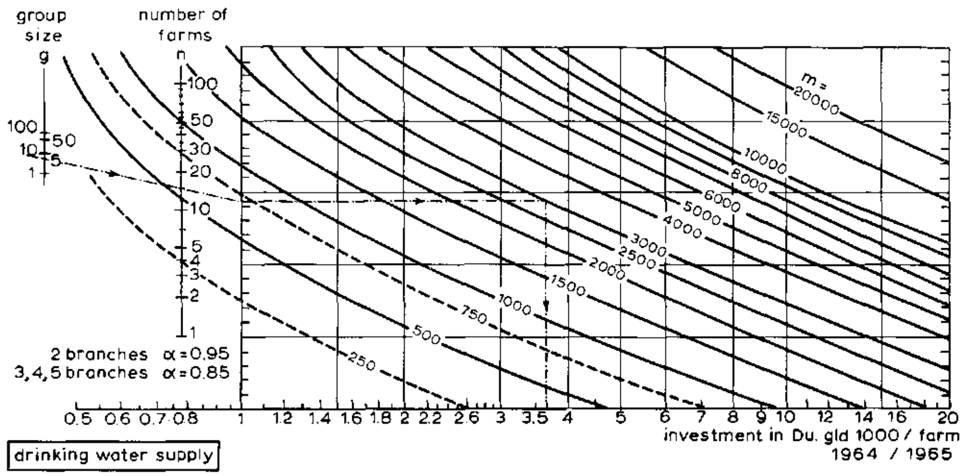


FIG. 34. *Nomograph for estimating the investment in drinking water supply in rural areas. Example: number of farms n = 15; number of farms per group g = 5; normative length of the line m = 3000 m, according to m = z + 0.8 (l−z), where z is distance from A (connection point of new line to existing main) to centre point of farms to be connected and l = length of the new lines; reduction-factor for branched networks α (for 3 branches) = 0.85. Hence investiment per farm 0.85 × 3675 = Du. gld 3120*

to be used when estimating the cost of utility works in alternative rural reconstruction designs.

SIZE OF HOLDINGS

The problem of the size of the holdings to be created is, as well in newly reclaimed areas as in rural reconstruction schemes, of major importance. This size in general determines the potential income to be reached. One of the primary purposes of all reconstruction measures is to obtain some degree of parity in income of agricultural workers with that of comparable professions. The monetary value of the production per farm labourer is therefore an important parameter. Since this value is highly influenced by the future degree of mechanization, the setting of a mean holding size when planning rural reconstructions always requires prophetic abilities of the planner. This also implies that solutions with a high degree of flexibility are to be preferred. When solving re-siting problems this aspect often leads to 'free' lots between adjacent holdings, at first to be utilized by farmers having their farmbuildings elsewhere, which can later be added to the neighbouring farms.

It must be emphasized that enlarging a holding will have only a slight economic effect, if the qualities of layout, accessibility and soil do not allow the use of modern machines. Generally speaking, the measures to improve these qualities are a prerequisite for increasing the area per man.

The mobility of labour and capital has the function of adapting these production factors to changed requirements. The speed with which this occurs after reconstruction of a rural area will have a large influence on the success of the whole operation.

Almost all measures which improve the economic situation of a rural area have as one of the results a decrease in labour demand. This implies that in view of national economy such measures are only of value if the manhours saved can be profitably used.

The ways to realize this within the sphere of agriculture are intensification of the cropping pattern on the one hand and enlargement of the holdings on the other.

The latter measure brings us to the problem of mobility of agricultural labour. In some cases migration to newly reclaimed land (the new IJsselmeerpolders) is possible, some farmers will retire, but others will have to find jobs in other sectors of employment. This means that the success of rural reconstruction works also depends on alternative labour opportunities in industry or services.

Information on mobility values are therefore of great importance when planning rural reconstruction works. As an example of the research done in this field fig. 35 is given, taken from a study to estimate the number of future labour in agriculture. The parameters derived from such graphs are correlated with other characteristics of a region. Corrected parameters are then used as inputs when estimating future developments.

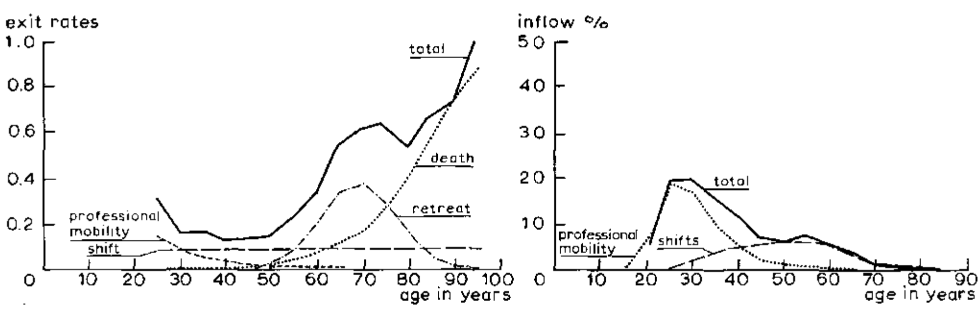
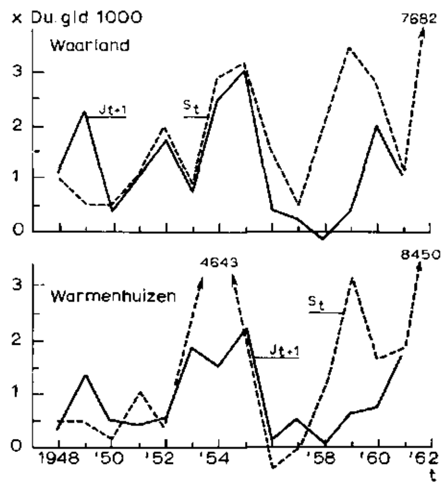


FIG. 35. *Exit rates (decrease in number of farmers divided by present number of farmers) and inflow (in % of total inflow) of farmers in relation to age (mean of interval, midst of period). Means of 15 agricultural areas with in total 6229 holdings larger than 2 ha*

The differences in economic growth between improved and not-improved areas (with-and-without-principle) are a measure of the success of the initial investments in rural reconstruction works. For that purpose, besides the above mentioned labour mobility research, investigations are made on the investments by farmers and on the factors which influence the saving quote.

A first study in two equivalent areas tending towards horticulture, one reconstruct-

FIG. 36. *Course of the net savings (S_t) and net investments in the following year (J_{t+1}) of farmers in two more or less equivalent areas, one with (area Waarland, reconstruction finished in 1951) and the other (area Warmenhuizen) without a carried out land consolidation scheme*



ed and the other not, gave a picture as given in fig. 36. Further studies in other regions may contribute to a better understanding of the long term effects of executed land consolidation plans.

ECONOMIC EVALUATION OF RECONSTRUCTION POSSIBILITIES

Modern economic research techniques are an important aid to evaluate the various reconstruction possibilities and to obtain an optimum reconstruction plan.

One of the manners to establish the direct economic effect of land consolidation measures is to work with parcellation models indicative of the present situation and of the reconstruction alternatives. Such studies are executed in connection with regional pilot plans for rural reconstruction made by the Institute, giving general solutions for the problems encountered without going too much into local details.

The economic studies carried out in this context, although only giving general norms, are giving an indication of the optimum adjustment of the farms to changing conditions of layout and of other factors influencing farm management.

Fig. 37 and 38 give the result of an evaluation of the gross returns minus variable costs of four grassland farm models of the Zuid-Holland peat area with strip parcelling, calculated by means of linear programming.

Another approach can be made by analysis with the aid of production functions of many bookkeeping data of groups of farm types. It is then possible to derive coefficients indicating the production value of land, of labour and of the private capital of the farmer in his enterprise. These values can differ considerably from actual market prices, so accounting prices will have to be used in economic evaluations of rural reconstructions. Some of the results of such an approach are given in table 6.

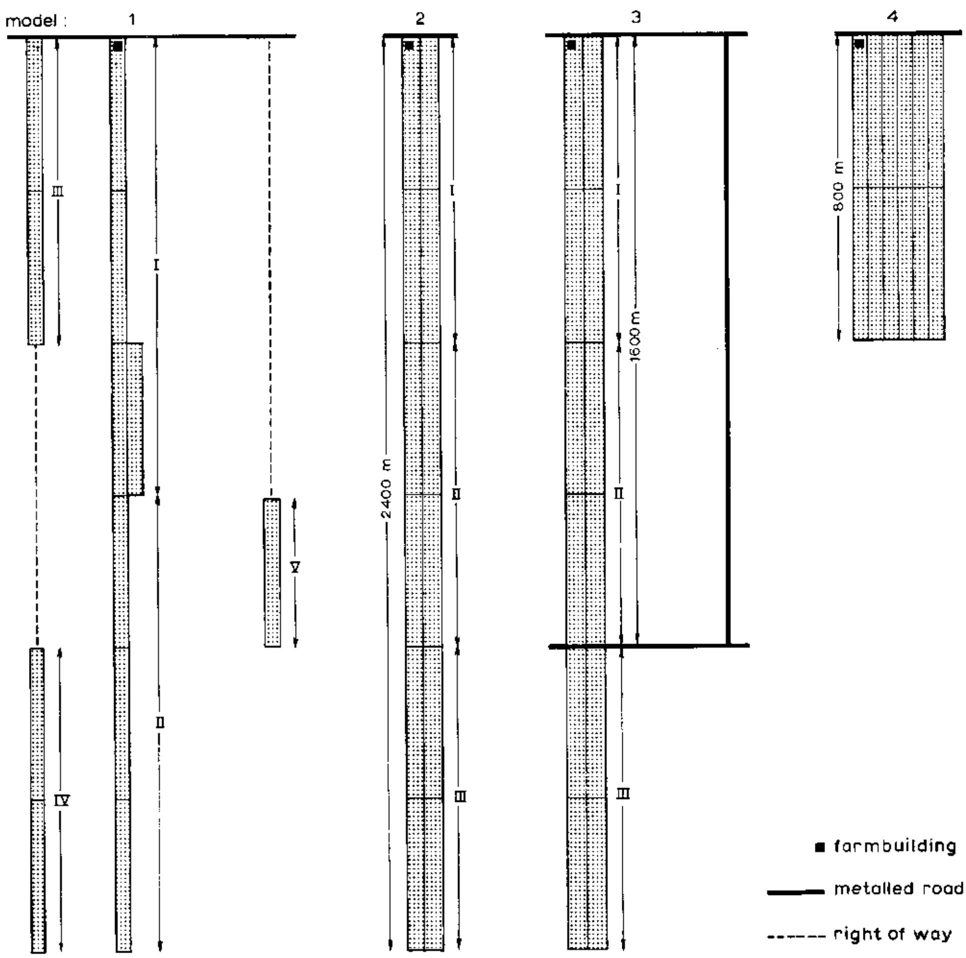


FIG. 37. *Scheme of the now existing situation (model 1) and three reconstruction models (models 2, 3 and 4) of grassland one-man-farms on low moor peat in the provinces Zuid-Holland and Utrecht*

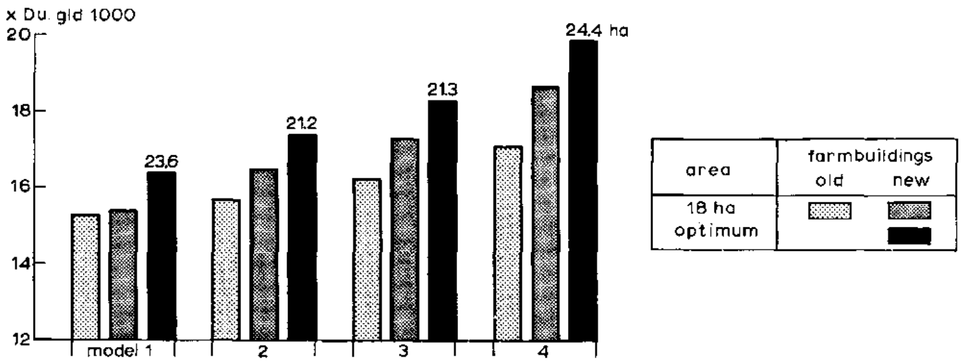


FIG. 38. *Gross returns minus variable costs (and as the area was set variable in some of the runs of the program, also minus area-bound costs of Du. gld 250 per ha) of the four models given in fig. 37. For the models 1, 2 and 3 parcel groupings were used to obtain the optimum results per group. The number of cattle and the N-fertilization were continuously variable. The area used to obtain fodder was variable within wide boundaries. Casual labour was made variable by introducing alternative work-methods for the fodder harvest. For old versus new farmbuildings different labour requirements were used during the stabling period*

Table 6. Derived accounting prices with a Cobb-Douglas function for Du. gld 1.– of rent, labour, capital and purchases, compared with values for British and Irish farms (Rasmussen, 1962)

	Netherlands* 1961/62–1963/64	Great Britain 1954/55–1957/58	Ireland 1955/56–1957/58
DAIRY FARMS			
rent	1.3 to 1.5	2.6	1.3
labour	0.27 to 0.28	0.6	0.3
capital	0.18 to 0.24	0.16	0.34
purchases	0.94 to 0.96	1.0	1.4
ARABLE FARMS			
rent	1.65	2.1	1.2
labour	0.4	0.8	0.8
capital	0.10	0.20	0.15
purchases	0.61	1.05	1.4
MIXED FARMS			
rent	1.1	1.2	0.9
labour	0.3	1.0	0.5
capital	0.15	0.19	0.25
purchases	1.06	1.0	1.5

*For dairy farms with < 2.4 labour units; arable farms with wages evaluated at < Du. gld 19,000; mixed farms with < 1.7 labour units

FACILITIES FOR OUTDOOR RECREATION

In the preceding pages the measures to change rural areas into regions that are efficient, economically optimal and livable were discussed, but almost only with the population engaged in agriculture in mind.

The Netherlands is very densely populated with as an average about 400 inhabitants per km^2. The western part of the country, with within its borders the cities of Amsterdam, Haarlem, The Hague, Rotterdam and Gouda, has a population density of around $1200/km^2$. The total population is now about 12 million of which some 8% is engaged in agriculture. In the near future the population is expected to rise fairly rapidly and the percentage of people engaged in agriculture is thought to drop to some 4%.

Reconstruction of rural areas will also have to make the country livable for non-agricultural labour and their families, particularly in their long weekends and holidays. One of the aspects to be looked after when planning reconstructions is therefore the increasing of facilities for outdoor recreation.

In some of the preceding chapters the making of cuts for obtaining sand to fill ditches, to build roads or to make town sites, in such a way that they can be used as artificial lakes for swimming, boating, fishing, etc. has already been mentioned. For such recreation sites, as well as for other kinds to be included in rural reconstruction works, many technical problems have to be solved. Basic knowledge on technical problems of recreation sites (for example distance from towns, relation with highway systems, accessibility, size, capacity, subdivision, ratio of land-water surface, drainage, soil properties and so on) is much less available than on economic, social and geographic aspects, which are often amply treated in literature.

The Institute is now carrying out research to fill for the Netherlands this gap in technical knowledge.

PHYSICAL PLANNING OF RURAL AREAS

More than once it has been mentioned in these papers that in the Netherlands land consolidation schemes have grown into complete rural reconstructions. This implies that while physical planning was formerly mostly concerned with town planning, taking with it country planning as far as it had influence on urbanization aspects, nowadays physical planning is interwoven with rural reconstruction plans. It is now not possible to ignore more or less the influence and demands of non-agrarian factors in land consolidation projects. The design of highways, provincial roads, village expansions, recreation projects, scenic elements and nature conservancies each year have a greater influence on reconstruction designs. Sometimes, and then in particular in the very densely populated western provinces, these aspects even can play a decisive role. In such very extreme cases the consolidation plans can contain from an agricultural point of view, merely measures to repare the damages to be done to

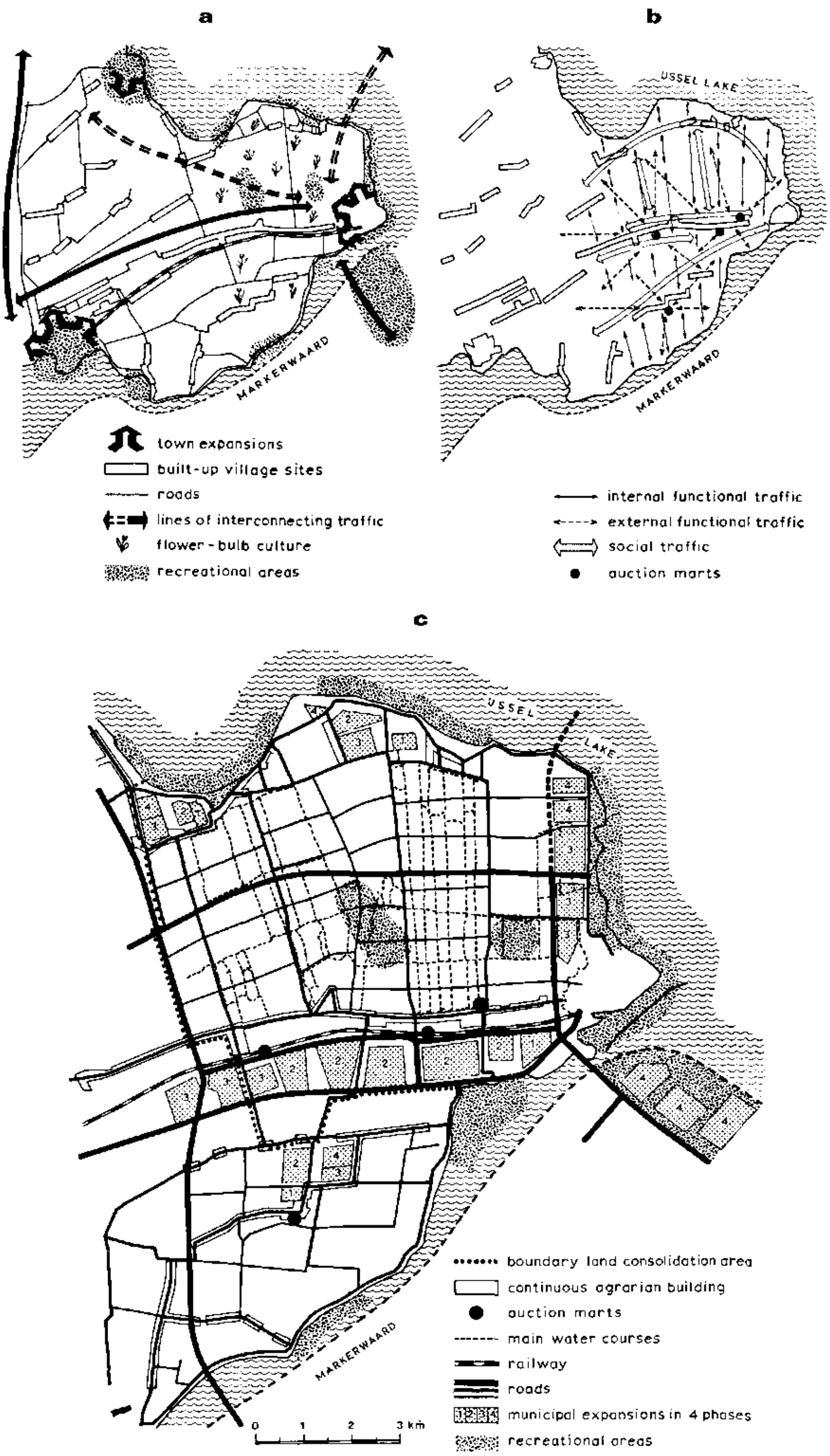


FIG. 39. *Land consolidation area 'Het Grootslag'. a, structure of the region; b, present lines of agricultural traffic in the region; c, combination of one structural alternative and one land consolidation alternative to ensure a harmonious development of the area. It must be emphasized that c gives only one of various possible alternatives*

the agricultural use of the land. Also in less extreme cases it is necessary to incorporate the non-agricultural aspects into the design to obtain adequate plans for rural reconstruction.

For this reason the Institute carries out research in and makes alternative plans for certain pilot regions. Alternative plans in which the physical aspects of a region much larger than the land consolidation area are incorporated. An example of such a study is given in fig. 39.

LAND DIVISION SURVEY OF THE NETHERLANDS

Fairly in the beginning of our research on rural reconstruction and development it became evident that data on the parcellation of rural areas were either lacking, or had not been gathered and worked out in a uniform manner. It was thought by us that having such data, and then uniformly gathered, worked out and presented, was imperative when dealing with the large number of rural reconstructions that have to be carried out in the Netherlands. Increased knowledge of the various functional relations mentioned earlier in this paper, made it possible to make a fundamental classification of the division of rural areas, comprising all facets that are of importance for farming and for rural reconstructions.

Recently it proved to be possible to work out a machine program with which computers can reduce the necessarily large number of initial data to a digestible form. It is now relatively easy to produce uniform reports dealing with specific areas, containing a written analysis, all initial data, machine produced summaries of particular groups of data and four basic maps, giving all the desired information. The machine program is flexible, so additional information can easily be produced.

After some successful test runs, this method is now applied in the selection of areas to be reconstructed and in the planning of land consolidation schemes in the Netherlands. At the same time the data are used for research purposes, of which the results are again to be used in practice. A nice example of how research and practice can go together.

The Institute, inside and out

E. W. SCHIERBEEK

GENERAL

Although the successful pursuit of knowledge is primarily dependent on the brains, the training, the experience and the judgement of the individual research worker, there are three main reasons why research in physical sciences nowadays can only flourish within a research organization. The first reason is the tremendous increase of available knowledge on detail subjects making it in many cases impossible to solve a problem without co-operation in a team of specialists. The second, that often costly tools and accommodations are required to carry out research, and the third that the receiving and dissemination of scientific information is taking an appreciable and increasing fraction of science's resources.

Although often regarded by the individual scientist as being of minor importance in his research, the organization to which he is attached influences to a great extent his way of thinking and the possibilities of his line of attack, and through this his research efforts and his results. It is for this reason that the picture of the Institute given in the preceding pages would be incomplete when nothing was said of the background of the research workers working in the Institute, of its organization, its facilities and of the ways in which information of others is received and our own research results are transferred.

THE PEOPLE

It will not be tried to introduce in person each of the 120 people working in the Institute, but the background of the various groups, in particular of the scientists and the research associates, deserves a closer look.

Scientists

Some thirty scientists carry out the major part of the research of the Institute. All attended one of the universities in the Netherlands to obtain a Master of Science or a Doctor of Science degree.

In the Netherlands a D. Sc. is equivalent to a Ph. D., as the requirements are identical. The tendency is to give a Ph. D. only to those receiving a doctor's degree in philosophy itself and to all others a D. Sc. There are two designations for the M. Sc. degree, one for those graduating in engineering and agricultural sciences ('ingenieur' or short 'ir.') and one for those graduating in other fields ('doctorandus', short 'drs.'). Both are equivalent as regards requirements and bachelor examinations are to be passed before starting the study leading to them. The normal study length is some 5 to 7 years for a M. Sc. and an additional 3 to 5 years for a D. Sc. The length of time needed depends on the field of study and for the doctor's degree also on the nature of the research tasks required for the degree and on the other duties (at the university or within the organization one is attached to) one has to perform.

As regards the study in agricultural sciences, which was followed by most of the scientists employed by the Institute, the approach in the Netherlands is somewhat different from that in most other countries. This modification is of particular importance for the basicly agricultural fields of land and water management. In most other countries those engaged in (agricultural) hydrology and the layout of land recieve a technological education, for example in hydraulics and physical planning, to which are added to some extent, either at the university level or in later years during their work, the biological sciences. In the Netherlands at the University of Wageningen, the basic studies are in the field of agriculture, but right from the beginning and increasingly in the later years of study the technological sciences, in particular higher mathematics and physics, are pressed. This is the main reason for the, in many ways exceptional, mathematical and physical approach of problems by agriculturists in the Netherlands, a trend which is clearly visible in the work of our Institute.

Three scientists and one research associate are, as a consequence of their duties, seconded to other organizations. They are the scientists engaged in bio-hydrology of horticulture in the open (Experimental Station for Horticulture in the Open, at Alkmaar), of horticulture under glass (Experimental Station for Horticulture under Glass, at Naaldwijk) and of bulb crops (Laboratory for Bulb Culture, at Lisse), and a research associate engaged in general water management in the Delta-area, situated in the southwest of the Netherlands (Government Service for Land and Water Use, Regional Office at Goes).

Research associates

A second group, of considerable importance to research, is that of the research associates employed by the Institute. In total some 40 of them, all having a degree of one of the Netherlands agricultural or technological colleges, are working under supervision of the scientists on the various research problems. The colleges require a high-school diploma, an attendance of 4 years and finish with a final examination. Although the scientific basis is certainly not neglected, during the courses emphasis is specifically laid on the practical use of the various sciences. The working together of scientists and such research associates gives a special blend of research and development.

Technical personnel

Added to the scientists and research associates are people from a third group, that of technical personnel. This group consists of some 30 persons with various backgrounds. They staff the laboratories, testing rooms, experimental fields, the data processing group, drawing and photography offices, the workshop and the general technical service.

Administration

The last group to be mentioned consists of administrative personnel, in total some 20 persons. Since the present publication is concerned with research, it will perhaps suffice to say this group supervises the appropriations for the scientifically engaged people, sees to it that they get the research tools they need, handles all personnel matters and all the other administrative tasks.

THE ORGANIZATION

It is evident that many years before the foundation of the Institute, research was already carried out at various institutes and laboratories in the Netherlands in the fields the Institute is now also engaged in. This research was done, however, by organizations having their main task in fields other than that of land and water management proper.

As has already been mentioned in the first chapter, after the Second World War rural reconstruction in the Netherlands received a strong impulse and although of necessity various other organizations would still be required to investigate problems in closely related fields, the Netherlands Government desired to centralize to a greater extent the research to be carried out in this regard.

Government Foundation

It was decided to establish a central institute to 'undertake research in land and water management and related sciences'. This decision was implemented in 1955 with the establishment of a non-profit foundation of the Ministry of Agriculture and Fisheries, our Institute.

The form of a foundation, instead of that of a government service or part of a government service, was chosen at that time mainly for two reasons. The most important was the idea that it would be possible for a foundation to carry out paid specific research for private enterprise. The second that instituting a Board of Control would take care to focus the research on the existing practical problems and to co-ordinate it with that carried out by other governmental and private organizations working in closely allied fields.

Board of Control

The past ten years proved the great value of the requirement to talk over and get the approval and backing of the Board of Control, the Board consisting of representatives of organizations executing land and water management works or otherwise employed with practical agricultural or civil engineering and its management. Probably due to these consultations the research that has been carried out appears to have been wide as well as specific enough, for the Institute to receive only very few requests to engage in paid research for other organizations.

Internal organization

The internal organization of the Institute (see also inside of back flap) with at the head a director and a deputy-director, is built up of 30 research sections grouped into 7 research divisions and in addition 3 specialist research sections, an editorial office (all headed by scientists) and a division of administration. In the preceding chapters an insight has been given in the work of the three divisions working on water management, of the division of soil improvement and of the three divisions of land layout, land development projects and economics. The work of the three specialist sections (physics, mathematics and laboratory) is involved with that of all other research sections.

The research is carried out (and also administrated) on a project basis, at the moment some 90 research projects are in progress. These research projects are often worked on by teams consisting of scientists and research associates belonging to various sections and divisions, which means that the research itself is not hampered by a more or less artificial and never flexible enough organization scheme.

Co-operation

As already mentioned in the earlier chapters a considerable part of the investigations is done in co-operation with other organizations. Aside from the many individual forms of joint ventures, a fairly large amount of such research is carried out under the aegis of working parties and committees having the purpose to integrate the work done in a special field of research or development. The Institute is represented in about 75 working parties or committees, among which are some dealing with international scientific co-operation or with giving advice to international organizations.

In the context of joint research, the names of a few organizations with which is worked in daily and close collaboration must be mentioned. They are the Government Service for Land and Water Use, the Ministry of Public Works, the Government Service for the IJsselmeerpolders, the various Provincial Services for Waterworks and Roads, many Water Boards, the Royal Netherlands Heath Society, the Grontmij Ltd., the Government Agricultural and Horticultural Advisory Services, the Experimental Stations for Horticulture in the Open and under Glass, the Laboratory for Bulb Culture, the Soil Survey Institute and the International Institute for Land Reclamation and Improvement.

RESEARCH FACILITIES

Experimental fields

The Institute operates two permanent experimental fields, one at Renkum (some 6 km from Wageningen) and one at Oudkarspel (some 40 km north of Amsterdam).

The field of 10 ha at Renkum (fig. 40) is situated on a sandy soil with the groundwater table at 12 m below soil surface, which means that in the experiments the natural groundwater level has no influence. The experimental field is primarily used for sprinkling experiments, for which a well with motor pump, subsoil mains and two automatic boom sprinklers have been installed. For larger experiments rotating sprinklers are used. On part of the field precipitation can be intercepted by means of movable glasscovers.

Three kinds of lysimeters have been built in. The first group, a non-weighable one, is composed of 30 containers (each with a surface 1.40×1.20 m^2) with in duplicate 15 artificially rebuilt soils (from sandy via loamy and peaty soils to clays and loess). Precipitation can be intercepted, the artificial groundwater table is controlled, the in and outflow can be measured with a mariotte-bottle system and the soil moisture content at all levels can be determined with gamma-ray and neutron counters. The second group is also non-weighable, built and operated on the same principles, but is composed of 38 containers with 50 cm diameter containing undisturbed samples of 20 soils from the Netherlands. The third group of lysimeters is weighable with a rather high accuracy by means of a hydraulic system of pressure box devices developed at the Institute, and automatically and continuously records in- and outflow and the depth of the (artificial) groundwater level. The screening against precipitation and the manner to measure soil moisture content is as in the other groups of lysimeters. The four containers (each with a surface of 1.40×1.20 m^2) are filled with four rebuilt soils.

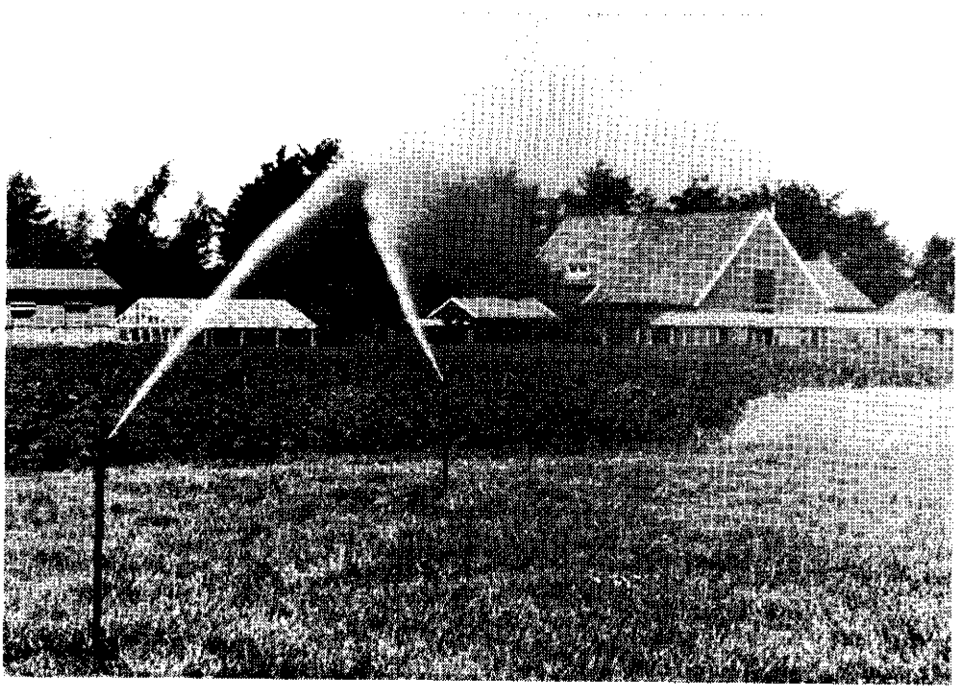


FIG. 40. *Part of the experimental field 'Sinderhoeve' at Renkum*

On the experimental field a glasshouse is present with added to it a small laboratory. The four independent compartments (each some 30 m^2) of the glasshouse are fully conditoned as regards humidity and carbondioxide content of the air. As temperature, light intensity and day length are only partially controlled, the climatic range is from the cool temperate to the hot subtropical.

In addition, 1 ha is occupied by a meteorological station, fully equipped to gather data for water balance studies.

The field at Renkum is used by the divisions General Water Management, Hydrology, Bio-hydrology and Soil Improvement.

The second permanent experimental field at Oudkarspel (6 ha) is situated on a heavy clay soil with groundwater influence. On half of the field groundwater level experiments are carried out. Groundwater levels of 165 cm minus surface to 30 minus can be maintained independently and automatically on 12 strips of 4 × 100 m^2, separated by 8 m wide buffer strips. A cross-section of the system is given in fig. 41. Each experimental strip has three soil profiles. The first is the original heavy clay soil deep some 30 cm, overlying a 60 cm thick sticky clay underlain by a sandy loam. For the second profile the topsoil was removed and the remaining sticky clay and sandy loam

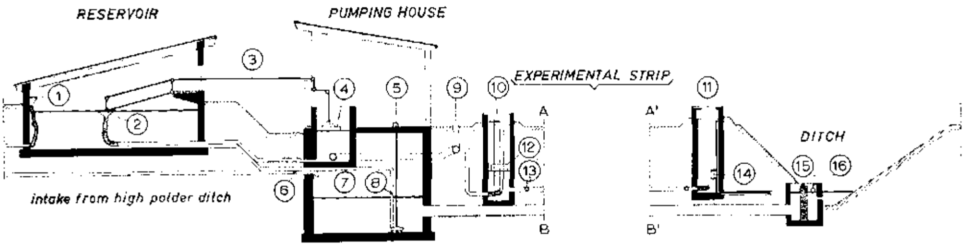


FIG. 41. *Cross-section of the water level regulating system (cutting the width of an experimental strip) at the experimental field 'Geestmerambacht' near Oudkarspel. 1. overflow; 2. floating overflow; 3. master-rod; 4. masterfloat; 5. pump; 6. valve; 7. delivery pipe; 8. nonreturn valve; 9. infiltration main; 10. infiltration well; 11. outlet well; 12. floating reduction valve; 13. groundwater level drain; 14. overflow; 15. coke filter; 16. servo-switch*

were turned over to a depth of 2 m. In the third profile the topsoil was brought back on the turned-over clay-loam.

In the 90 and 120 cm groundwater level strips groups of 6 non-weighable lysimeters with a diameter of 80 cm have been built, containing the three profiles of the experimental field. The same groundwater level, including all the small fluctuations, as in the experimental strips is maintained within the containers by means of a mercury-manometer system. This experimental field also includes a meteorological station which provides data to calculate evaporation according a combined aerodynamicenergy balance approach.

On the other half of the field sprinkler and soil structure experiments are carried out.

Besides these two permanental fields some 100 temporary or semipermanent research and trial areas scattered over the Netherlands are in use. On many of them the experiments are executed in combination with other services and institutes. They range from fairly small soil improvement, infiltration and drainage fields to pilot polders and whole pilot regions some for water some for land management purposes (for example the Achterhoek area of 200,000 ha, the 'Peat Colonies' of 100,000 ha, the northern clay area of 150,000 ha and the western grassland-on-peat area of 200,000 ha).

In our wing (fig. 42) of the Staringbuilding at Wageningen a number of other research facilities have been built in.

Laboratories

The first to be mentioned is a laboratory (fig. 43) with a floor space of some 550 m^2. It is divided into four adjacent sections of which two are temperature and humidity controlled. The instrumentation allows to carry out soil-physical, soil-mechanical and mineralogical experiments.

In the cellar the hydrological division has a model space of some 150 m^2 (fig. 44), it is temperature and humidity controlled and adjacent pumping rooms make it possible to work with hydrological models needing a flow of up to 70 m^3/hour. Also situated

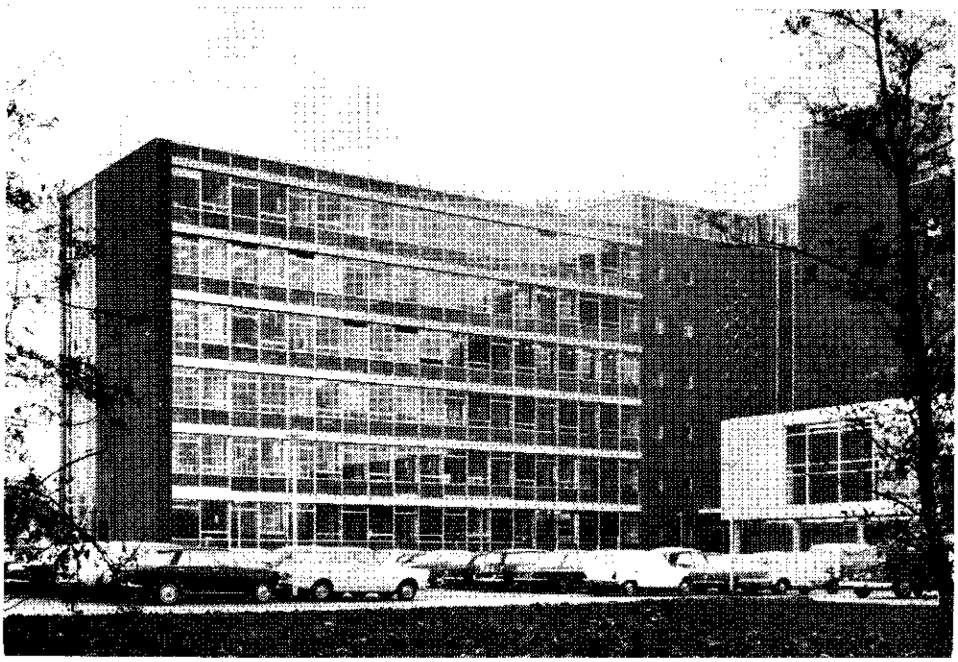


FIG. 42. *The Institute at Wageningen*

FIG. 43. *Part of the laboratory*

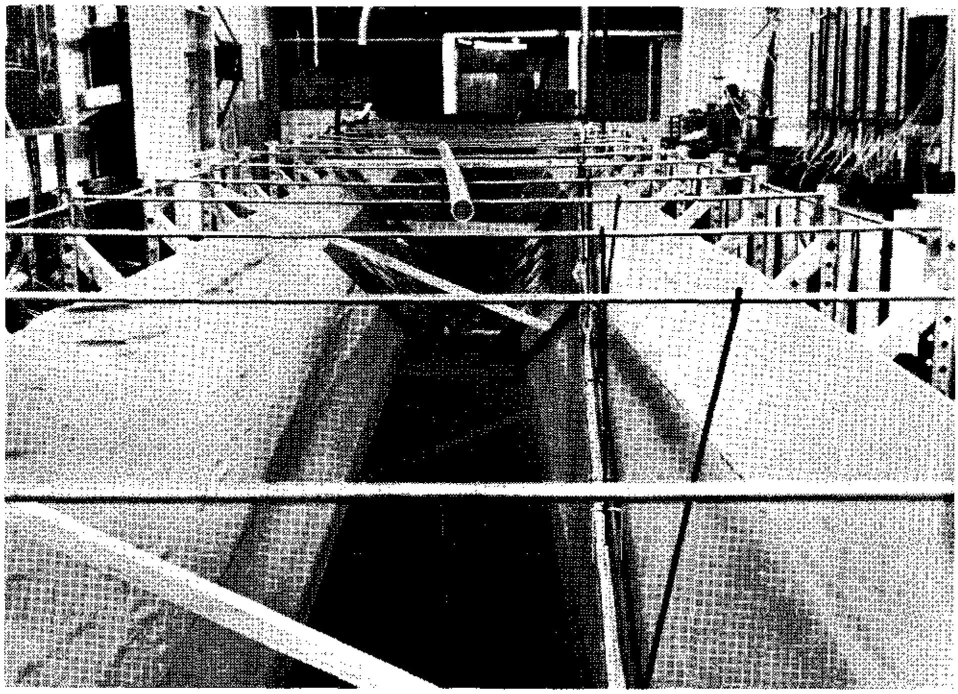


FIG. 44. *Part of the model space*

there are two small radiation laboratories (total floor space about 75 m^2) for moisture determinations and four small laboratories (each 22 m^2) for soil-physical research. All six are separately conditioned as regards temperature and humidity. The division of Bio-hydrology has on that level four fully and more accurately conditioned rooms (each 10 m^2) to be used for plant-physiological experiments. All data can be continuously recorded outside these last mentioned experimental rooms.

Data processing

For data processing, besides a number of mechanical calculating machines, a small table computer is available. Although its memory is small, the possibility to cut immediately into the run of a program, its magnetic card input, which makes it possible to preserve specific programs, and the ease with which research personnel can master its use, make it a useful research tool. To run more extensive programs time is hired of larger machines belonging to data processing organizations, one of which is occupying part of the Staringbuilding. All programs, also for these large computers, are made by the mathematical section of the Institute, which sometimes also runs them on computers of others.

Workshop

The workshop of in total some 100 m^2 is meant to develop and construct prototypes of new research tools in metal, glass or wood.

The making of maps, geo-hydrological profiles, graphs, photographs, slides, etc. is entrusted to the drawing (110 m^2) and photography (55 m^2) offices. They have the tools to carry out any job required. Drawing and photography

Last but not least, it should be mentioned that the general technical service can give aid when labour peaks occur in any investigation, by assigning some of its personnel temporarily to that particular research. Technical service

SCIENTIFIC INFORMATION

Many papers, reports and books have been written on the importance of and the problems with scientific communication and this is not the place to add to the existing literature in this field. It should be mentioned, however, that the Institute regards the dissemination of research results as well as the handling of information as an integral part of research.

Scientific information is received and given, and can be communicated in written form or orally. In this context the library, the publications, the courses and lectures, our visitors and our own visits to other countries, and the technical assistance of our experts to projects abroad will be mentioned in this section.

Right from the founding the library of the Institute was set up to serve as well a sister institute, the International Institute for Land Reclamation and Improvement. The first five years the library was run by our Institute, then the supervision went over to the International Institute. When moving into the new Staringbuilding the libraries of the other services housed in it, of which in connection with our research the most important is the Institute for Soil Survey, went up in the main library run by the International Institute. Library

It consists of a reading room (floor space some 100 m^2, see fig. 45), a book storage of about 1100 m shelf length and the offices of the librarian, the section literature retrieval, the section catalogs and the section loan. At the moment the stock numbers 11,000 books and reports, 9,000 reprints, 400 current journals and 650 serial works. With that it is the largest library on land and water management and soils in the Netherlands. Each year some 1000 to 1500 books and reports, and 500 reprints are added, the current journals and serial works are tried to be kept at a more or less constant number, but are slightly increasing each year.

The library is headed by an agricultural scientist, the retrieval section by a research associate. This ensures that the research workers can easily use technical language to describe their interests when asking for a literature research and that the selections made of existing literature have a greater affinity to the problems under investigation than would otherwise be possible. As regards literature retrieval full use is made of review journals and bibliographies, of which the library has an almost complete collection. All scientists working in the Staringbuilding, and on request those of other organizations, are regularly informed on literature having newly appeared in the fields of land and water management and soils. Since inter-library loan is well-organized in

FIG. 45. *Part of the reading room*

the Netherlands, duplication of incidently used literature is not deemed necessary and neither the necessity to build up large stocks of literature in our subsciences.

As we are greatly indebted for the use we can make of other libraries, our library is, as far as its manpower permits, always ready to extend its facilities to others. Of this service an increasing number of organizations and scientists as well in as outside the country avail themselves.

Publications

The research results of the Institute are published in Dutch or foreign journals or proceedings. In addition three series of research papers are printed and distributed. They are called 'Mededelingen' (Technical Papers), 'Technical Bulletins' and 'Miscellaneous Reprints'. The first two series partly consist of reprints of articles that were published elsewhere, the third one entirely consists of such reprints. Duplication of articles within the three series does not occur. The series do not differ in their scientific value.

The *Mededelingen* (Technical Papers) are written in Dutch and as the series do not overlap this would mean that part of our research results would not be available to scientists working in other countries. To overcome this, all Mededelingen contain an 'integral' English summary. This means that all figures and tables contain also English inscripts; that the subscripts of the figures and the captions of the tables have been fully translated, that an English definition of all used symbols is given in addition to a very extensive English summary. When an original journal article also to be published in this series does not have this 'integral' summary, the type is partly reset or additions are made before having it reprinted.

The *Technical Bulletins* are published in English, the *Miscellaneous Reprints* in Dutch, in English or in any other language. When in our lists of publications in this last mentioned series an English summary is mentioned, here also an 'integral' summary is meant. The series Miscellaneous Reprints was instituted when a few journals publishing in our field of research went over to a size differing from the size of our Mededelingen and Technical Bulletins (the size of this publication).

The three series are sent without cost, on request and on an exchange basis, to interested parties. As addressee we prefer the name of an organization, but private persons engaged in our field of research can be listed. The exchange basis is not held too strictly, requests for a one-way exchange of our publications will be considered.

The Institute realizes that these series add to the already immense flow of scientific literature. With two, already mentioned, principles it is tried, however, to evade the negative sides of private publications while still keeping up the personal information of specifically interested research workers. The first of these principles is: when ever possible the research papers are published in journals and only the reprints (in some cases extended with an 'integral' summary) are used; the second one: the separate publications or the series are only sent on request.

The mailing lists have been set-up according to the following general subjects: water management; plant-soil-water relationships; soil improvement; land layout plus farm economics; land development projects plus their economic evaluation.

Table 7 gives some data on the number of publications during the first ten years of the Institute and their distribution.

TABLE 7. Number of publications (1957 to 1968) and their distribution (1967)

Number	Addresses in system	Meded.	Techn. Bull.	Misc. Repr.	Other*
published (tot. 384)		108	56	59	161
distribution:					
Netherlands	369	369	179	368	approx. 75
other countries	839	518	829	518	approx. 125
total	1208	887	1008	886	200

* Other printed publications (books on specific subjects and articles of a more general nature) some with its own additional distribution by the Institute.

Aside from this distribution according an address system, each year some 500 (100 Dutch and 400 foreign) requests are received for a copy of one or more specific publications. When this is a first request, in most cases an offer to exchange literature is made.

To speed up internal communication and to compile the results of partly finished research, use is made of 'Nota's' (up to 1968, some 475 have been written). These research memo's or progress reports are not official publications, however, and their availability is restricted.

Editing

In connection with the publications the work of the editorial section (headed by an agricultural scientist and a research associate) should be mentioned. To this section belong the drawing and photographic offices, but its most important job is to screen all papers meant for publication. Although the research papers in most cases have already been reviewed by colleagues of the authors and by their division heads, a final scientific check is given them, if thought necessary also involving specific specialists of the Institute. The scientific argumentation is reconsidered in discussions with the author and after agreement between editor and author has been reached, the paper is made ready for a journal, for our own series or for a publisher. When publishing in English it proved that the best scientific narratives were obtained by having the author write the paper directly in that language and correcting it within the Institute.

Teaching

Although the Institute itself has no teaching task, some of the scientists have been asked to give courses and lectures at universities and training centres. In the past ten years they have included series of lectures at the Delft University of Technology, the University of Nijmegen, the Post Graduate Training Centres on Land Drainage at Wageningen, the International Courses in Hydraulic Engineering at Delft, the B-Courses on Land and Water Management for Dutch research associates, the University of Haifa and the ECAFE-courses on The Use and Interpretation of Hydrologic and Meteorologic Data at Manilla, Hong Kong and Taipeh.

Speeches

In addition each year some 25 speeches are given at meetings and symposia in or outside the country. Special mention should in this regard be made of the Symposium on Water in the Unsaturated Zone held in 1966 at Wageningen. Organized by the Institute on request of UNESCO it was attended by 244 scientists from 28 countries.

Visitors

Research workers do not only work they also travel, and when travelling they visit other scientists to talk about their work. It must be stated right here that the Institute in general does not regard these visits as lost time. Our own scientists also seek information abroad and we are very grateful to the people and organizations which have received them with great hospitality and have given them most interesting and sometimes vital new information.

However much is written and published, the necessary shortness of research papers and their scientific aloofness must now and then be remedied by talking with research people from other countries working on related problems. In such talks not only the newest advances made can be talked over but also the as yet unsolvable problems. For these reasons the Institute has always welcomed and in future will continue to welcome its scientific visitors from abroad.

From 1957 to 1968 in total some 1150 foreign scientists have come to the Institute, in the last years about 150 each year. Some stay only a day, some a week, and a few (some 5 each year) extend their visit to some months. In the last cases an agreement will have been made with the visitor on the kind of research problem he will engage in and in which of the Institute's research groups his work will be integrated.

Although differing each year, the following procentual distribution may give some idea of the regions of origin of our visitors: Western Europe 30%; Eastern Europe 20%; North America 15%; Near East 10%; Far East 10%; Australia 5%; Africa 5%; Central and South America 5%.

Technical assistance

The Institute was founded to work on the problems of land and water management existing in the Netherlands. It proved, however, that many of these problems were identical to or closely related with those present in other countries and some of our solutions proved to be equally usable elsewhere. This brought with it that to an increasing extent scientists of the Institute have been asked to act as consultants in land and water management projects and scientific ventures abroad.

The rendering of assistance has more than one side to it. The Institute as such suffers a temporary but relatively important loss during the leave of absence, but gains on the other hand through the larger experience the returned scientist will have. It would be hypocritical to say that giving aid to projects outside the Netherlands does not hamper our proper research work, but far more important is the knowledge that, whatever is our primary task, we not only live in our country but also in the present day world.

The requests for technical assistance, generally coming from international organizations or the governments concerned, have led to the giving of our advice on, or taking temporary scientific participation in, projects in the following regions:

- Medjerda Valley, Tunisia
- Niger Delta, Nigeria
- Adana Plain, Turkey
- Coastal Plains, Israel
- Konya Valley, Turkey
- Polder Projects, Chad
- Danube Valley, Jugoslavia
- Planning a Research Laboratory at Ankara, Turkey
- Project Evaluation, Mexico
- Sebou River Project, Marocco
- Varamin Garmsar Project, Iran
- Plain of Albenga, Italy

It will be clear that it is not possible to denude the Institute of its scientists to carry out tasks outside the Netherlands, but all requests will receive in the future the same sympathetical attention as has been given them in the past and after due consideration some will undoubtedly be granted.