

**Land reclamation and water
management**



ILRI Publication 27

Land reclamation and water management

Developments, Problems and Challenges

A collection of articles published at the occasion of ILRI's silver jubilee (1955–1980)

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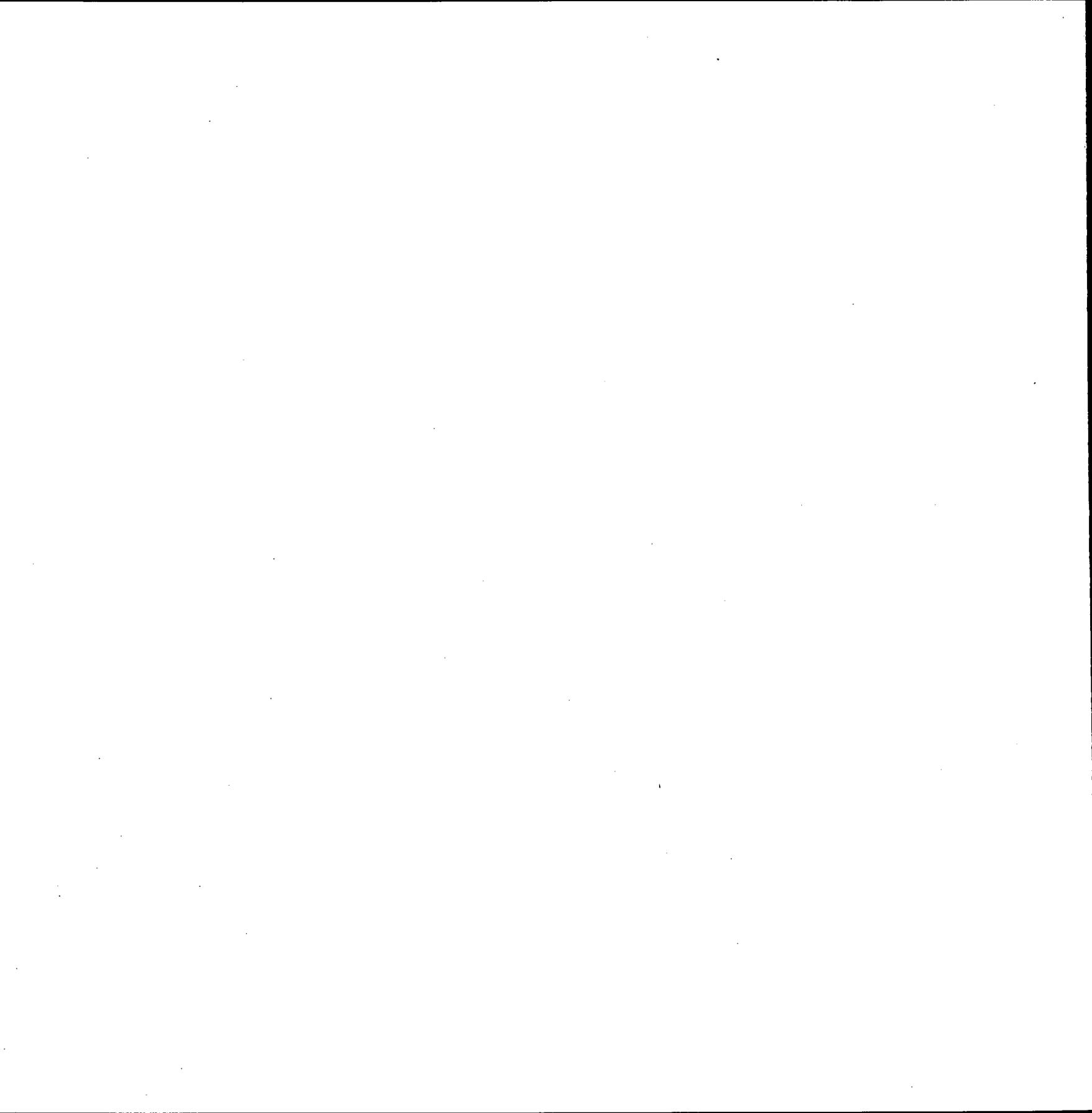
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Preface

On the 13th of September 1980 the International Institute for Land Reclamation and Improvement commemorated its Silver Jubilee.

The Institute owes its existence to the great flood that struck The Netherlands in February 1953. At that time the country received offers of help from all over the world. One of these offers was financial aid from the W. K. Kellogg Foundation of Battle Creek, Michigan, U.S.A.

The Dutch authorities decided to use the aid offered by the Kellogg Foundation to found an institute. This decision was based on the consideration that The Netherlands, with its centuries of experience in battling against the water, possessed enormous expertise that could be passed on to benefit other countries. The major task of the institute would be to collect and disseminate knowledge in the fields of land reclamation and improvement. The institute would be a non-profit organization under the Ministry of Agriculture and Fisheries and would be located in Wageningen because other institutions working in fields closely allied to land reclamation and improvement were already established in that town. And so, on the 13th of September 1955, the International Institute for Land Reclamation and Improvement came into being.

In the ensuing 25 years, the Institute's major task has remained the same, although in 1971 its statutes were altered to direct the activities of the Institute more clearly to meeting the needs of

the world's developing countries.

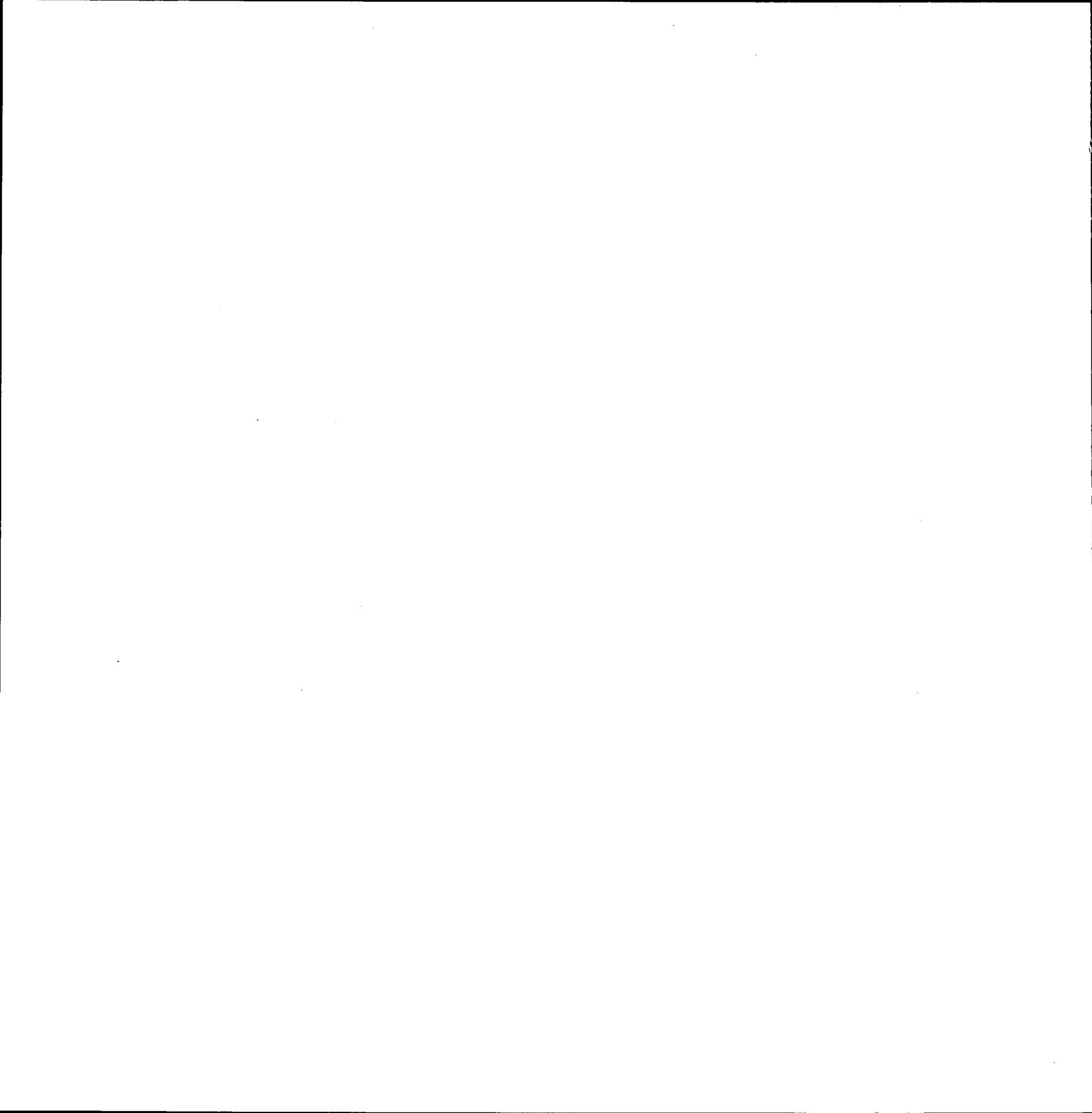
The increasing amounts of funds made available in the 1970's for overseas development work has left an indelible mark upon the Institute. Its advisory services, rendered within the context of the Dutch bilateral programs of technical cooperation, has increased to such an extent that the Department of Development Cooperation of the Ministry of Foreign Affairs now contributes 50 per cent of the Institute's budget.

To mark its Silver Jubilee, the Institute decided to issue a special publication – not one summarizing the Institute's history, but one focusing on the activities in which it is involved: the improvement of land and water use for agriculture, with emphasis on the developing countries.

By drawing attention to what has been achieved in these fields over the last 25 years and by pointing out the problems that still remain to be solved, it was felt that such a book would be of interest to a wider public than one merely reminiscing about what is, after all, the Institute's brief past.

Most of the articles have been written by the Institute's own specialist staff members, and one or two with the collaboration of outside specialists. These articles certainly do not claim to cover all aspects of the complicated process of land and water development in the Third World. They do, however, reflect some of the elements on which the Institute, as part of its statutory task, concentrates its efforts.

F. E. Schulze, Director



Abstracts

Land and water development in the Third World

F. E. Schulze and J. M. van Staveren

Mention is made of successive development approaches and their impact on the use of land and water resources. Estimates of these resources and factors affecting their use are discussed. Agricultural growth targets for developing countries as set in various development strategies are reviewed. The two ways of realizing these targets, i.e. by expanding the cultivated area (horizontal expansion) and raising production on already cultivated land (vertical expansion), are treated extensively, as are the tremendous world-wide efforts they will require. Finally attention is drawn to a number of other factors that affect the development process and to the need to strike a proper balance between the sometimes conflicting goals of a broader based development and the compelling need to raise food production.

From soil survey interpretation to land evaluation

K. J. Beek

The increasing and competitive demand for land both for agricultural production and for other purposes requires that decisions be made on the most beneficial use of limited land resources. After a short historical review of land evaluation, three well-known systems are discussed: the U.S. Dept. of Agriculture's Land Capability Sys-

tem, the U.S. Bureau of Reclamation's Classification for Irrigated Agriculture, and FAO's Framework for Land Evaluation.

Problem soils: their reclamation and management

K. J. Beek, W. A. Blokhuis, N. van Breemen, R. Brinkman, P. M. Driessen and L. J. Pons

Vast areas of problem soils exist in the world. Discussed in this article are vertisols, peat soils, acid sulphate soils, planosols, saline and sodic soils and fine-textured alluvial soils, none of which can be used properly without moisture control and water management. For each of these soils, their properties, problems, present land use, and possibilities after reclamation and improvement are described and their world-wide distribution in tables and maps is given. Some of the lessons learned during the last decades and some of the local solutions to the use of these soils are mentioned.

Groundwater resources management research

N. A. de Ridder

Groundwater resources offer great prospects for development to meet the world's growing demand for water. Three concepts of groundwater resources management are reviewed. Attention is drawn to contaminant transport in groundwater systems and to salt water intrusion into fresh-

water aquifers. In the complex problem of managing groundwater resources, models of some sort are of great help. The most important models are discussed. Two powerful techniques, the finite differences method and the finite element method, are dealt with more extensively. Model calibration is necessary if the predictions are to have a meaning.

Methods and models in surface water hydrology

J. Boonstra

The problem of matching society's demand for water with the availability of water in nature involves various disciplines, one of which is water resources engineering. The role of hydrology in water resources engineering is described, and an explanation is given of how a hydrologist arrives at his design discharge. A review is made of the many methods and models the hydrologist has at his disposal for the quantitative assessment of flood and low flows. A distinction is made between deterministic and statistical methods. Deterministic methods are subdivided into empirical methods and conceptual models, and statistical methods into probabilistic methods and stochastic models.

Developments in planning of irrigation projects

M. Jurriëns and M. G. Bos

The importance of irrigation in the developing countries and the expansion of the area under irrigation are discussed. Sprinkler and drip irrigation are compared with surface irrigation methods, with consideration given to labour requirements, energy consumption, the efficiency of water use, and costs. Improvements in surface application methods are discussed. Several aspects of the conveyance and distribution systems, such as operation and maintenance, efficiencies, and terminal facilities, are reviewed. Some thoughts are given to the performance of irrigation projects in relation to the necessary improvements in the planning and design of the schemes.

Rice cultivation and water control

J. de Wolf

Throughout vast areas of the less well-fed world, rice provides much of the population's total calorie and protein intake. Water, and consequently irrigation, plays an important role in rice cultivation. Attention is drawn to the farmer within an irrigation scheme, to the tertiary unit, and to factors to be considered in on-farm design for water control. Technical issues involve decisions on water distribution, on the magnitude of the irrigation module, and on the tertiary unit size. Also

discussed is the desired degree of intensity in irrigation scheme rehabilitation.

Factors affecting the viability of small-holders' irrigation

L. F. Kortenhorst

The introduction of irrigation into areas where irrigation is not a traditional practice has been receiving high priority in recent years. Irrigation schemes in such areas have been found to contribute little to rural development. A major cause of failure is an overall lack of viability of the project design itself. It is explained that irrigation is a radical intervention in existing farming systems. Some constraints against the successful introduction of irrigation are discussed: culture and tradition, felt needs, skills and knowledge, land tenure, land area, land suitability, water, climate, human health, labour, means, markets, crop health, and risks.

Crop response to water under irrigated conditions

P. J. Slabbers

In the search for ways of raising food production under irrigation, a central theme is the study of soil-water-plant relations. A large majority of the work reported concerns methods with which to estimate 'potential evapotranspiration'. These methods are reviewed. Then a shift away from this philosophy is noted, along with an accep-

tance of 'deficit' irrigation and thus of methods to estimate 'actual evapotranspiration'. Models describing the effect of water availability on crop yield are reviewed and their relevance for application in developing countries is discussed.

The use of saline water for irrigation

J. W. van Hoorn and R. van Aart

Arid and semi-arid countries are facing the exhaustion of their water resources and are being forced to use poor quality water for irrigated agriculture. The result is often disastrous as extensive productive regions become salinized. In determining the criterion for the suitability of the water for irrigation, the following factors are considered: the quality of the water, its total salt content and chemical composition; the structure and permeability of the soil; the climate, especially evaporation, rainfall, and temperature; the crop, yield depression in relation to salt content, salt tolerance; the quantity of leaching water; the irrigation and drainage conditions; and the management practices of the farmer.

The study of effects of drainage on agriculture

R. J. Oosterbaan

In view of the world's vast need for drainage, the data base on the effects of drainage on soil, plant, hydrology, and agricultural practices needs to be expanded. The lines along which past re-

search efforts have developed are reviewed. Results of research in field experiments, where the elements of nature cannot be controlled, often conflict with results found under controlled conditions. The need for monitoring programs and economic evaluations of drainage projects after their implementation is stressed.

Developments in subsurface drainage techniques

G. Zijlstra and C. L. van Someren

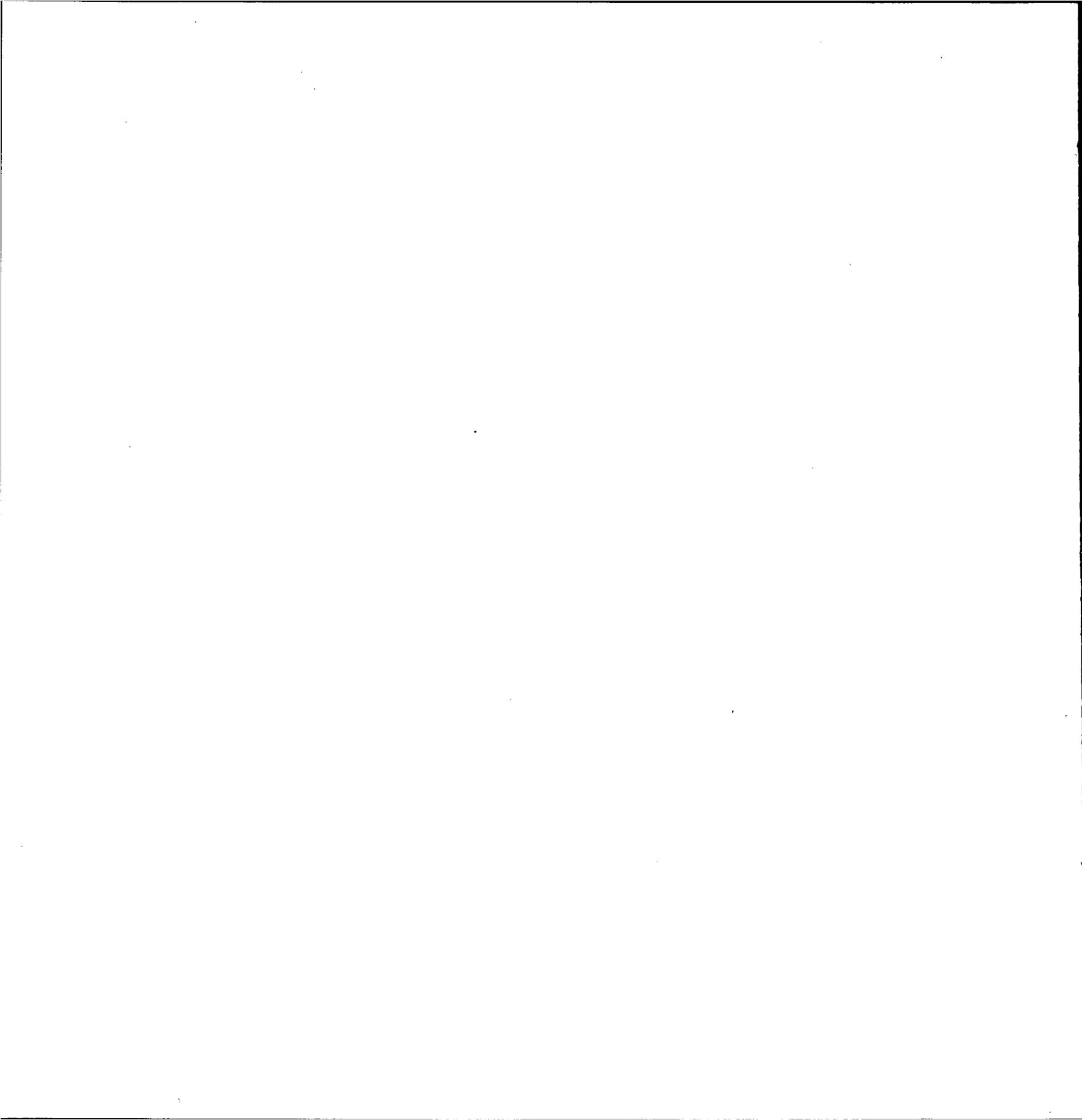
After a short historical review of drainage techniques, the development of the trencher and trenchless drainage machines (or drain plough) is discussed. Dealt with are: depth and grade control, the drain pipes (formerly of clay or concrete and now of plastic), the envelope materials used, and the handling of these materials. Attention is drawn to a new technique, 'horizontal well pointing', which can overcome the problems met in collector pipe laying.

Scientific information: transfer and retrieval

G. Naber

Because of the great quantity of information being produced and the variety of ways in which it is published, the scientist faces a formidable task in keeping track of it all. In an attempt to lighten his task, the structure of scientific information is described, together with the regulatory mech-

anisms that control the flow of publications. Techniques to gather information are reviewed, with particular attention to on-line information retrieval from computer-stored bibliographical records.



Land and water development in the Third World

Successive development approaches

The approaches to land and water development have undergone many changes in the course of time. Some of these changes came about because of changing insights into the use of natural resources, others because of new insights into the problems of underdevelopment that exists in so many countries.

Before World War II, land and water development in industrialized countries was marked by:

- The growing realization that the use of natural resources for economic development was only justified if at the same time care was taken to conserve these resources. What primarily led to this realization was the enormous damage brought by erosion, a dramatic example of which is the 'dust bowl' in the U.S.A. in 1934.
- The concept of multi-purpose projects that regarded a river basin as a unit. Within this unit, water resources were developed under the keywords: irrigation, flood control, navigation, and power generation.

The end of World War II marked the beginning of decolonization. The first post-colonial period was characterized by a great optimism – by a belief in the equality of all nations and a belief in their universal potential for economic growth. Admittedly, some countries (the developed ones) were more advanced; others (the developing countries) less; but policy was directed towards catch-

ing up on arrears. The optimism that marked this period sprang from an implicit faith in an evolutionary, self-strengthening development process. (In conformity with the use of these terms in U.N. publications, *developing countries* are the 90 countries under development market economies, located in the four regions of Africa, Latin America, Near East, Asia (excluding China) and the Far East, and *developed countries* are the countries under developed market economies, and the countries of Eastern Europe and the U.S.S.R. under centrally planned economies.)

When, in spite of these high-pitched expectations, the developing countries did not magically achieve overnight development, the blame was successively placed on: the backwardness of their industry, their lack of infrastructure, their too rapid population growth, and the ill-adapted structure of their society.

Much of the land and water development in this post-war era was focussed on large-scale irrigation projects. These were implemented in the belief that once infrastructural works had eliminated the constraint of water shortage, further development would automatically follow. But here too one soon noted a shift in emphasis: the initial concern for 'water' as the specific constraint was promptly followed by a search for other reasons to explain why development lagged behind expectations. And so began an increasing interest in soil conditions and land clas-

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Ministry of Agriculture and Fisheries (former director ILRI)

sification in their relation to irrigation and drainage. The approach of eliminating one or more bottlenecks continued.

At the beginning of the sixties, other ideas entered the picture. These expressed that the blame lay not so much on the technical problems within the development process, but more on other factors – factors that were inherent to developing countries. Mentioned as examples were that the machinery of government did not function properly and that there were gross inequalities in the distribution of property and income. A different adapted approach was advocated, one that would:

- devote more thought to the agro-technical, economic, and social factors that affect the (small) farmer's production;
- regard the design and construction of tertiary unit facilities as an essential part of a water management project and not leave these matters exclusively to the farmers, who usually lack both the means and the knowledge to handle them;
- institute pilot projects so that experience could be acquired and a better insight gained into local problems before large-scale implementation;
- accept the complexity of the planning process and adopt a multidisciplinary, integrated approach.

In the seventies, the developing countries sounded a note of their own, with insistence upon self-reliance (Non-Aligned Countries' Conferences in

Lusaka 1970 and Georgetown 1972). With faith in their own powers, they would pursue a development policy aimed at creating their own social and economic communities. This concept was soon followed by another; that of basic needs, which emphasized the urgency of providing all people with food, housing, education, and health care. A logical consequence of the basic needs approach was an increased concern for the plight of the poorest elements of society, whereby high priority was given to the issues of employment for all and an equitable income distribution.

As both these concepts – that of self-reliance and basic needs – still feature prominently in discussions, we cannot say what ultimate effect they will have on national development plans or on bilateral aid programs. However, they include obvious desiderata that are most certainly influencing trends in land and water development. These are:

- a growing interest in, and a consequent larger flow of funds to, small-scale development;
- more consideration being given to appropriate technologies, low costs, and labour-intensive methods;
- the active involvement of the local population in planning and implementing a project and in its subsequent operation and maintenance;
- the selection of land and water development projects on broadly-based development goals of

income distribution, social services, employment promotion, etc., rather than on purely technical and economic criteria.

This fragmentary account shows how turbulent the process of development is. Within the space of a quarter of a century, changing insights into economics and techniques and changing socio-political attitudes have all had their repercussions on development. One could regard the process as the inevitable pains that accompany growth, and, of course, no experience could ever be acquired without trial and error, even though such exercises are expensive in terms of time and money. But it would be naïve to imagine that the process is nearing any definitive form. Instead, one can expect a constant flux of impulses (from within and without) – all calling for adjustments in national and international policies. The uncertain future of the world's energy supplies is a case in point.

One obvious conclusion is that any long-term planning should consist of a series of programs that have broad aims and an in-built flexibility that allows them to be adapted to new insights and events. Within this flexible framework, a continuous stream of small projects can be implemented, all designed to yield their socio-economic benefits with a minimum of delay and each drawing upon the experience gained in preceding projects.

Land resources versus their threats

In the course of time, various authors have produced appraisals of the magnitude of potentially arable land. Some of the more recent appraisals are presented in Table 1.

From a comparison of the potential areas with those at present cultivated, one could get the impression that there is still ample land for development. But, as will be explained later, it is feared that the costs of developing much of this land will be prohibitive.

A breakdown of the figures per continent shows that the reserves are principally found in:

- Latin America and tropical Africa, under developing market economies

Table 1.
Estimated potential arable land, in million hectares.

Authors	World total	Developing countries only
Kellogg and Orvedal (1969)	3,200	
Kovda (1974)	5,000	
Buringh (1975)	3,400	1,800
Revelle (1976)	3,150	1,575
FAO (1979)		1,774
Presently cultivated (1975)	1,400	730

- the Asiatic parts of the U.S.S.R, under a centrally planned economy
- North America and Australia, under developed market economies.

In their estimates of potential arable land, the authors cited have disregarded possible losses of land. Throughout history, however, irreparable damage has been done to land through drastic deforestation (for fuel, building materials, etc.) and the over-hasty reclamation of marginal soils. The total area of destroyed and degraded soils that were once biologically productive is estimated at 2.000 million hectares, thus more than the world's present-day cultivated area! The main loss took place in the last 100 to 200 years (BENNETT 1939, KOVDA 1977).

Today's generation recognizes the dangers, and is in principle familiar with the procedures of curbing erosion and conserving the land. Nevertheless, the process of land degradation continues—often as a side-effect of land development, and especially at places where population pressure, overgrazing, and mismanagement have upset the natural equilibrium between soils and vegetation. KOVDA (1977) estimates that world-wide a total of 5 to 7 million hectares of land are lost to agriculture each year through water and wind erosion, salinization, urbanization, rural settlements, road systems, industrial enterprises, mines, oil fields, and soil contamination. At least half of the yearly loss of land (or approx-

imately 3 million hectares) is attributable to the conversion of crop land to non-agricultural uses (BROWN 1978). As this encroachment is proceeding in the same proportion as the growth in population, this negative component can be expected to double in the coming decades, with most of it concentrated in the developing countries. Other negative effects of this conversion are that the quality of the newly-won land will be lower than that of the converted land (and the costs therefore higher) and that it will in general be farther removed from the existing population centres.

Apart from the loss of crop land through its conversion to other uses, there is every reason to fear that the natural soil fertility in areas sensitive to erosion—and these constitute a far from negligible part of the arable area—will decline as the top layer of soil is gradually removed by wind and water. This creeping process of gradually declining yields can ultimately lead to the abandonment of the land. No reliable mondial figures are available on the extent of these processes. Their effects are often blurred, and they can be temporarily compensated for by increased fertilizer applications. But recent figures from certain countries and regions (e.g. the Sahel) present anything but a cheerful picture.

We even venture to cast doubt on the statistical figures that governments supply regarding their areas of arable land. Do they, we wonder, in their

figures, properly take into account the land that is lost through degradation, urbanization, etc.?

The further expansion of arable land will take place on soils that are even more sensitive to erosion than the present arable land. What is more, the future areas are now under forest or other vegetation and thus fulfil a function in maintaining ecological equilibrium. Gross exploitation of natural forests, as is now taking place in Asia and Latin America (respectively 8 and 5–10 million hectares a year) will, if allowed to proceed unchecked, form a serious threat to ecological equilibrium within two or three decades.

Another problem, for which one must be increasingly on the alert, is the dispersion of toxic substances (fertilizers, biocides, etc.) through the air and through waterways. Industrial countries have already suffered damage from these pollutants. Their widespread use in developing countries will call for great ecological awareness on the part of those responsible for research and development, both in governmental and industrial circles (de BIVORT 1975).

It will be clear that strenuous efforts must be made to prevent any further losses of land. Reforestation must provide degraded land with a new vegetational cover, and a halt must be called to further upsets in the ecological equilibrium. Nevertheless, none of this will be achieved without a heavy flow of finances, a large measure of legislative action, and intensive programs to

make everyone involved aware of the gravity of the situation.

Water resources

Few estimates have been made of the available quantities of river flow, although it is generally accepted that the total annual flow is between 40,000 and 47,000 km³. Part of this, however, concerns flood flows, which cannot be regulated economically and are therefore unusable. LVO-VITCH (1973) estimates flood flows to be 64 per cent of the total, so that in principle 36 per cent of the river flow, or some 14,000 km³ a year, is available.

This appears to be quite a large quantity in comparison with the present total quantity used (roughly 3000–3500 km³). But one must not forget the variability in space and time: the water is not always available in the right place or at the right moment. It is therefore not surprising that groundwater is nowadays receiving widespread attention. The article by de Ridder makes clear that a great potential exists for groundwater. But here too one meets problems, in the sense that in many places where groundwater is needed it is not always of good quality or it cannot be exploited economically.

Estimates of the present – let alone the future – water use for irrigation are characterized by a great diversity, not only because the quantities

required per project differ owing to variations in evaporation, effective precipitation, etc., but also because of variations in the irrigation losses, which ultimately determine the gross demand. One must therefore not be too surprised at the widely divergent estimates of the present and future water use for irrigation as shown in Table 2. FAO (1974) reckons with a gross demand (crop use and irrigation losses) of 15,000 m³ per hectare per year for rice and 7,000 m³ for other crops. At first glance these figures seem rather low, but they are not improbable when one considers that they are average values which include the low water requirements for supplementary irrigation.

Estimates of the water needs for non-irrigation purposes are even more difficult to make. To give an idea of the order of magnitude, however, in comparison with the 2,500 km³ used for irri-

Table 2.
Estimated world-wide water use for irrigation.

Source	Year	Present use		Future use	
		(km ³)	year	(km ³)	year
Doxiades	1967	1325	1960	3120	1990
FAO	1971	1400	1965	2800	2000
Lvovitch	1973	2300	1965	–	–
FAO	1974	2570	1970	–	–
FAO	1977	1250 ¹	1974	1700 ¹	1990

¹ Developing countries only.

gation, industry currently uses 500 km³ while another 200 km³ is used for various other purposes, including domestic water supplies. It is obvious that under the present circumstances, irrigation, which accounts for roughly 80 per cent of all water now used, is by far the greatest consumer and is likely to remain so for some time to come.

But we must reiterate that these figures are only very rough estimates and claim to do little more than indicate an order of magnitude. The future water use depends on such a great many factors, including the future world economy, that any estimate of its quantity can be regarded as no more than an educated guess. Certain factors, however, seem to indicate that by the year 2000 the world will be using some 6,000 to 7,000 km³ a year, which comes close to half the earlier-mentioned total available quantity of river flow: 14,000 km³. A much-heard cry nowadays concerns the need to practise greater economies in the use of water. Forming part of this trend are the efforts being made to improve the efficiency of water use in irrigation schemes. Rehabilitating existing schemes and improving on-farm water use are key words in this process. The FAO Committee on Agriculture in its 1979 session rightly called for national and international action programs on these subjects.

There is indeed no real need to argue the case for safeguarding earlier investments and preventing

further land degradation by improving and rehabilitating existing schemes, rather than embarking on new schemes. For the planner and designer, this may be a far less glamorous task, but there is no doubt that rehabilitation will offer considerably higher and far more rapid returns on investments than will new projects.

Until now, most of our remarks have been concerned with water quantities, which does not in any way imply that the quality of the water is unimportant. The article by van Aart and van Hoorn discusses the use of saline water for irrigation. Even if theoretically usable, however, saline water requires a highly sophisticated management to prevent the delicate relationship between soil, water, and crop from being disturbed. That such careful management is all too often underrated is clear from the estimates by the United Nations (1977) that approximately 120,000 hectares of irrigated land are annually lost to production.

Irrigation itself is one of the major polluters of water. In a study of the Colorado River, EL ASHRY (1980) showed that 47 per cent of the river's salinity load could be ascribed to natural causes and 45 per cent to irrigation.

The very low efficiency of water use common to irrigation projects – sometimes only 20 to 40 per cent – results in the outflow of huge quantities of unused irrigation water, whose quality often leaves much to be desired. In many countries

with a shortage of irrigation water, apart from the efforts being dedicated to raising irrigation efficiencies, the re-use of drainage water has become a central issue. It speaks for itself that the problems faced by management in manipulating both water quantities and water qualities are very complicated indeed.

Agricultural growth targets

The current world population is roughly estimated at 4,200 million (1978 figures), half of whom live in developing countries. A major distinction between the two halves into which the world can thus be divided is the growth rate of their populations: in the developing half a growth rate of 2.6 per cent per annum, and little more than 1 per cent in the developed half (including China). A country's demand for food is closely linked to the size of its population and to their income. The relatively high growth rate in the developing countries generates, at the very least, a proportional growth in their food demand. Any improvement in their income – which, unfortunately, is difficult to realize – drives the food demand even higher. A grim truth is that in the developing countries, approximately 450 million people (more than 20 per cent!) are suffering from severe undernourishment (FAO 1978).

These malnourished people are found mainly in the poorest countries, in the poorest urban popu-

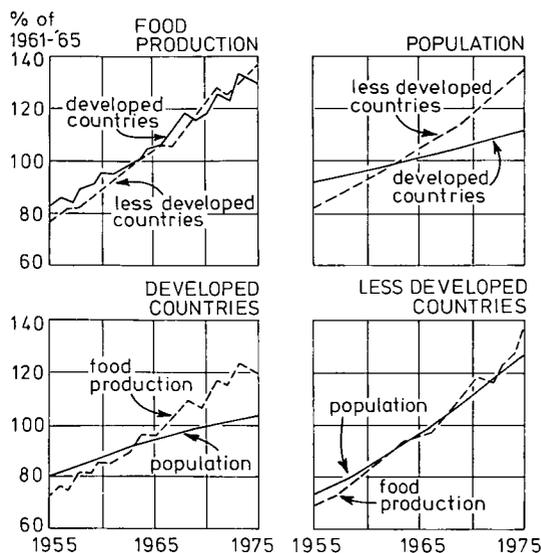


Figure 1.
Food production and population in developed and developing countries (Economic Research Service, U.S. Dept. of Agriculture 1979).

lations, and in rural areas where adverse ecological conditions or other factors have led to widespread unemployment.

The world's food production is indeed growing, but it fluctuates because of weather conditions or natural disasters that constantly upset the balance. The neck-and-neck race between food demand and food production is reflected in Figure 1.

The most important aim in food production is to achieve regional self-sufficiency, either per country or per group of countries. The recent trends in self-sufficiency shown in Figure 2, however, reveal an almost unanimous decline.

The question of future food supplies thus remains an urgent and challenging issue for which the answers must be sought in the developing countries themselves. Shipments of food from the developed half of the world — except incidentally in emergencies — would not lessen the predicament. Much more than just food supplies are at stake. Between 60 and 70 per cent of the people in developing countries depend on agriculture for their livelihood. The only way they can obtain the sorely needed increase in their income

is to raise production, with room to market high-quality crops.

The target set for the developing countries in the Second U.N. Development Decade — DD 2 — (1970–1980) was an average annual increase in agricultural production of 4 per cent. This target was reaffirmed by the U.N. World Food Conference of 1974. For years now, however, the actual increase has not exceeded 2.6 per cent, which is just sufficient to keep pace with the population growth and does nothing to alleviate undernourishment or to improve incomes.

In preparing the strategy for DD 3 (1980–1990), the magic figure of 4 per cent has once again been set. What this means in terms of accelerated agricultural growth and the development of land and water resources is shown in Table 3.

In principle, production can be raised in two ways: by expanding the area of cultivated land (horizontal expansion) and by intensifying production on already cultivated land through irrigation, improved seeds, etc. (vertical expansion). From 1963 to 1975, roughly one-third (or 0.8 per cent) of the annual increase in production was realized by horizontal expansion and roughly two-thirds (or 1.8 per cent) by vertical expansion. To meet the target set for DD 3, these two expansions will have to accelerate by half as much again, which means, maintaining the same ratio, an annual increase of 1.2 and 2.6 per cent respectively.

The targets set in *Agriculture: toward 2000* (FAO 1979) are 3.6 per cent per annum for crop production and 4.7 per cent per annum for livestock. As livestock constitutes 20 per cent of the gross value of agricultural production, the mean target growth rate is some 3.8 per cent per annum. According to this study, 28 per cent of the additional crop production will result from horizontal expansion and 72 per cent from vertical expansion. For the countries concerned, this will mean vigorous extra efforts. Let us now examine the possibilities and the constraints of such a meritorious but ambitious program.

Vertical expansion

Crop yields in the developing countries are lower than those in the developed countries. For instance, the average yields of cereals in the developing countries are between 1100 and 1500 kg per hectare, but are considerably higher in Europe and the U.S.A. These differences are primarily due to differences in levels of farm management and consequent differences in farm inputs. The importance of various yield-improvement factors, and their cumulative effect, can be seen in Table 4 (see also article by Jurriëns and Bos). The traditional closed subsistence system adopted in most developing countries does not include the use of fertilizers, which means that not all the land can be cropped each year and that

Table 3.
Growth rates for some selected key figure (90 developing countries).

	Average annual growth from 1963–1975		Target annual growth for 1980–1990	
	in per cent	in million ha	in per cent	in million ha
Gross value of agr. production ¹	2.6		4.0	
Gross value crop production	2.6		3.8	
Arable land	0.8	appr. 6.0	1.2	appr. 10.0
Yield (per ha)	1.8		2.6	
Irrigated area	2.6	appr. 2.2	2.2	appr. 2.5

¹ including livestock.

part of it must lie fallow. Cropping intensity is rarely more than 60 per cent. With a transition to more modern systems of farm management, cropping intensities could be raised to more than 100 per cent through multiple cropping. Admittedly, this is only possible in areas that have a good rainfall distribution or are irrigated under good water management, but many parts of the tropics and subtropics can satisfy these requirements. To give an idea of the yields that could be obtained, reference is made to a study by BURINGH, van HEEMST, and STARING (1975). On the basis of climatological data and the rea-

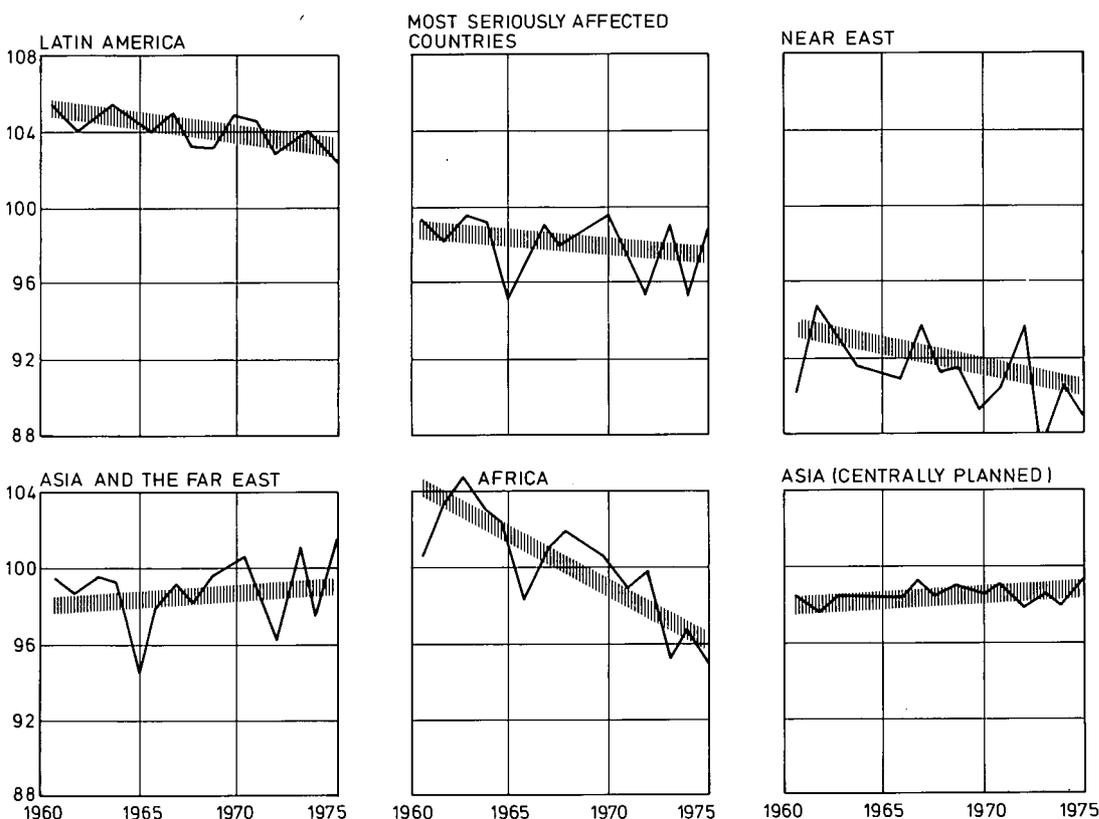


Figure 2.
Trends in self-sufficiency¹.

¹ Only in Asia and the Far East, including the Asian centrally planned economies, is there an upward trend in levels of food self-sufficiency. The situation for all other regions and groupings reflects a steady downward trend, although there have often been sharp year-to-year fluctuations. The most dramatic decline has been in Africa where the self-sufficiency ratio has dropped from a height of 104 in 1963 to about 95 in 1975. The decline in the Near East reflects, in part, the demand for imported food among oil-exporting countries. Only Latin America has been able to sustain a food self-sufficiency ratio above 100, but even there the trend is downward. (Source: FAO, Ceres, Vol. 12-1)

sonably well-known process of photosynthesis, these authors calculated the theoretical absolute maximum food production, which they expressed

in dry matter production per hectare per year for 222 broad soil regions of the world. In their calculations, they assumed that the soils had been

brought to optimum condition, that they received fertilizers and other amendments, had an optimum water supply, and that plant diseases did not occur. They used two reduction factors; one where soil conditions would be a limiting factor and one where water deficiency might occur. In this way they arrived at a world-wide average yield of 14 tons per hectare per year, with averages per continent varying from 10 tons in Europe and Australia and 18 tons in South America. In spite of the reduction factors, however, these yields must be regarded as theoretical only. They will never be attained in practice because of economic and organizational limitations. Nevertheless, it is interesting to see how closely these maximum yields are being approached by yields obtained here and there under optimum circumstances (see Table 5).

The study by Buringh et al. shows that the potential production level in tropical and subtropical areas, where most of the Third World countries lie, is significantly higher than that in the temperate zones, which contain the main industrial countries. According to van ITTERSUM (1971) the best farmers ought to be able to reach a production level that lies 25 to 35 per cent below the theoretical maximum. In its 1977 Annual Report, the International Rice Research Institute (IRRI 1978) estimates the practical production potential in the order of 50 per cent of the biological potential. If developing countries

Table 4.

Assumptions regarding contributions to yield growth from selected yield-improving factors over the period 1965–2000 in the Indus Plain of Pakistan (LIEFTINCK et al. 1969).

	Factor contribution in isolation %	Cumulative yield %	Apparent contribution in combination %
Present yield		100	
Factors			
Additional water supplies alone	10	110	10
Elimination of waterlogging and salinity	10	121	11
Application of fertilizers	40	169	48
Disease and pest control	15	195	26
Improved seed preparation and cultivation practices	20	234	39
Improved varieties	20	281	47

Table 5.

Observed and calculated maximum yields.

Country	Crop	Actual yield in tons/ha	Calculated max. yield in tons/ha
Philippines	3 rice crops per year	26	28.6
N.W. U.S.A.	wheat	14.5	15–18
Netherlands	wheat	8–9	10.5
Madagascar	2 rice crops per year	16.2	17.7
Senegal	2 rice crops per year	14	16.9
S.W. Finland	winter wheat	6.2	7.2

could achieve even this level, it would mean crop yields at least five times as high as those obtained at present.

In spite of the many factors that make it impossible to attain the theoretical maximum yields – a phenomenon that has currently become known as the 'yield gap' or the 'potential performance gap' – there is still abundant scope, especially in the Third World, for increased production through vertical expansion.

Horizontal expansion

For agriculture, the factor 'land' is, both literally and figuratively, the basic resource. Within the identified total potential arable area of about 3,400 million hectares, many different soils occur. Throughout the course of history, in the nature of things, the best soils were always the first to be brought under cultivation. The reserves of land that still remain can be regarded as 'inferior', with explicit limitations to their use. Or to put it another way, the cultivation of these soils will mean relatively high reclamation costs and high recurrent costs for their proper management. Of the 3,400 million hectares of potential arable land, more than 1,400 million hectares are at present under cultivation, thus leaving some 2,000 million hectares of potential reserve. This physiographic statement, however, gives expression to highly charged hopes that are far removed from reality.

As the population growth in the developed countries is relatively small (about 1 per cent) and as there is no other urgent economic stimulus to expand agricultural production, it is unlikely that any large-scale development of new land will take place there. The reserves of land in those countries can therefore be regarded as latent.

Further, experience has shown that one must not entertain any great expectations of permanent agriculture in areas at present covered by tropical rain forests. In the Amazon Basin in Brazil, for example, little more than 5 per cent of the land is fertile; as well, the cultivation of annual crops is greatly hampered by plant diseases. Before these areas can be used for basic food crops, an entirely new 'agroforestry' method will have to be developed. Anyway, in the interests of maintaining ecological equilibrium, the area of arable land within this agroforestry structure will have to be kept to a certain minimum, which will be only a small part of the whole.

Under the pressure of population growth in the last decades, vast areas of land in the developing countries have been opened up for cultivation, although not always with success. The costs (primary and recurrent) of reclaiming the land usually far exceed the estimates, while one also finds that current management practices often prove futile in keeping the fragile newly-won land in sustained production.

The investments needed to reclaim new areas will be considerably more than the investments that went into previous reclamations. The study by BURINGH et al. (1975) grouped the yet reclaimable land into classes on the basis of the cost of their development. Table 6, which was compiled from their data, shows the areas and classes per continent.

The table forces the conclusion that, because of the high costs, not more than 200 or 300 million hectares of land in the Third World countries could justifiably be considered for development in the coming decades. (This is apart from some millions of hectares of the lowest cost classes that occur dispersed over extensively exploited agricultural areas).

The margin for expansion thus totals only 25 to 30 per cent of the existing arable land, of which by far the major part lies in Africa and a small part in South America, whereas Asia offers almost no opportunities for further reclamation at a reasonable level of investment. The unfavourable distribution of the land reserves over the continents is clear when one considers that Asia (excluding China) has twice as many inhabitants as Africa and South America together.

Taken all round, and whilst admitting the differences between continents, one should not entertain any great hopes of large-scale expansion of the arable areas in the Third World. In their development planning of the past decades, some

Table 6.

Yet reclaimable land, classified according to investments (Areas in million hectares. Costs in U.S. \$¹, 1975 prices) (BURINGH et al. 1975).

	Potential arable land	Already cultivated land	Potential ² arable land reserve	Classes of development costs in U.S. \$ per ha				
				(1) less than 300	(2) 300 to 1500	(3) 1500 to 3000	(4) (5) 3000 to 4500	(5) more than 4500
Africa	711	158	533	—	176	206	162	9
South America	596	77	519	—	31	163	125	200
Asia ³	887	689	198	—	—	—	82	116
Subtotal	2,194	924	1,270	—	207	369	369	325
Europe ³	399	211	188	—	—	140	369	325
North America	627	239	388	—	—	351	37	—
Australia	199	32	167	—	—	31	123	13
Subtotal	1,225	482	743	—	—	522	200	21
World	3,419	1,406	2,013	—	207	891	569	346

¹ The costs refer exclusively to works for the reclamation proper: clearing, soil conservation, terracing, levelling, drainage, subsoiling etc. Not included are the costs of infrastructure (roads, waterways, main irrigation works, etc.) or of settlement (housing, service centres, etc.)

² The figures for the potential arable land reserves for Africa, South America, and Asia are approximately 20 per cent more than the estimates given in the recent FAO study: *Agriculture: toward 2000* (1979)

³ The U.S.S.R. area is divided over the European and Asian continents

developing countries have placed great emphasis on new reclamations; the total annual increase has been approximately 6 million hectares. We cannot help wondering, however, why these countries do not shift their planning into the line of vertical expansion, which offers far more opportunities of increasing production than does horizontal expansion. But here we are merely repeating a recommen-

ation heard at a succession of international conferences.

The current rate of new land development can scarcely keep pace with the losses of land through erosion and other forms of degradation. There is a lack of logic here when one observes the great technical and financial efforts being put into reclaiming new land, while elsewhere land is being lost as a result of neglect or inexpert

management. The costs of land conservation and land improvement are only a fraction of those of development. What is more, once land has been rigorously degraded, it can usually be written off as lost for use as future arable land.

Perspective plans

During the last ten years, various U.N. agencies

have devised strategies for agriculture and included in those strategies estimates of the investments that would be required to make them succeed. Some of these studies are:

- Indicative world plan for agricultural development, FAO, Rome (1970)
- World food problem – proposals for national and international action, World Food Conference (1974)
- A perspective on the food grain situation in the poorest countries, World Bank (1977)
- Investment and input requirements for accelerating food production by 1990 in low-income countries, International Food Policy Research Institute (IFPRI 1979)
- Investment requirement for food production, U.N. World Food Council (1979)
- *Agriculture: towards 2000. A normative scenario*, FAO, Rome (1979)

All these studies share one basic consensus: that the growth rate of the gross agricultural production in the developing countries must increase from its historical 2.6 per cent per annum to a new level of approximately 4 per cent.

The contents of the successive strategies reflect the ever-deepening insight into the priorities within the development process. That the cost estimates of each successive strategy are higher than those of the preceding one is not just a matter of inflation; they reveal the growing awareness that alongside costs at project level, there is

a need to include other costs as well. FAO's most recent effort, *Agriculture: toward 2000*, for instance, differentiates between:

- Net and gross investments, the difference between them accounting for depreciation charges on existing capital stocks. Those charges may vary considerably per type of investment. On the average the depreciation share of the present package amounts to between 41 and 43 per cent of the gross investments.
- Investments according to OECD's narrow and broad definition. Included in the broad definition but not in the narrow are, for instance, the investments required for the manufacture and maintenance of agricultural inputs, agro-processing industries, infrastructure and transportation, and regional or river development projects.

Let us now take a look at some of the more salient points that emerge from *Agriculture: toward*

2000. This study assesses the implications for the development of agriculture as a whole (including non-food crops and livestock production) and for the 90 developing countries together.

The target set by this perspective plan is that between 1980 and 2000 agricultural production in the 90 developing countries will have to increase at an average rate of 3.8 per cent per annum. The funds needed to hit this target are tremendous, as can be seen in Table 7.

According to the table, to achieve the projected average annual growth rate of 3.8 per cent, the annual investments in agriculture must double in the coming 20 years. The proportion of investments for crop production spent on land development, soil conservation, irrigation and flood control will decrease from approximately 70 per cent in 1980 to 50 per cent in 2000 as far as the net investments are concerned and from 50 to 40

Table 7.

Annual investment requirements for agricultural development in 90 developing countries (amounts in \$ 1000 million, 1975 prices).

	1980		1990		2000	
	net	gross	net	gross	net	gross
Crop production	15.4	31.0	22.5	44.6	29.0	59.7
Livestock production	3.5	3.5	6.7	6.7	10.8	10.8
Storage and marketing	2.7	3.9	4.1	5.9	5.3	7.9
Transporting and processing	8.4	14.0	13.1	21.2	16.7	28.3
Total	30.0	52.4	46.4	78.4	61.8	106.7

per cent for the gross investments.

The program scheduled for the land and water investments is broadly in line with the possibilities that have been discussed earlier in this article.

Summarizing this program, it incorporates:

- the reclamation of rain-fed arable land at an annual rate that starts at 5 million hectares in 1980 and rises to 10 million hectares by 2000
- soil and water conservation for a total of 190 million hectares to be reached by 2000
- flood control works for the protection of an additional 15 million hectares by 2000
- the development of new irrigation schemes at an annual rate of 2.4 million hectares
- the rehabilitation of 13.4 million hectares of existing irrigation schemes.

The question arises how the required investments are to be financed. There is no doubt that the developing countries will have to mobilize immense new resources to cope with the investments, both within their own borders and outside. The low income countries, in particular, will have to rely heavily on development aid.

The FAO projection is based on the assumption that aid from outside, i.e. from the developed countries, will cover the major part of the foreign exchange component of investments, together with a 10 per cent share of the component of current inputs, as well as the usual contribution of technical aid.

Thus aid from outside will amount to roughly

one quarter of the gross investments, or \$ 13,000 million in 1980 and \$ 27,000 by 2000. When these figures are compared with the 1977 level of \$ 4,300, it is obvious what a tremendous increase this will mean in outside aid.

The contribution on the part of the developing countries themselves is in no way a modest one. Indeed, tremendous efforts will be required of them in financing their part of the affair, and most of the funds will have to come from an increase in agricultural production.

The astronomical amounts involved in the projected development of land and water make it clear that financing the programs will be one of the major constraints. It can only be hoped that new international development strategies will find the means to implement these programs, programs that are becoming – literally and figuratively – a matter of life or death!

Other factors of development

In the foregoing analysis of the needs on the one hand and the potentials on the other, the stress lay primarily on the physical factors of land and water. This may have created the impression that the solution to problems like the world's food situation is purely a matter of making a better and more intensive use of these natural resources. Although nobody will deny that this is indeed one of the requirements, it has been made abundantly

clear in practice that a number of other factors, all of a socio-economic nature, play a role of decisive importance. In this article, it is not possible to go into all these factors in detail. Yet we would be failing in our task if we did not mention at least some of them, even if only briefly.

One of the first issues that thrusts itself into the foreground is the question: why, when it has been shown that agricultural production per unit of land in the developing countries could be increased five times over – why then has the annual average increase from 1963 to 1975 been a mere 1.8 per cent? This leads automatically to a second question: what value can we attach to growth targets of 2.6 per cent yield increase per hectare per annum as set, for instance, by FAO in *Agriculture: toward 2000* or for the Third U.N. Development Decade (1980–1990).

If the reader expects well-reasoned answers to these two questions here, he will be disappointed. We could list many factors that are involved in one way or another, but instead we shall restrict ourselves to some general observations.

The first of these concerns the growing cognizance that the failure of development projects and programs in the Third World is primarily due to the lack of proper knowledge of the local situation. The article by Kortenhorst discusses some of the human aspects surrounding the question: why does the farmer act the way he does and why can't he or won't he act otherwise?

In his decision-making, the farmer is influenced by factors that are rooted deep in the total socio-economic context within which he functions. There are actually two sets of factors: one over which the farmer can exert control and which have to do with his pattern of expectations, and the second set of factors which are inherent to his environment and over which he has no control. It is vital that planners have a thorough knowledge of both sets of factors if projects and programs intended to develop the rural areas of the Third World are to succeed. The first step, recognizing the importance of this knowledge, has already been taken. If it is followed by other steps which translate this recognition into action, a moderate measure of optimism for the success of further projects might not be out of place. For our second observation, we refer to a publication by de WIT and van HEEMST (1976). In this publication, the production increases in a number of countries, expressed in kilograms of grain per hectare per year, are compared in a historical perspective. It appears that in countries that can be classified as developing, the production increase over a great many years is at a level of about 17 kg per ha per year. Expressed as a percentage, this annual increase at a production level of, say, 1500 kg is only slightly above 1 per cent. But, it also appears that as soon as the yield level reaches some 1700 kg, other agricultural techniques are introduced,

which causes the annual increase to rise abruptly to 78 kg per ha. This is a 4 per cent rise, and is more than the rate of population growth. So on this matter too, a moderate measure of optimism is justified.

Another issue that warrants discussion is the need to modernize agriculture. By this we do not simply mean improved production methods and better management, but the absolute and dire necessity to modernize in order to meet the world's demand for food.

BURINGH and van HEEMST (1977) calculated that without mechanization, motorization, and the use of fertilizers and biocides, it is utterly out of the question that the world can be provided with sufficient food. Moreover, a system without these measures would, because of the enormous areas of land that would have to be brought under cultivation, mean an unacceptable onslaught on the already fragile ecological equilibrium. Modern agriculture confined to a minimum area would therefore seem to be the only way to maintain ecological equilibrium and at the same time produce enough food.

A further issue that deserves consideration is what are known in economics terminology as 'externalities' and in technical terminology as 'disruptive side effects'. Both these phenomena are closely interwoven with the knowledge that the planner has of the processes in which he intervenes to make them satisfy certain development goals.

An example of disruptive side effects is the occurrence of high watertables and consequent soil salinization that result from irrigation. Such effects can occur if the planner is insufficiently knowledgeable of the natural processes that follow the implementation of a project. In how far they occur because they were deliberately left out of consideration for political or financial reasons, we shall not venture an opinion.

Even more drastic effects can be produced by project externalities. These come into play when the only way the goals of certain projects can be achieved is at the expense of other, wider, development goals. A case in point is the green revolution. Nobody will deny that the green revolution contributed substantially to the increase in grain production and therefore achieved the goal of greater supplies of staple food. But nor will anyone deny that this was often realized at the expense of the wider development goals of, for instance, a redistribution of income and the achievement of social equality.

At the World Conference on Agrarian Reform and Rural Development (1979), this was a much discussed problem, particularly in relation to the inequality of land distribution among owners and users of the land.

The occurrence of project externalities can often be traced back to the earlier-mentioned inadequate knowledge of the local situation, especially of those factors that lie beyond the

control of the farmer. A better knowledge of these factors can also lead to a better-founded opinion on the possibility or not of attaining certain national or rural development goals. This brings us to the next issue, that of development goals. Each development plan is based on certain development goals, and in a world where social values are rapidly changing, there is also a change in development goals. The Fournex report (UNITED NATIONS 1971) suggests that a redefinition of development goals must include greater stress on income distribution and employment, more attention to social services and welfare-oriented public goods, and greater provision for political participation.

The report also stresses the need for a quantification of social goals in development plans so that actual progress can be measured against these goals. One of the ways to quantify the social goals would be to establish the concept of minimum, or threshold, environmental standards (health, food, housing, etc.). Here, one comes very close to the earlier-mentioned concept of basic needs.

That development goals can sometimes be highly conflicting is clear from the continuing fight over the price policy for agricultural products, particularly the main food crops. On one side are the producers who must receive a price that guarantees them a reasonable income (one of the producers' minimum environmental standards) while

on the other side are the nonproducing consumers who must be able to buy sufficient food at reasonable prices (one of the consumers' minimum environmental standards).

Here is not the place to go further into these issues. Suffice it to say that the development process is a highly complex one, calling for an approach that can integrate numerous technical, social, and economic factors, all of which have to be considered simultaneously.

With all the risk inherent to any oversimplification, one could say that the current development effort is characterized on the one hand by endeavours to broaden development goals as advocated in the Fournex report, and on the other by the compelling need to raise food production to meet the increasing demand.

The problem dominating all else for the immediate future would seem to be the striking of a balance between these two often contradictory goals — a balance that will have to be found not only within the framework of the limited means available (and means are always limited) but to find it in time to safeguard the imperilled world food situation.

Conclusions

In the decades that lie ahead of us, land and water development will have a vital role to play in striving to increase the world's food production — an

increase that must primarily take place where food shortages are to be expected, i.e. in the developing countries. Not only must food production be raised, there must also be significant improvements made in the incomes of large groups of the rural population of those countries. Efforts should first concentrate on raising productivity per unit of land. The low yields obtained on arable land in the developing countries as against the high potential of those lands make it possible, technically speaking, to raise production many times over, and, what is more, to do so at an investment level far below that of developing new land.

It is alarming to observe that the development of new land scarcely keeps pace with the loss of land due to degradation and urbanization. All possible steps must be taken to prevent further degradation of land. The rehabilitation of existing irrigation schemes and improvements in the drainage of irrigated and non-irrigated lands are in line with this viewpoint.

Land and water development to raise food production and improve the income of rural people demands tremendous world-wide investments, not only for primary investments at project level but also for the vast scale of secondary investments that must be made if the projects are to achieve their ultimate objectives. A substantial increase is required in both the external aid volume and the internal contribution by the devel-

oping countries themselves, not merely to keep pace with the demand for food but to raise living standards in general.

Two matters will be decisive for the success of these undertakings. These are:

- The political will on the part of both the richer and the poorer countries to unite in a concerted effort to realize the ambitious but vitally necessary programs that must bridge the prosperity gap between the two halves of the world.
- Within the development effort, a balance must be struck between the sometimes conflicting goals of a broader-based development and the compelling need to raise food production.

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