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The reuse of drainage water. Technical and economic aspects in Egyptian agriculture

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I - A few words about the problem

The problem of soil salinization is of major importance when irrigation is used in dry areas. In these regions fertile lands could be irreversibly damaged by the quantity and quality of salts which are applied through irrigation.

The process of gradually increasing soil salt concentration, resulting from the high evapotranspiration rate of arid regions, is noticeable when water is reused many times for irrigation.

The major elements of the soil-water-plant system relevant to the use of water for irrigation are (besides quality) soil permeability, drainage conditions and salt-tolerance of the crops. Using only these elements, it is possible to prepare plans for cultivation or for the use of marginal resources.

The above elements are somehow replaceable among each other, so that it could be said that they represent, as a whole, the conditions needed for a permanent irrigation practice. On the other hand, the conditions which suffice are the economic returns, which are also affected by the size of cultivated areas, the ratio of cash crop to salt-tolerant crops, and the irrigation technique adopted.

Given the single functions of production according to crop and type of water, it is possible, based on the substitutability of quality and quantity, to identify for given supplies the combinations corresponding to higher soil and water yields. This is done by applying linear programming models to representative farms.

Generally speaking, the above on-farm approach is an economic solution to the best utilization of poor quality brackish water. It is indeed more feasible and advantageous than on-scheme transformations or the non-cultivation of arable lands.

In areas where considerable amounts of drainage water flow in canals next to "fresh" water, there are better operational possibilities which concern not only water but the entire soil-water-plant system. High salt content could, indeed, imply negative effects on crop yields and on the fertility of soils which may be irreversibly damaged by a "cascade" process.

This occurs through many complex mechanisms. It has to be pointed out that, at equal soil moisture content, the water potential that a plant should reach to use a unit of water from the soil decreases as the water salt content increases (or its osmotic potential decreases with subsequent stress conditions). If the use of good quality water for irrigation does not limit the choice of cultivable crops, the use of a water with an increasing salt content progressively reduces the range of possible crops and even limits it to those crops more resistant to direct salinity stress and less sensitive to water stress, i.e., those crops that maintain their productivity despite being irrigated with highly saline water.

It does seem not necessary to dwell upon the serious consequences of the forced restriction of cultivable crops on both the organizational level and on farm income. It has to be underlined, on the other hand, that contrary to expectations, this limitation is a problem to which farmers unconsciously and passively give due consideration, abandoning in many areas cash crops in favour of less salt sensitive crops.

As explained before, these events are but the first step of a degradation process which, if not properly managed, could in the short-run imply a change of physical and chemical soil properties: the glomerular structure disappears and a new structure by single particles settles; permeability is suddenly reduced and normal drainage stops ; permanent water logging occurs and all gaseous exchanges between telluric and atmospheric air stop, resulting in an anaerobic habitat which hampers the growth of any agricultural crop.

Once this phenomenon occurs, it is quite difficult and expensive to find a remedy. The actions to be implemented and studied, case by case, could be risky as well as unsuccessful.

II - ... but coming to a real case

Following in the wake of the population increase and the improvement of living standards, the Arab Republic of Egypt considerably increased agricultural consumption. Since 1974, when food imports exceeded for the first time exports, the deficit, which amounted to 3 million dollars in 1984, has steadily increased. This is also due to the reduction in exports of the three main commodities produced in Egypt: cotton, rice and oranges.

To cope with this worsening situation, different types of action have been defined such as: the launching of agricultural development, both horizontal and vertical, the improvement of cropping techniques, the introduction of new crops; research in genetic engineering to obtain cultivars tolerant to dryness or to salt water; the strengthening of extension services, etc...

All of these actions will certainly result in yield improvements and a subsequent expansion of Egyptian farming, the potential of which seems quite considerable: the favourable climate and soil fertility – known since ancient times for the abundant crops obtained – as well as a good technical level, allows satisfactory yields for most crops, above the world average and similar to those of developed countries.

Despite such potential, many limiting factors still persist such as deficient technical organization, and inadequate development of research, markets and credit. But the real constraint is undoubtedly the water deficit and the low efficiency of its utilization for production.

In ancient times the Nile flood was expected to inundate the surrounding lands which were later cultivated, once per year, when the water receded. Although there are traces of very ancient irrigation works, only at the dawn of the last century, with the introduction of new crops whose growing season did not coincide with the river flood, was the need realized for new irrigation works to be constructed: the big Aswan (the old one), Esna, Neg Hammadi, Asyut, El Kanater and, more recently, the new Aswan dam which, following the 1959 agreement with Sudan should supply to Egypt 55.4 billion cubic metres of water per year.

The recent guidelines of agricultural policy are directed, as said before, towards quite important horizontal (cultivation of new lands) and vertical plans (re-organization and improvement of cultivated areas, control and modernization of irrigation systems, better water use and strengthening of irrigation).

Therefore, agricultural expansion, both horizontal and vertical, is mainly based on a larger availability of irrigation water to meet requirements which are expected to increase to 85 billion cubic metres/year by the end of the century.

Water supply is not enough to match such requirements: expressed in billion cubic metres, supplies consist at present of Nile waters (55.4), underground water (5.0), Gangli Canal water (10.0) and the economic outcome resulting from a better and more efficient use of the present availability. The remaining fraction is supplied by the reuse of the drainage water which is available in considerable amounts.

In short, we can say that the future development of Egyptian farming mostly depends on the expansion of farming activities, closely related to the availability of larger amounts of irrigation water.

Since the amount of water resources is, as already pointed out, quite fixed, this increased availability will result from a better use of underground water and, in particular, of drainage water, together with an improvement of the distribution network and an optimization of structures and techniques.

The reuse of this water is a very old practice: before the construction of dams it occured naturally, as drainage water was forced again into the Nile where it mixed with flowing fresh water which periodically flooded land. More recently part of this water started to be utilized or stored by pumping and recycling systems.

In the 1970s, the reuse of drainage water became more important. Following recent studies, 2–3 billion cubic metres of drainage water are estimated to be used every year for irrigation and about 10 billion cubic metres are expected to be reused by the year 2000.

The reuse of wastewater is a complex practice, requiring great care, involving hydrogeological, hydrologic, agronomic as well as water management and economic policy studies. Nor can we neglect the long run effects of this practice on the physical and chemical soil properties, on crop yields and on the environment in general. This aspect seems to be the most delicate and noteworthy, as the reuse of drainage water, together with the changing flow conditions of the Nile after the construction of the High Aswan dam – and its consequences on surface water – revealed some side effects implying serious risks, such as the general rise of groundwater and the salinization of wide areas both recently and long since cultivated.

For an appropriate use of such drainage water, a careful preliminary analysis of its quantity, quality and location is necessary. At present, barely 15% ot the available drainage water is used, whereas the rest still flows to the sea. Although not all could be reused in the future for agriculture, taking into account the requirements of the other production sectors, at least part of it – that with the lowest salt content – could be reused for the cultivation of new areas. This possibility is obviously limited to those areas now available, i.e. the lower part of the delta, since in the upper part this practice has already been implemented for a long time. The main obstacle to a general spread of this type of reuse of waste water is at present the distrust of farmers, mostly small land holders (landed property is strongly fragmented with an average size of 1 to 2.5 feddans which have to provide a living for a family of 5–6 people) who are strongly unfavourable, unless they realize the viability of this practice to overcome the long-standing problem of permanent or periodic water deficiency.

Another point to be considered is salinity resulting from the water which gets richer in soluble salts by running through the soil. Such a problem is supposed to increase since even water which has an acceptable quality level at present, mainly due to the losses along the irrigation network, is expected to have a higher salt concentration in the future as a result of the modernization of the irrigation system designed to improve its efficiency, and of the introduction of water-saving techniques.

The mean salinity of drainage water in Egypt is about 1,500 ppm with some fluctuations – throughout the year – mainly due to evapotranspiration; the predominant salts are calcium carbonate and sodium chloride. Iron, zinc, manganese and copper are below the toxicity level for plants, whereas some problems could be caused by significant amounts of boron.

Water salt concentration is obviously extremely important, not only because of direct consequences but also because of the long-term effects which might seriously and irreversibly damage the soil structure and fertility.

A common practice is to mix drainage and fresh water in order to reduce the mean salt content and to make its use for irrigation purposes possible. So far, results of studies show that this practice is not costly and is more economic than other "alternative" uses of water.

Nevertheless, for an extensive reuse of drainage water, agronomic trials seem indispensable in order to select salt-tolerant crops and cultivars. In areas where mixing is not advisable nor technically feasible, special practices may be applied, centering on the possibility of applying alternatively fresh and brackish water according to the varying tolerance of crops during their growth stages. Experiments and trials – which have been completed or are under way – have shown a promising response of some crops.

This is why the choice of the remedy, either mixing or alternate application, will depend on the type and tolerance of the crops to be grown as well as on the irrigation systems which can be applied in the various areas, in that the alternate application implies a double distribution system of water – both saline and fresh – to farms.

The major hydrologic problems concern the water level. If it is low, pumping and mixing for the use of water in upper lands may not be economically advisable. In other words, there is no universal solution, but specific situations should be thoroughly studied and evaluated case by case.

For an efficient and economic use of such water, a differentiated plan is needed for the various areas, taking into account some characteristics and constraints such as: hydrologic conditions, soil type, soil and groundwater salinity, crop rotation, quality and quantity of water resources, and the conditions of water works.

The implementation of an agricultural policy aimed at horizontal development – needed to minimize the recession of the country – is closely related to an increase of available water. In view of the above constraints and limitations, a far-reaching use of drainage water might be a practical and feasible solution for water shortage.

However, we cannot underestimate the fact that a significant increase in water resources and the subsequent enlargement of new cultivated areas could also result from better utilization of existing resources. At present, they are used with only 50% efficiency due to considerable losses along the main conveyance network, frequent leaks at the farm distribution and crop level, poor maintenance, carelessness in night-time irrigation, unconventional behaviour of users, and lack of skilled labour.

In the past, Egyptian irrigation policy gave priority to the implementation of big infrastructures – indeed necessary – rather than to integrated plans aimed at improving the irrigation system. As a result the distribution network rapidly deteriorated over the years due to poor maintenance.

The re-organization and modernization of the water network are thus major purposes of the development plan. In spite of the significant improvement of water conveyance along the big distribution networks, however, losses are estimated at about 40–50% at farm level.

An integrated development strategy for irrigation is thus necessary. Its goals are the achievement of a network (both for irrigation and drainage), the start of a distribution system based on time (with adequate amounts of water and an interval related to crop and soil requirements), as well as water rationing to minimize wastage by farmers. The introduction or strengthening of extension services is also necessary to promote efficient irrigation methods, aimed at saving water and improving yields.

III - If development is the new name for peace, irrigation is the key to development

With the financial support of the Italian Ministry of Foreign Affairs and the Egyptian Ministry of Irrigation, the Mediterranean Agronomic Institute of Bari – a CIHEAM body – coordinated a pilot project based on an integrated approach to the reuse of drainage water for irrigation in the Fayoum area (over 16,000 feddans).

A considerable amount of data, findings and experimental results have been collected, collated and produced by an international multi-disciplinary team of highly qualified scientists. They carried out accurate and painstaking investigations on each aspect of this multi-faceted problem.

Whilst some points required only scientific confirmation, most of the acquired information cast new light on long debated issues or revealed altogether new feasible solutions. A careful perusal of the findings enabled us to draw several conclusions for the integrated approach solution of the problem:

– the project area is fully representative of both the Ibshawi District and of the El Fayoum Governorate in which it is located, for physical as well as agro-economic characteristics. Therefore, all information gathered, solutions envisaged and conclusions arrived at in the study area display the common feature of being easily transferable, hence applicable to the entire Governorate and possibly to the rest of the country as well;

– agronomic research findings prove that the reuse of drainage water for irrigation, if properly managed, is neither damaging to crops nor the cause of irreversible land degradation processes. Experimental results also indicate that adapted, salt resistant crops or varieties may produce sustained, highly satisfactory yields, even if irrigated with slightly saline water and grown in salinity prone soils, provided adequate amounts of water, inclusive of the required leaching fraction, are applied. Finally more productive rotations may also be implemented;

– pedological results show that salt-affected soils represent only a minor fraction of the surface area. Most of the arable land is suitable for irrigated agriculture, albeit in varying degrees, which can be improved if adapted crops and varieties, as well as cultural practices are employed. Reclamation and salinization control are also feasible if leaching is practiced.

Hydrological findings and studies prove that the efficiency, as well as the capacity of the irrigation network, can be easily improved to match future requirements also on the tail-end zones by means of moderate efforts/costs. Project implementation will also help control the phenomenon of the lake's increase in level. Sizeable water savings can also be obtained through the improvement of the efficiency of both the irrigation network and of the irrigation system, as well as of the distribution modes. Summer water shortages might also be eliminated, thus reducing water stress damage on agricultural crops, which seriously affects yields. Other findings were that drainage water is available, not only in sufficient quantity but also of acceptable quality, to make its reuse for irrigation both possible and safe, particularly if the suggested modalities of mixing and timing of application are adhered to; and that the recycling of drainage water into the irrigation network is feasible, at relatively contained costs and without excessively complicated engineering works. This would permit the expansion of irrigated agriculture into new areas (the surface of which is about 60% of the Project Area), which at present are barren and unproductive.

Agro-socio-economic surveys and studies prove that, by implementing the Project, seasonal unemployment will disappear; higher yields will be attained, the cropping intensity will be optimized resulting in an agricultural input increase of the order of 50% over present levels in the currently irrigated area; and that the total expected production in the Expansion Area (calculated as 60% of that of the Project Area) should also be added. Additional findings were that some 1,500 more families will be able to make a living from agriculture, at a reasonable standard, which will be increased, along with the farmer's know-how; that the livestock sector will benefit, mainly from the availability of fresh forage throughout the year brought about by both the introduction of new rotations and by the elimination of summer water shortages; that not only the farmer's net income will increase more than 30%, but the Area or Project benefit, will also be sizeable. In fact, the forecast net products from both the Project Area and the Expansion Area, if compared to the proposed cost, prove the high advisability and viability of the Project.

For the determination of the internal rate of return, it is necessary to fix the project life, the incremental benefits from the projet and the additional costs borne. In fact, it represents the discount rate that makes the difference between the benefit flows received and the costs borne equal to zero.

As for the determination of costs, one should refer to each of the two major technical alternatives chosen among the ones proposed, for evaluating the financial feasibility of the project.

In the first solution considered (alternative A) ,we provide for the construction of a canal which conveys water from Wadi Rayan Drain to Bejr El Nazha. In this solution, the internal rate of return is 78.6%.

In alternative B, the technical solution consists of the installation of a pumping station to lift the Wadi Rayan water and to force it through a conduit into the Bahr El Nazla. In this case the internal rate of return is equal to 78.6%.

These rates might seem to be too high, but they derive from the very nature of the project which requires limited investments if compared to the benefits attainable.

In fact, it is an area already equipped for irrigation and the work to be carried out simply aims at the introduction of drainage water into the delivery network, with some repair work to the existing canals.

On the other hand, the increases in production which could be obtained (especially in summer) and the extension of the cultivated area with the increase in the cropping intensity produces a substantial flow of incremental benefits that can justify the high returns of investments.

Table 1 gives the schematic distribution of adverse environmental conditions, limiting factors and difficulties which jeopardize agricultural development in the El Fayoum; indicative solutions and recommendations have also been included.

In the following pages, the various topics of interest which came to light during the collection of information are discussed briefly, not necessarily in order of importance.

Soil salinization control

The widely occuring presence in the area of a shallow, brackish water table and of high evaporation and evapotranspiration due to a very arid climate (intense solar radiation, wind and high temperature) all combine with the physical and chemical characteristics to make the soils of this area very liable to salinization. To prevent this, to curb its effects, or to reclaim saline soils, salts must be removed by "leaching", a practice which entails good drainage and the application of additional quantities of water. As previously mentioned, both quantity and quality of the water which will become available for the area throughout the year, including summer, will permit the implementation of this practice. Hence, the second important limiting factor will be kept under control; new tracts of land now marginal will become suitable for irrigated agriculture and crop potential will increase.

Leaching fraction

The leaching fraction, also known as leaching requirements, is the amount of water which has to be added to the crop water requirement in order to obtain water duties which not only ensure optimal crop growth and production, but also prevent the accumulation of salts in the soil profile or remove them, if already present.

The leaching fractions for the area have been calculated according to the various crops grown, their water requirements and the characteristics of the dominant soils. A total yearly figure of 15.4 million cubic metres has been obtained.

Soil conditions

Besides the already mentioned salinity control, fertility will also be improved through adequate rotations, cautious utilization of residual effects of fertilizer/amendment applications, and management practices. Livestock activities will also increase which will bring about full utilization of by-products and availability of farm yard manure, making possible the introduction into the rotation of new, or more widely grown crops, which could be considered as catch, relay or ameliorating crops.

A better irrigation mode

This will also become feasible to the extent that not only greater than strictly necessary water quantities will become available to all farmers in the entire area throughout the year, but it will also be possible to rationalize the whole system for timing, quality and quantities according to season, crop, growth stages, leaching requirement per soil type and drainage conditions. Careful monitoring of the mixing process of relative quantities of drain and fresh water, of resulting mixture quality, of the crops to which and when, as well as where, the mixture will be applied, will be necessary.

Farmers will have to be assisted by properly trained field staff, belonging to the re-structured and strengthened extension service and/or to the Irrigation Ministry Water Drainage Institute. Their continuous effective presence in the field will have to be ensured through the provision of adequate financial and transport resources.

As seen above, water stress hazards will be minimized, thus permitting crops to fully achieve their potential; for each species, high yielding varieties will become utilizable; a wider choice of crops, particularly in summer, will be accessible to farmers making it possible to select not only the species but, within them, those varieties most sought after on the market. The reduction of the lag-times beween crops will also be possible; cropping intensity will be maximized from the current 182% up to 200%; and bigger unit/year produce, hence higher returns, will be attainable.

Lake Qaroun's water level control

This will be possible in that the quantity of drain water discharged into it, currently of the order of 440 million cubic metres/year, will be greatly reduced.

This, of course, will be true only if and when the practice of reuse of drainage water for irrigation will be widely applied all over the catchment area which drains into the lake. The reduction in drain water discharge into the lake, brought about by the implementation of the proposed Project, will nevertheless be quite sizeable, of the order of 26 million cubic metres/year.

This is due to the fact that only a minor fraction of the 35 million cubic metres of recycled water will be again drained into the lake. It is generally considered that the amount of drainage water does not exceed 30% of that applied as irrigation. The majority of it will in fact be evapotranspirated by the additionally, or more intensively, cropped area.

Larger irrigated area

The climate in the area is very dry: average yearly evaporation values are of the order of 3,000 mm, whilst the average of 53 years rainfall amounts to only 16.0 mm/year.

Therefore, no agriculture is possible in the area without irrigation. This means that the proposed horizontal development requires, in practice, the expansion of irrigation onto new land. This will be possible only if higher amounts of water become available. On the other hand, the country's water resources, to which the Egyptian share of the Nile River water of 55.5×10^9 m^3/year contributes by 95.5%, are already fully tapped, allocated and totally utilized. The reintroduction of drainage water into the irrigation system will permit, by increasing during supply shortage/peak demand periods the amount of available water of still acceptable quality, the extension of the irrigation system onto lands which currently lay idle, making possible an increase in agricultural production.

Increased cropped area

With reference to the rather small, but representative Project Area, the reuse of drainage water will permit a 50% increase of the cropped area. The magnitude of the implications of a likely and desirable spread of the practice on a much larger scale throughout the country, and of the impact on Egyptian agricultural production, is evident.

The proposed Expansion Area, in which agriculture will be made possible by irrigation water availability, furthers the implementation of the proposed most viable solution. It is about 60% of the Project Area, at least as far as extension is concerned. Irrespective of its potential, say the suitability classification arrived at for its lands, it has been assumed that equal conditions, mainly socio-economic, will be reached after a reasonable lapse of time, very similar to those expected to be attained in the Project Area.

The same 60% proportion has therefore been applied to other factors, i.e. the number of farms, which is about 2,570 in the Project Area and therefore will be approximately 1,500 in the Expansion Area, assuming 2.95 feddans as the average farm size. The ratio of the total to the cultivated areas (which is 10,000 to 7,578 feddans, about 76) is also assumed to apply. Hence the Expansion Area, which totals 6,000 feddans, will have some 4,500 feddans of cultivated land.

When making the calculation of the Projet benefit, it will have to be taken into account that, for the Expansion Area, the present agricultural return is zero. Thus the increase over "Situation 0 before-Project" will be the entire "Situation x" net product due to the Project implementation.

Irrigation water cost

By tradition, water is supplied to farmers in the area at no cost. Therefore, free of charge water supply is also assumed to be practised in the future.

Labour cost

Practically no hired labour is utilized by the small farmers of the area, who very often resort to "exchanges" in the peak requirement periods for such operations as harvest-threshing, picking, etc. However, occasional labour is paid at the rate of 8 to 10 E.L. per day, plus food and small items (cigarettes, soft drinks). Cultivation operations have been costed on that basis.

Fresh water savings

By re-introducing 37.06 million cubic metres/year of drainage water into the irrigation network during the June through August period, an equivalent quantity of fresh water is theoretically released for new irrigation commitments. This does not actually occur, but the total amount of water of acceptable quality (i.e. EC lower than 4.0 mmhos/cm) available for the irrigation of the area (s) will be increased during the water shortage period by that very quantity. Thus, water will become sufficient for the area(s) served, not only to fully match crop water requirements so as to ensure sustained production, but also to include the calculated leaching fraction, for the curbing or prevention of soil salinization.

Moreover, sizeable fresh water savings can be obtained by improving the efficiency of both the irrigation network and of the irrigation method currently employed. The losses occuring at present have been calculated as 3.6 and 15.2 million cubic metres/year respectively for a total of 28.8 million cubic metres of irrigation water lost yearly, before being applied to crops.

By simple and not excessively costly improvements to the network, the relevant losses could be almost halved. An equally sizeable reduction could be obtained by the improvement of the method.

Crop yield increase

Among the various beneficial effects to be brought about by the Project, a sizeable increase in the unit yields of the various crops is also expected. The magnitude of this depends, of course, on a number of factors, mainly:

- present yields,
- present technological level,
- species and varieties potential,
- cropping calendar.

Yields increases are expected as 37% on average, although they vary widely from 8% for onions to 100% and more for grain, maize and sunflower.

This can be explained by the fact that onions are currently produced with a rather advanced technology and great care, whereas the husbandry of the two other crops is not so advanced. Moreover, being summer crops exposed to water shortage risks, their production is so low at present that, without being over-optimistic, it would appear possible to easily double today's average yields.

In fact, the sharpest increases can reasonably be expected to be attained from those crops for which farmers' know-how, cultural practices, fertilizers or pest control are either inadequate or absent. Current yields are rather poor in that the varietal potential, if any, cannot be fully expressed. The same applies to those crops whose growing cycle coincides with water-shortage periods, i.e. summer. They are more liable to suffer from water stress, thus to yield poorly under the present conditions. Improvements in crop husbandry and water supply/irrigation management, removing the limiting factors, will permit higher yields. It is well known that crops respond to application of inputs according to a pattern of a parabolic, quadratic curve, following the general rule of diminishing returns.

However, besides the unit yield increase, the foreseen improvement in cropping intensity is also expected to strongly contribute to the sizeable increase in the agricultural production of the area, anticipated from the project implementation.

Cropping intensity increase

With the availability of ample amounts of irrigation water in summer and the implementation of well adapted crop rotations, it will become possible to attain optimal soil utilization which is presently restricted by water shortages and by excessively long time-lags between crops. Crop intensity is already generally high in the area; in fact, according to the data collected through the socio-economic survey, it amounts to 182%.

Nevertheless, a value of 200% is considered to be a realistically attainable target, not only for the Project Area, but also for the Expansion Area.

A note of warning has to be introduced here: as crop intensity values are expressed as a percentage of arable land, it would be easy to fall into the error of referring to an 18% increase. As a matter of fact, although the figure will grow by 18 points, only a 10% increase over the present value will be really attained.

Accordingly, forecasts and projected productions shall take into account these last values.

Livestock

Although a complete inventory of the animals raised in the Projet Area is not available, the data collected during the socio-economic survey result in quite reliable figures. From these a few, simple but important considerations can be drawn.

It has been estimated that some 2,110 cows and 540 female buffaloes are present, with a total average of 2,000 calves per year; goats, sheep, kids and lambs are respectively: 3,000; 2,000; 1,500 and 1,000 heads. These figures make very clear the importance of the livestock sector in the agricultural economy, also indicated by the fact that cattle alone contribute almost 19% of the current yearly farm gross income. Camels and donkeys have not been counted.

As reflected by low production, animal husbandry is somehow wanting, particularly for food. This is, however, to be ascribed more to the adverse local conditions than to farmers' inadequacy, in that summer water shortages provoke severe scarcity of fodder, mainly of green forages, resulting in production drops.

As far as the Project Area is concerned, little scope therefore appears to be left, especially in connection with the cattle herd's magnitude, for major improvements in the livestock sector. The only exception is the improvement of cattle feeding, by which meat and milk production will be affected positively, albeit modestly. In fact, only a 5% increase in the yearly gross income is foreseen as a result of the production of abundant fresh fodder throughout the year, equal to a net income increase of 26.5 EL per farm/year.

However, the start of production in the Expansion Area, presently unproductive, is expected to contribute heavily to both cattle herd size and total sectorial output increases. As seen previously for other sectors and parameters, it is assumed that both areas will eventually reach a very similar situation, with the only difference being their territory extension, which for the second area is 60% of the Project Area. Thus in the Expansion Area, 1,542 farmers will raise 1,590 adult cattle heads, with a total yearly net income of 800,300 EL.

Costs and prices

To simplify calculations, neither agricultural product prices nor the cost of agricultural inputs (such as labour, chemicals, operations, etc.), have been adjusted to the 20th year, but always kept at 1987 values. It has been considered that likely inflation/devaluation effects might, as is often the case in the primary sector, be compensated mutually and therefore nullified.

Larger returns

These will be possible both at farmer and Project level because, as many production factors will be better utilized or improved, costs will be lowered. Moreover, it will become feasible, as well as worthwhile, to improve other related aspects, such as technologies and know-how.

Sustained agricultural production

This will be attainable through the removal of the main limiting factor to crop growth and production in the area, identified as summer water shortage, which provokes water-stress conditions in the plants. With the elimination of water stress, steady optimal production (after the project) can be expected, which should result in an overall increase of the present (before the project) production, without productivity decreases.

Labour efficiency and distribution

Because of summer water shortages, summer crop production does not reach optimal levels. Accordingly, labour requirements are very low in that period, resulting in seasonal unemployment. The removal of the limiting factor will result in a better labour distribution, hence a more even employment of the family labour units throughout the year.

Increase of agricultural output

As a result of the implementation of the proposed actions and of the improved efficiency of the various production factors, an increase of the order of 50% is expected for the total agricultural production in the Project Area. In fact, as previously seen, crop yields will on average be 37% higher than at present. The cropped area will be about 10% larger than the present one, due to the higher cropping intensity (182% to 200%).

An altogether new and sizeable output will be contributed by the Expansion Area, currently unproductive. Close similarity has been assumed between the two areas and, considering that the surface ratio is 0.6, the same proportion has been extended and applied to all other parameters,inclusive of the attainable agricultural production. This will therefore be equal to 60% of the Project Area output in the 20th year, say $0.6 \times 150 = 90\%$ of current output of the Project Area.

Adding the two total area output expected increase in the 20th year, 140% of the current production will be obtained.

Transfer of technology

This will become feasible in those areas with similar problems or conditions. Methodologies and practices of proven and confirmed viability and efficaciousness will allow the extrapolation of data and forecasts for the preparation/implementation of agricultural development programmes and activities, not only in Egypt but also in other countries.

The project, quite complex from the organizational point of view, even within the limits of a pilot project, showed:

– the interest and opportunity of exhaustive research in the field of reuse of drainage water in those countries where irrigation water is in short supply or of low quality; and

– the high margins of economic advantages such interventions have on the agricultural development of countries, for which the problem of food self-sufficiency appears day by day in its unvarnished truth.

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Table 1: Adverse conditions or difficulties of both technical and social nature, which jeopardize agricutlural development in the study area, and respective solutions

Sector		Limiting factor	Problems, constraints, risks	Solution	Project results for development: Vertical	Project results for development: Horizontal
Environment	Arid climate	Absence of rainfall intensity and rates	Desertic conditions, high water requirements	Irrigated agriculture Abundant irrigation watger supply		
	Geography	Land-locked system BSL altimetry	Lake's level raise Difficult drainage	Recycling of drain water, salt extraction Improvement of existing system		
	Soils	Saline soil occurence	Loss of high percentage of cropped area High percentage of non-suitable land	Reclamation, leaching, marginal areas' utilization for suitable crops only		
		Salinization hazards	Leaching necessity	Leaching implementation with ample water		
		Water-logging hazards	Higher costs of drainage Loss of sizeable areas Loss of production	Proper drainage		
		Shallow water table	Reduced effective soil depth	Improved drainage, cultural practices		
		Brackish water table	Increased salanization risks, irreversible soil degradation, desertification			
		High capillarity raise rate	High rate salinization process	Proper drainage, cover crops, leaching Use of amendments		
		Low fertility	Low yields, need for heavy fertilization	Proper fertilizer use Good rotations		
	Water	Brackish ground-water	Prevented usage for irrigation	Adaptation of new rotations and introduction of new crops/varieties	Cropping intensity increase (182-200)	Cropped area increase fed. 4,500
		Irrigation water scarcity H_2O deficit = 1/s/fed 0.23	Non optimal cropping intensity Limit to agriculture expansion Summer water shortages Unperformed leaching Improper reuse of drainage water	Reuse of drainage water for irrigation either mixed or undiluted Promotion of leaching practice **Reintroduction of drainage water (37Mm³) into irrigation network by either pump-lifting or connecting canal** Controlled mixage of drain and fresh water	High cropping intensity (200%) Ample supply (0.61 l/s/f) of irrigation water to fully satisfy both crops requirements and leaching (0.43 l/s/f) Surplus	to Expansion area
	Crops	Low varietal potential Low resistance to salinity Liability to water stress Inadequate rotations Inadequate succession	Low unitary yields Risk of total loss of production Excessive time lags Fodder scarcity FYM scarcity	Introduction of HYV, responsive to improvements Reduction of time-lags Introduction of adequate rotations Promotion of fodder crops and of efficacious simple improvements	Yields increase (37 %) Sustained production Additional production Better producing animals	High yields Increase in cattle (1,59(Additional animal production
Human resources	Farmer	Inadequate husbandry	Low yields, high incidence of pests attacks	Assiduous assistance, promotion of improved practices	Proper crop and animal husbandry	
		Scarce know-how	Untimely or inadequate interventions	Training, field days, demonstration, continuous assistance and advice		
		Labour efficiency	High costs, low returns	Training, promotion of impreoved tools & instruments	Full useful employment of farm family	Useful profitable employment in agricultu for 1,542 families more
		Labour uneven distribution	Seasonal unemployment	Introduction of new rotations and crops		
	Institutions	Inefficient extension service Lack of feed-back to research Inadequate research Lack of maintenance to network Inadequate control of water distribution Inefficient irrigation modes Inadequate credit system Inadequate commercialization Inadequate financing and/or staffing	Scarce diffusion of improved cultural practices Inadequate applied, adaptive research High losses, low carrying capacity Water scarcity at tail-ends High water losses Low returns Inefficient assistance, monitoring, feed back	Adequate financing Up-dating, training, staffing, transport Conclusion of practically oriented adaptive research Simple lining of canals Reconsidering of structure Proper supervision and control Rationalization of turns and duties, ample supply Introduction of drip and sprinkler systems Strengthening of and assistance to Co-operatives Provision of resources, staff motivation, training	Effective Extension Service Motivated well trained & equipped Effective, useful & applicable results Sizeable water savings Increased canals' capacity Losses reduction Higher efficiency of network & system Higher returns Motivated staff and farmer	