NILE VALLEY REGIONAL PROGRAM
PHASE II

Resource Management Series

Volume 5

INVENTORY STUDIES

Old Irrigated Lands of Egypt

Synthesis

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Volume 5

Resource Management in the Old Irrigated Lands of Egypt: Synthesis

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Foreword

Limited soil and water resources and threatened sustainability of agricultural production call for an effective resource management strategy and farming systems approach in agricultural research. Implementing a long-term research program where more emphasis would be on systems-oriented rather than commodity-oriented agricultural research would represent such a strategy. Therefore, the Resource Management Component of the Nile Valley Regional Program (NVRP) of the International Center for Agricultural Research in the Dry Areas (ICARDA) was developed. The Component, which started in 1994 in one of the Nile Valley countries, Egypt, and is expected to be extended to the others, aims at achieving sustainable production at a high level, based upon the need to protect the resource base (land and water) through good management. This would be achieved through basic intensive technical research (long-term on-station trials) and on-farm extensive monitoring of resources in farmers' fields and farmers' decision making logic.

Preparatory studies were carried out prior to conducting the trials and monitoring activities. The objectives of these studies were to define and characterize the major farming systems of the main agroecological environments; to identify and prioritize—with respect to the natural resources—the constraints to optimum utilization and the threats to sustainable production; and to provide an outline for the strategy, design and implementation of the long-term research activities.

The preparatory studies involved three procedures for information collection: **Inventory Studies**, in which existing information and details of the ongoing research and development, related to soil and water management, agronomy and cropping systems, and socioeconomics were collected; **Rapid Rural Appraisals**, which included qualitative sampling of farmers and extension views concerning current limitations, constraints, dangers, and opportunities in the utilization of soil, water, and inputs; and **Multidisciplinary Surveys**, which employed short-focused questionnaires to fill some important information gaps. In general, information collected in the preparatory studies dealt with resource description, resource utilization and management, productivity, and threats to sustainability. This knowledge was used in planning the long-term research activities at selected locations by identifying high-priority researchable resource management problems, in the context of realistic cropping sequences and farm level economics.

The outcome of these studies is hence presented in what is called the **Resource Management Series**. The series includes a total of 18 volumes on Inventory Studies, Rapid Rural Appraisals, and Multidisciplinary Surveys in the Old Irrigated Lands, New Lands, and Rainfed Areas. In the Inventory Studies, five volumes on the research and development activities and findings in each of the Old and New Lands were compiled. These volumes were on Agronomy, Soil Fertility and Management, Water Management, Socioeconomic Studies, and a Synthesis of all the latter. The Inventory Studies of the Rainfed Areas included two volumes, one on the Northwest Coast and the other on North Sinai.

These studies were conducted in Egypt with the involvement of the Agricultural Research Center (ARC), Desert Research Center (DRC), National Water Research Center (NWRC), National Research Center (NRC), Ain Shams University and ICARDA within the NVRP with financial support from the European Commission. Appreciation is expressed to all those who contributed to these important reviews and studies.

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Weights and Measures

1 feddan (fed) = 0.42 hectare = 1.037 acres
1 hectare (ha) = 2.38 feddans
1 ardab wheat = 150 kg
1 ardab barley = 120 kg
1 ardab faba bean = 155 kg
1 ardab lentil = 160 kg
1 ardab chickpea = 150 kg

Acronyms

AERI = Agricultural Economics Research Institute
Ad = Advisor
ARC = Agricultural Research Center
ARE = Arab Republic of Egypt
BOD = Biochemical Oxygen Demand
BYDV = Barley Yellow Dwarf Virus
CEC = Cation Exchange Capacity
COD = Chemical Oxygen Demand
DO = Dissolved Oxygen
ET = Evapotranspiration
EU = European Union
EWUP = Egypt Water Use and Management Project
FCRI = Field Crops Research Institute
ICARDA = International Center for Agricultural Research in the Dry Areas
IIP = Irrigation Improvement Project
IPM = Integrated Pest Management
IRR = Internal Rate of Return
ISAWIP = Integrated Soil and Water Improvement Project
MALR = Ministry of Agriculture and Land Reclamation
MPN = Most Probably Number
NRC = National Research Center
NVRP = Nile Valley Regional Program
NWC = Northwest Coast
RS = Resource Scientist
SAR = Sodium Adsorption Ratio
SWERI = Soil, Water, and Environment Research Institute
TDS = Total Dissolved Salts
TP = Total Phosphorus
WDISRI = Water Distribution and Irrigation Systems Research Institute
WRC = Water Research Center

Executive Summary

Old Lands is a term identifying those lands that were under cultivation in the Nile Delta and Valley before the 1950s, when extensive land reclamation programs were launched on the fringes of both regions, resulting in the New Lands. The Old Lands in Egypt are highly productive, with an intensive system and close animal–crop integration. An improved understanding of the utilization and limitations of resources in the Old Lands helps to identify constraints facing the sustainability of agricultural production and to plan for future research programs.

A review of the socioeconomic status of the Old Lands shows that: i) the ownership and tenure system is fragmented; ii) the agricultural labor force has decreased to 33% of the total labor force in Egypt; iii) there has been a rapid increase in the number and use of agricultural machinery, particularly tractors, irrigation pumps, and threshing machines; iv) the difficulty of instituting a cost recovery system among the various water users is considered a major problem facing the rational use of limited water resources; v) adopting new varieties and applying the recommended technology packages has had a positive effect on crop yield and net return; vi) continuous losses in the Old Lands due to urbanization, land fragmentation, and rapid population growth are the major threats to sustainability; and vii) future research topics include the impact of the agricultural policy reform program, the role of different institutions in resource management and utilization, the impact of new technology on unemployment, and the study of the gap between real and potential yield.

Soil and soil management practices in the Nile Valley and Delta can be described as follows: i) the soil is alluvial, dominated by vertisols, with entisols and aridisols also present; ii) the soils are poor in organic matter and nitrogen, phosphorus is moderate and potassium is high; iii) deficiencies of zinc, manganese, and iron have been reported in several areas; iv) the recommended rate of fertilizer application to wheat has increased 60% during the last 20 years; v) little attention has been given to barley fertilization in the Nile Valley and Delta; vi) phosphorus fertilizer application to faba bean, chickpea and lentil is recommended for higher yield; vii) the response of clover to P is significant, and a positive response to K has been reported; viii) *Rhizobium* seed inoculation of food and forage legume crops is recommended for improving the N fixation ability of these corps; ix) the farming system in the Old Lands depends more on chemical fertilizers than on organic and biofertilizers; x) fertilizer abuse, salinity, a high water table, and soil pollution with heavy metals are the main threats to sustainability; and xi) for better management of soil and water resources in the Old Lands, future research topics include modeling fertilization based on soil tests and plant tissue analysis, and long-term trials to assess the impact of soil management, utilization of biofertilizers, soil pollution, and water-use efficiency.

Water management of the Old Lands encompasses: i) an irrigation system divided into sections, i.e. the Aswan High Dam to Esna Barrage, Esna Barrage to Naga Hammadi Barrage, Naga Hammadi Barrage to Assiut Barrage, Assiut Barrage to Delta Barrage, and the Damietta and Rosetta Branches in the Delta; ii) irrigation water is distributed through an intensive network of irrigation canals; iii) evaporation and evapotranspiration are the main components of water loss throughout the irrigation system; iv) irrigation rotation is practiced and there is a winter closure period; v) considerable amounts of drainage water are pumped into the irrigation system; vi) open and subsurface systems are the main drainage

facilities in Egypt; vii) the subsurface drainage system in Egypt has a specific design suitable for the agricultural system and the water table depth; viii) different areas with specific drainage problems include heavy clay soil and areas under artesian pressure; ix) yield increases due to the installation of tile drainage systems have been marked; x) the consumptive water use of wheat ranges from 36.7 to 47.5 cm, depending on variety, with higher consumption in Upper Egypt; xi) values for faba bean vary between 29.0 and 41.6 cm, and between 47.6 and 66.0 cm for Egyptian clover (berseem); xii) water-use efficiency of different crops varies according to variety and location; xiii) River Nile water is generally of good quality, with the most polluted sites between Naga Hammadi and Assiut; xiv) salinity and pollution of drainage and groundwater, as well as sewage and industrial waste water, should be considered, since this water is sometimes used for irrigation; and xv) changes of water quality and quantity, inadequate drainage systems, rising water table and pollution due to excessive fertilizer and pesticide application are the main threats to sustainability.

The agronomy and cropping systems in the Nile Valley and Delta can be summarized as follows: (i) wheat is the main staple food in Egypt, with an average grain yield of 5.8 t/ha; (ii) planting takes place in early November and is fertilized with 180 kg N/ha (in three splits) and 35 kg P_2O_5/ha; (iii) wheat is subject to attack by many diseases; (iv) losses of wheat due to aphid can be as high as 23%; (v) the area planted to barley in the Old Lands is gradually decreasing, replaced by wheat; (vi) faba bean occupies 80% of the area cropped by food legumes; (vii) productivity of faba bean increased from 2.25 t/ha in 1982 to 2.94 t/ha in 1990, recently decreasing due to epidemic viral disease in 1992 associated with an outbreak of aphid vectors; (viii) broom rape (mostly *Orobanche crenata*) is the most serious biotic stress for faba bean, with yield losses of 100% commonly observed in heavily infested areas; (ix) although lentil production increased by 80% in the last decade, Egypt still depends on imports; however, the country is self-sufficient in chickpea; (x) a newly introduced summer legume, soybean, faces several constraints as a result of competition from other summer crops, damage by insects, and problems with N fixation; (xi) the average livestock holding is almost 2.4 head per ha, higher in the Delta; (xii) pricing policy reforms have increased the profitability of wheat and cotton and have had a negative impact on the amount of area under berseem, the main fodder for livestock in winter; (xiii) the dominant rotations are three-year and two-year cotton rotations, where cotton rotates with clover, food legumes, wheat or barley, rice, maize, and oil crops every second or third year, with perennial sugarcane rotations practiced in Qena, Aswan, and Minya; (xiv) multiple cropping of more than two crops a year could be achieved through the introduction of newly selected short-duration crops, the use of no-till systems, and mechanization of land preparation and harvesting; (xv) intensified cropping patterns are practiced in Egypt, such as intercropping soybean with maize, onion with cotton, sugarcane with legumes, and sugar beet with faba bean; and (xvi) applying new agro-technologies to increase the rate of intensification is essential.

Introduction

The purpose of the preparatory studies for the resource management component of the second phase of the Nile Valley Regional Program is to collect information on the natural resource base and its agricultural utilization in specific agro-ecological environments (including past and present research activities) and to analyze, synthesize, and interpret that information to identify problems in sustainable resource management, and design the multidisciplinary research activities needed to tackle these problems.

This report is concerned with the inventory studies on resource management in the Old Lands. The studies were carried out by a multidisciplinary team of national scientists representing different institutions in Egypt. Four different components are included in these studies, focusing on food legumes, cereals, some forage crops, and animal production. These components are:

- Socioeconomics
- Agronomy/Systems
- Soil Management/Fertility
- Water Management

Background and Justification

Egypt is located between latitudes 21° 55' and 32° N and longitudes 24° and 37° E. The total area of the country is 1,001,450 km^2. The country is usually divided into three main geographic regions, namely: i) the Nile Valley and Delta, representing the Old Lands; ii) the Eastern Desert and Sinai; and iii) the Western Desert.

Agricultural production represents more than 20% of Egypt's gross national product. In addition, agriculture has a significant impact on other sectors of the national economy, because it stimulates activity in local industries, transport, and commerce.

The present status and future prospects of Egyptian agriculture must always take into consideration two basic facts: Egypt has an extremely limited cultivated land area due to the limited availability of water, as well as a rapidly increasing population. Land traditionally cultivated, i.e. the Nile Valley and the Delta, totaling 2.6 million ha, constitutes only 3.5% of the total area of Egypt. More than 96% of Egypt's area is desert. Egypt's agriculture has depended on the Nile Valley and Delta throughout its history. The majority of the cultivated soils in the Old Lands are alluvial.

The population growth rate of 2.5% in the 1980s was not matched by a similar increase in food supply from the Nile Valley and Delta. Despite significant growth in agriculture production, the country currently imports over 50% of its wheat and vegetable oil and one third of its maize. To increase domestic food supply, Egypt is reclaiming New Lands, and developing new production systems. However, the Nile Valley and Delta remain the backbone of Egyptian agriculture.

Winter cereals (wheat and barley) and food legumes (faba bean, lentil, and chickpea) are staple food crops in Egypt. Egypt is among the highest wheat-consuming countries in the world, with a per capita consumption of 194 kg/year. Considering the high population growth rate, increasing wheat production is an important national goal to reduce wheat imports, save foreign currency, and provide enough food to meet increasing domestic demand.

In 1987, wheat grain yield per unit area and total wheat production started to increase, and is still rising due to the adoption of agricultural reform policies, the release of improved varieties, and the adoption of research-recommended production packages. The increase of grain yield per unit area of some wheat cultivars between 1986 and 1990 was 35–37%.

Barley is grown under a wide range of environmental conditions. It is used mainly for animal feed and breadmaking by Bedouins, as well as for the brewing industry. It has good yield potential for low-input agriculture in the New Lands under irrigation, and in salt-affected areas. New drought-tolerant varieties and improved cultural practices introduced to the Northwest Coast through the efforts of NVRP increased yield by more than 45% and net revenue by 102%.

Food legumes and faba bean are among the most important food crops in Egypt, constituting a major part of the daily Egyptian diet. Because of their high protein content (23–26%), food legumes also provide a major portion of the daily protein requirement, particularly for low income classes. Per capita consumption of faba bean increased form 4.1 kg in 1982 to almost 7.0 kg in 1992. With the increase in both population and per capita consumption, the demand for faba bean increased considerably. In addition, the use of faba bean seed as animal feed almost doubled in the past decade, reaching 70,000 tons.

To meet increasing demand, the area cropped with faba bean in Egypt increased from 115,000 ha in 1982 to 160,000 ha in 1992. As a result of adopting improved cultivars and improved cultural practices, the average national seed yield gradually increased from 2.25 t/ha in 1982 to 2.94 t/ha in 1990. This declined to 2.36 and 1.61 t/ha in 1991 and 1992, respectively, due to chocolate spot (*Botrytis fabae*) and viral diseases in the 1990/91 and 1991/92 seasons. Such decreases in yield affected total production and led to considerable reduction in self-sufficiency. The deficit was compensated with imports.

Lentil and chickpea, grown on about 6,000 ha each, are also important food legumes in Egypt, but to a much lesser extent than faba bean.

In addition to their nutritional value, food legume crops also play an important role in sustaining the productivity of the farming system in Egypt, due to their beneficial effect on soil fertility through the fixation of atmospheric nitrogen, thus reducing the need for N fertilizers and conserving the environment.

Agricultural production practices in the Nile Valley and the Delta are very intensive due to a favorable climate that allows cropping during most of the year, and the steady stream of the Nile water. The very intensive use of agricultural land and continuous cropping in the Nile Valley has created a set of production problems. To sustain the high productivity in the Nile Valley and the Delta, these problems should be tackled through research on conservation of natural resources.

Agricultural Resources

The inventory study of the Old Lands comprises four separate reports covering agronomy, soil management and fertility, water management, and socioeconomic studies. Each report contains information about resources, resource utilization and management, details of ongoing research activities, current policy and development plans, and constraints. A summary of each report is presented below.

Socioeconomic Component

The objective of the inventory study under this component is to review the important and recent socioeconomic studies on resource management in the Old Lands. The report includes six chapters. The first chapter is an introduction that includes objectives and sources of information. The second deals with agricultural land resources, description, utilization, and threats to sustainability. The third chapter deals with water resources, availability, the economics of water use, and water use rationalization. The fourth describes the labor force, wages, and productivity. The fifth chapter describes other agricultural inputs and technology, including mechanization, seed, fertilizer, and the impact of technology packages. The sixth chapter deals with livestock resources, development, and production. A review of land ownership and tenure shows that more than 90% of holders have less than 5 fed (2.1 ha). Continuous fragmentation is the most obvious characteristic of the ownership and tenure distribution.

In 1992, the cultivated Old Lands in Egypt were about 6.17 million fed (2.6 million ha). The cropping intensity was about 2.1, reflecting the accessibility of irrigation and the favorable climate. Land utilization is expected to change as a result of liberalization of the agricultural sector. The cropping structure is expected to shift to the production of the more profitable crops.

Different studies have shown that yield has increased for most crops during the last ten years as a result of the introduction of different vertical expansion programs. Studies also show that the tile drainage project has had a positive impact on the productivity of most crops.

The agricultural labor force was approximately 4.6 million workers in 1991/92. The relative importance of the agricultural labor force to the total labor force decreased from 49% in 1968/69 to 33% in 1991/92. The annual growth rate was 0.26, 0.03, and 0.23 for the total, agricultural, and non-agricultural labor forces, respectively.

Agricultural labor wages have increased, but are still lower than in most other sectors. Comparing labor wages to labor productivity in agriculture shows that labor wages represented about 22 and 35% of labor productivity in 1963 and 1987, respectively. Previous studies reported both seasonal and technical unemployment in Egyptian agriculture.

Water is the natural resource that exerts the greatest constraint on Egypt's agricultural production system. Previous studies explored ways to maximize the available water resources through improving management practices and use. Water-use rationalization studies include the use of different water qualities, different irrigation systems, and the cultivation of different cropping patterns. However, the difficulty of assigning a costsharing system among various water users is a major problem facing the rational use of limited water resources.

Mechanization is widely perceived as a means of generating economic benefits, eliminating production constraints, and improving production technology. Over the last 20 years, there has been a rapid increase in the numbers and use of agricultural machinery, particularly tractors, irrigation pumps, and threshing machines. Previous studies revealed that mechanization has a positive impact, reducing costs and losses, and increasing productivity through the improvement of farm operations.

It has been proved that using improved seed and new varieties of various crops has had a positive impact on yield and net returns. Applying technology packages has also had a positive effect on crop yield and net return for the target crops, i.e., wheat, barley, food legumes, and berseem. Introducing credit to small farmers in support of recommendations has had a positive impact on yield and profitability.

Agronomy/Systems Component

The report includes a detailed review of cropping systems and rotations, tillage systems, crop productivity, number and kind of livestock, animal feed sources, and animal product yield. It also discusses common problems facing crop and animal production in Egypt. It is divided into four main topics.

Cereal production

Wheat and barley are among the most important winter cereals in Egypt. They are grown in large areas that could, where favorable climatic and soil conditions exist, be increased using irrigation. Wheat is the main source of food in urban, suburban, and rural areas. National wheat consumption in 1984 reached about 8 million tons (80% imported) and is projected to reach 12.5 million tons by the year 2000, which reflects the size of the problem and the effort needed to increase production in Egypt through vertical and/or horizontal expansion.

Cultural practices, irrigation management, water-use efficiency, and the response to fertilizer application, are discussed in this section. Biotic and abiotic stresses confronting wheat, such as disease, insects, pests, weed infestation, heat, and salinity are also discussed. Technical constraints and recommendations for cereal production are discussed, including sowing time, dose and timing of fertilizer application, land preparation, pest and weed control, seeding rate, sowing method, etc.

The gap is still wide between actual and potential farm yield. Therefore, it is anticipated that if proper technology is applied, and constraints facing cereal production are minimized, yield increases between 20–25% could be achieved in the field.

Cool-season food legumes

Cool-season food legumes, including faba bean, lentil, and chickpea, are among the crops that have the most potential to meet Egypt's increasing demand for food. In addition, these crops maintain soil fertility and productivity, as they fix atmospheric nitrogen.

While faba bean acreage and productivity increased in the 1980s, they declined in 1991 and 1992 due to disease. Because of the limited lentil acreage (6,300 ha), Egypt depends on imports of this crop. Egypt is considered self-sufficient in chickpea, with 5,5,00–6300 ha producing 11,000–12,000 tons annually.

Association of biotic and abiotic stresses with food legumes is discussed in this report. This includes hot environment, salinity, foliar and soil-borne diseases, aphid, and virus problems, leaf miner, white fly, seed beetle, and broom rape (*Orobanche* spp.).

Soybean, as a summer legume crop, is included in various rotations, especially those lines that exhibit high yield potential with early maturity characteristics.

Major production constraints for food legumes are also discussed, including various biotic and abiotic stresses in different farming systems. Due to unsuitable cultivars and inadequate crop management, the yield potential of these crops is seldom achieved.

Cropping patterns and crop rotations

Agriculture in the Nile Valley and Delta is fully dependent on irrigation from the River Nile, which is available year-round. Consequently, continuous cropping is the general practice. The dominant practice is a three-year cotton rotation followed by a two-year cotton rotation. Crops included in these rotations are cotton, clover, food legumes, wheat, barley, rice, maize, and oil crops (peanut, sesame, sunflower, and soybean).

The role and benefit of crop rotation and crop sequence are discussed. Intercropping systems such as sugarcane/soybean, maize/soybean, sugarcane/faba bean (lentil) and sugar beet/faba bean are reviewed, as well as some prevailing cropping systems, including berseem, clover, barley, and other crops. Current and future trends and benefits of crop intensification and rotation patterns are detailed in the report, as well as sequential and cash crops.

Animal production

Egypt has a large livestock population. The average livestock holding is 2.4 animals per hectare. The number of cattle (55%) and buffalo (45%) is 5.28 million head, while sheep and goats amount to approximately 6 million head.

Most of the cattle are in the Delta (60%), with 38% in Middle and Upper Egypt. The buffalo population exhibits the same trend, being concentrated in the Delta, with only 39% in Middle and Upper Egypt. About 93% of the cattle in Egypt are owned by small farmers. The average herd size is 1.5–2.5 head. About 55.3% of the sheep population is concentrated in the Nile Valley, especially Sohag Governorate, and 34.7% is located in the Delta. Approximately 64.8% of the goats are in the Nile Valley, especially in Assiut, Sohag, and Qena Governorates, and 24% are located in the Delta. Approximately 160,900 head of camel are distributed between the Nile Delta (38.3%) and Valley (51.3%). There is no published data available on the numbers and distribution of horses, donkeys, or mules. However, it is obvious that the use of animals for farm work has been greatly affected by mechanization, and is the main reason for the decrease in numbers evident today.

Animal products, such as red meat (beef and veal), camel meat, milk and dairy products, and poultry and egg production are discussed.

Threats to sustainability and constraints to cereals, food legumes, cropping patterns, crop rotations, and animal production, are discussed under each topic. Technology packages for various crops are recommended to secure high yield with improved quality through efficient use of resources.

Soil Management/Fertility Component

This report gives a brief description of Nile Valley and Delta soils as an important resource for Egyptian agriculture. Recent studies dealing with soil management, fertilization, and soil–plant relationship in the Old Lands are reviewed:

- Classification of the Nile Valley and the Delta, according to the USDA Soil Taxonomy System, shows that vertisols dominate the soils of the West Delta, East Delta, Middle Delta, Fayoum Depression, and Nile Valley, while the entisols are present in narrow strips along the Rosetta Branch, Damietta Branch, as well as small areas along the river branches, along the river banks, and around the lakes.
- The physical and chemical characteristics, as well as the fertility of soil samples collected from various sites in the Valley and the Delta show that: i) soil texture ranges from light to heavy clay; ii) pH is 7.3–8.3; iii) calcium carbonate is 2.1–8.3%; iv) total soluble salts are 0.09–0.33%; v) organic matter is 1.22–2.24%; vi) CEC is 31–61 meq/100 g soil; vii) total N is very poor at 0.07–0.113%; viii) available P is generally moderate (1–29 ppm); and ix) available K is fairly high (between 288 to 663 ppm). As for micronutrients, Fe deficiency has been detected in some calcareous soils, Mn deficiency in alluvial soils, Zn deficiency in light textured as well as in lowland soils, and Cu accumulation, due to heavy applications of pesticides, sometimes occurs.

The response of wheat, barley, faba bean, lentil, chickpea, and some forage crops to the major and minor nutrients is reviewed. Optimum rates, time and method of fertilizer application, and the most suitable sources of fertilizers for each crop are presented.

Due to the ability of legumes to fix atmospheric N, they have the advantage of requiring only a minimum use of chemical N fertilizers. Biological nitrogen fixation by legumes depends on several factors, among which are crop variety, soil property, inoculation with rhizobia, rate of N application, and phosphorus application.

Different sources of organic manure, such as farmyard manure, pigeon refuse, green manure, compost straw, and dried blood, are rich in organic matter in addition to their positive effect on chemical and physical soil properties. Better nutrient uptake and residual effect have been reported when organic manure is used, compared with chemical nitrogen fertilizers.

Utilization of biofertilizers, such as N-fixing bacteria, phosphate-dissolving bacteria, VA mycorrhizal fungi, azolla and blue-green algae, has received great attention lately as a possible partial substitute for chemical fertilization.

The idea of using soil tests to predict fertilizer requirements in Egypt was begun a long time ago. The fertilizer packages recommended to farmers are general and based on field trials carried out throughout the crop belt. Specific recommendations based on soil tests, plant tissue analyses, and field trials are needed for the different agro-climatic conditions.

The report also discusses several threats to sustainability:

- Fertilizer abuse.
- Nitrate concentration in the Nile, canals, drains, and in drinking water wells.

- Salinity and sodicity problems.
- Soil pollution with heavy metals.

Possible research issues for future work have been proposed: i) practices to improve the efficient use of fertilizers; ii) better management of salt-affected soils; iii) conserving the environment; and iv) interactions between fertilizer management and other issues.

Water Management Component

The report reviews the irrigation and drainage systems in the Old Lands and their merits and drawbacks. Water management is also reviewed, its concept, approach, and targets. An introduction on the importance of improved water management under scarce water conditions for the development of sustainable agriculture is included.

The report gives a detailed description of the irrigation system, including the conveyance, distribution, and on-farm systems. The description of the conveyance and distribution system includes losses and efficiency in each part of the country.

The on-farm irrigation system involves: irrigation practices, the condition of structures and channels, and how the system operates. The main features of the irrigation system, such as rotation, upstream water level control, winter closure, and the reuse of drainage water, are reviewed in detail. Future plans to improve irrigation through the Irrigation Improvement Project are also outlined. This project is under implementation as a pilot project, and will be implemented on a national scale in the near future. Water needs of different farm crops are also included. The report also gives a detailed description of the drainage network in Egypt, including the layout of both open and subsurface drains, drainage water flows, the effect of drainage on crop production, the effect of drainage water reuse on soil and crop production, and drainage problems in Egypt. The last chapter of the report deals with the quality of irrigation and drainage water, and their variability according to location and time.

Integrated Inventory Studies of the Agricultural Resources of the Old Lands

The individual reports of the aforementioned components have been synthesized and integrated under four broad categories to meet the terms of reference of the inventory studies, which provided general guidelines for this and other studies.

These categories are:

- Resource description.
- Resource utilization and management.
- Productivity and profitability.
- Threats to sustainability.

Resource Description

Climate and meteorology

The climate in the North Delta is typically Mediterranean, with dry mild summers and cool wet winters. Due to proximity to the Mediterranean and northern lakes, as well as to prevailing northeasterly winds, the summer in the area is most agreeable. In the rest of the Delta, the climate almost resembles that of the Great Desert area of North Africa, with little rainfall occurring, mostly as occasional thunderstorms. In Cairo, 10–12 rainy days a year is the average. Further south the amount decreases rapidly. The influence of the sea extends southwards as far as the apex of the Delta, but the air is warmer in summer after its passage over the heated Delta, and colder when the south wind blows in winter.

The average maximum temperature in the Delta is about 34°C (in July or August), while the minimum is about 6.4°C (in December and January), and the mean annual temperature is around 20°C, which places Nile Delta soils under the thermic temperature regime. Evaporation is relatively high, especially during the summer—approximately 8 mm/day in June and 2 mm/day in December. The annual mean evaporation is approximately 5 mm/day (1.825 m/year). The relative humidity is low in summer and high during winter months. It amounts to 65% in May and 82% in January.

Soil fertility and taxonomy

The soil of the Nile Valley and Delta was formed from Halocene alluvial deposits consisting mainly of dark grayish-brown suspended Nile matter. Because the river has changed its path from time to time, the thickness of the deposits varies according to location as well as the irregular surface. However, the general thickness of the suspended matter varies from approximately 6.7 meters in Aswan in the south to approximately 11.2 meters in the North Delta.

Soil classification, according to the USDA Soil Taxonomy System for the Nile Valley and Delta, shows that vertisols dominate the soils of the West, East, and Middle Delta, Fayoum Depression, and the Nile Valley, while entisols are present in narrow strips along the Rosetta Branch, Damietta Branch, in small areas along the river branches, in strips along the river banks, and around the lakes. Aridisols are found in large areas along the Cairo–

Alexandria Desert Road, around and west of El Natrun Depression, in a narrow strip along the coast of Abu Qir Bay, along the coast and west of the Suez Canal, in a large area along the Cairo–Suez Desert Road south of Birket Qarun, and west of Beni Sueif.

Since most of the agricultural research work is conducted in the research and extension centers in the Valley and Delta, soil classification for the main centers is reported. Gemmeiza (Gharbia Governorate) is classified as vertisol, subgroup typic torrets, with clay content between 40 and 68%. The soil of Sakha (Kafr El Sheikh Governorate) is the same as Gemmeiza, with clay content between 38 and 78%. Sids (Beni Sueif Governorate) is classified as entisol, subgroup vertic torrifluvents. Shandaweel (Sohag Governorate) is classified as entisol, subgroup typic torrifluvents.

Physical and chemical analysis of soil samples collected from different sites in the Valley and Delta show that textures range from sandy to heavy clay, pH 7.3–8.3, calcium carbonate 2.1–8.3%, total soluble salts 0.09–0.33%, organic matter 1.22–2.24%, CEC 31–61 meq/100 g soil, total nitrogen 0.07–0.113%, available P (by Olsen method) 1–29 ppm, and available K (by am. acetate method) 288–663 ppm.

Before the High Dam was constructed in the 1960s, Nile deposits played an important role in maintaining the fertility of Egyptian soil. Earlier studies showed that the flood water carried a considerable load of sediment. Approximately 8.8 million tons were deposited annually on the basin-irrigated lands of Upper Egypt, 2.7 million tons on the perennially irrigated lands, and 0.5 million tons in the Delta. Considerable amounts of macro- and micronutrients and organic matter were deposited annually over the cultivated land in Egypt. Significant reduction in nutrient supply was reported after building the High Dam. Soil fertility surveys show that micronutrient deficiencies are 80.5% for Fe, 83.4% for Mn, 80.9% for Zn, 76.5% for Cu, and 78.7% for Mo. In conclusion, the discontinuity of precipitation of Nile sediment over Egyptian soils after the High Dam means that soil must be replenished with macro- and micro-plant nutrients to ensure high crop production for the increasing population.

Several studies have established the poverty of most Egyptian soils in organic matter and nitrogen content. Results from soil survey studies of approximately 14,000 soil samples representing eleven governorates show that 50–100% of the tested samples were poor in nitrogen, while 3–70% were poor in available phosphorus. Potassium was fairly high, and in many cases there was no significant response to K fertilizers, except for some horticultural crops grown on sandy and calcareous soils. With regard to micronutrients, Fe deficiency dominated in calcareous soils, while Mn deficiency was found in alluvial soils. Zn deficiency was detected in some sandy and lowland soils. Cu accumulation sometimes occurred due to heavy use of Cu fungicides.

Irrigation water

Irrigation system

The irrigation system in Egypt is a closed system that starts with one single inlet of irrigation water at the Aswan High Dam and ends at the Mediterranean Sea and the coastal lakes, which are directly connected with the sea. The irrigation system can be best described if the Nile system is divided into stretches. These stretches are:

- Aswan High Dam to Esna Barrage.

- Esna Barrage to Naga Hammadi Barrage.
- Naga Hammadi Barrage to Assiut Barrage.
- Assiut Barrage to the Delta Barrage.
- Damietta Branch in East Delta.
- Rosetta Branch in West Delta.

Nile water, from Aswan to the Esna Barrage, is lifted by floating pumping stations in the river, and released into the main irrigation canals which serve approximately 170,000 fed (71,428 ha) of cultivated land. The major perennial crop is sugarcane. Winter crops are wheat and berseem and summer crops are grain sorghum and sweet maize. The cultivated area in this stretch is irrigated by gravity, and drainage water is also returned to the Nile by gravity. An exception is the newly reclaimed area in Wadi Abbadi and Radi Sea, where water is lifted to irrigate high elevations of originally desert land. Irrigation is carried out on the Kom Ombo Plateau, which was reclaimed from desert lands at the beginning of the century. Land reclamation is still taking place in this area.

From the Esna Barrage to the Naga Hammadi Barrage, the Nile feeds two main canals, which run parallel to it: the Asfoun and Kallabia Canals. The major summer, winter, and perennial crops are similar to those of the previous stretch.

The area downstream of the Naga Hammadi Barrage is irrigated by the East and West Naga Hammadi Canals, which run parallel to the River Nile.

The stretch from Naga Hammadi to the Assiut Barrage is marked by the gradual switch from sugarcane to other farm crops. In the Governorate of Assiut, wheat, faba bean, berseem, and vegetables are the major crops.

The total cultivated area from Aswan in the south to Assiut in the north, which is usually called Upper Egypt, is about 465,000 ha divided between winter and perennial crops as follows: wheat and barley 0.379 million fed (0.159 million ha), faba bean and lentil 0.114 million fed (0.0478 million ha), berseem 0.204 million fed (0.0857 million ha), vegetables 0.091 million fed (0.0382 million ha), sugarcane 0.269 million fed (0.113 million ha) and orchards 0.051 million fed (0.021 million ha). This means that the area grown with cereals, legumes, and berseem is almost two thirds of the total area cultivated.

Upstream of the Assiut Barrage, the Ibrahimia Canal, one of the largest man-made canals in the world, is fed by the Nile. This canal irrigates the land north of the city of Assiut in Assiut, Minya, Beni Sueif, and Giza Governorates. About sixty kilometers north of Assiut, the Dairout head regulator is constructed to feed Bahr Yousef, a large irrigation canal which provides water for the agricultural lands in Fayoum. The irrigated area in Fayoum is about 0.350 million fed (0.147 million ha), while the area cultivated from the intake of the Ibrahimia Canal to the Delta Barrages is about 1.296 million fed (0.544 million ha). This area is divided between different winter and perennial crops as follows: wheat and barley, 0.284 million fed (0.119 million ha), faba bean, 0.158 million fed (0.066 million ha), berseem, 0.399 million fed (0.167 million ha), vegetables, 0.263 million fed (0.11 million ha), sugarcane, 0.038 million fed (0.0159 million ha), and orchards, 0.154 million fed (0.064 million ha).

The Nile Valley downstream of the Aswan High Dam ranges in width from 0 km (north of Aswan), to 2 km (near the town of Daraw) and 26 km (near the city of Beni Sueif). A schematic diagram of the irrigation system in the Upper and Middle Egypt is given in the main report.

The irrigation and drainage system in the Delta is usually divided into three areas:

- The area east of the Damietta Branch, usually called the East Delta.
- The area between the two Delta branches, known as the Middle Delta.
- The area west of the Rosetta Branch, called the West Delta.

Each of these areas depends on a major canal (*rayah*) fed directly from one of the Nile Branches. Rayah Tawfiki is the major irrigation canal in the East Delta, Rayah Menoufi in the Middle Delta, and Rayah Beheiri in the West Delta. Schematic diagrams of the irrigation system in the East, Middle and West Delta are shown in the main report.

Characteristics of conveyance and distribution systems

Irrigation water is distributed through an extensive network of irrigation canals, which vary according to function:

- Carrier canals, from which abstraction of water is not allowed.
- Distributary canals, which divert water either to lower order canals or directly to the irrigated fields.

A distinction is made between irrigation canals according to their size or the area they serve:

- Principle (public, first order or *rayah*) canals receive water directly from the Nile or its branches and convey it to the main canals.
- Main, or second order, canals take water from first order canals and pass it to branch canals. In most cases direct irrigation is not permitted from the first two classes of canal.
- Branch canals receive water from first or second order canals and convey it to distributary canals. Direct irrigation at the lower reaches of branch canals is sometimes permitted.
- Distributary canals receive water from branch canals for distribution to field ditches called *mesqas* through legal outlets. Irrigation rotations are normally applied at this level.

On-farm irrigation from distributary canals is carried out by lifting in approximately 80% of the areas. Gravity irrigation takes place only in Aswan and Fayoum Governorates. Almost all irrigation canals in the Old Lands are unlined.

Estimates of conveyance and distribution efficiency are 95, 85, and 80% in Upper, Middle, and Lower Egypt (Delta), respectively. The Irrigation Efficiency Indicator, as given by ISAWIP for the total research area of 80,000 fed (33,613 ha) served by Bahr El Saghir Canal, ranges between 67 and 72%. For El Nazl pilot area the range is 55 to 62%.

Irrigation rotation and schedules

The land served by a set of distributary canals, fed from a branch canal, is divided into two approximately equal areas, with water delivered by a dual (two-turn) rotation, or into three approximately equal areas, with water delivered by a three-turn rotation. For example:

- Two-turn rotation
    - 4 days on and 6 days off (rice).
    - 7 days on and 7 days off (cotton).
- Three-turn rotation
    - 4 days on and 8 days off (general crops/summer).
    - 5 days on and 10 days off (general crops/winter/Upper and Middle Egypt).
    - 7 days on and 14 days off (general crops/winter/Delta).

The system was recently changed to 7 days on and 7 days off in summer, and 5 days on and 10 days off in winter, except in rice areas, where the rotation is 4 days on and 6 days off.

The main reason for using a rotation system is to save water. When water does not flow in half or two thirds of the distributary canals (two- or three-turn rotations, respectively) evaporation and seepage losses are reduced. When the farmers realize that if they do not irrigate during their designated rotation, they will not be allowed to irrigate until their next turn—which might be a long period of time, causing a loss in production—they do their best to irrigate during their rotation. If only half (or one third) of the area is irrigated at a time, the drainage system will be relieved and will perform more efficiently. The off period can be used to carry out small repairs and system maintenance. It also gives farmers the opportunity to do other works such as fertilizing, applying pesticides, etc.

Disadvantages of the rotation system include the inability to schedule irrigation. Problems arise, for instance, if three winter crops—wheat, faba bean, and berseem—are grown in the same rotation area. Wheat needs to be irrigated only once a month, faba bean needs irrigation once every three or four weeks, and berseem requires irrigation once every two weeks. If water is delivered according to a 7 days on and 7 days off rotation, then the first two farmers will irrigate once every 14 days, which is, in fact, more than the actual crop water requirement, and represents a loss to the system.

The situation is even worse with summer crops during peak demand, because many farmers—those at the canal heads, those who grow crops sensitive to moisture deficit, and those who have sandy soils—occasionally irrigate both at the beginning and at the end of the rotation to be certain that there will be adequate soil moisture until their next turn.

Since the rotation continues even when farmers have little demand for water, canal water flows unused through the system to the nearest drain. A strong recommendation is thus made to switch from a rotation to a continuous flow system, in which water will pass continuously through the irrigation canals and farmers will abstract water when their crops need it, and not more.

Drainage facilities in Egypt

With the introduction of perennial irrigation at the beginning of the century, the construction of open drainage systems was initiated. It is the responsibility of the state to construct the main drainage facilities as a public service. By 1965, nearly 5 million fed (2.1 million ha) was served by main open drains, but farmers did not respond as expected by building the required system of field drains. They could not afford to lose the area that would have been covered by the ditch drains. Consequently, the drainage system was neither complete nor effective.

Recognizing the inadequacy of the ditch drainage system, research was initiated in 1939 to try tile drainage in different parts of the country. By 1952, pilot projects had been extended to 50,000 fed (21,000 ha). Encouraged by the results obtained, a law was passed in 1956 making the government responsible for building field drains. Between 1961 and 1965, modern installation techniques for tile drainage were tested through a pilot project covering five areas, each up to 2,000 fed (840 ha), implemented under the auspices of the United Nations Special Fund, with FAO as the executing agency.

When irrigation water became available from the High Aswan Dam in 1964, it allowed the introduction of perennial irrigation to all irrigated areas, thus reclaiming New Lands and increasing cropping intensity. Direct consequences of this intensified irrigation include a rising groundwater table, and increased problems of waterlogging and salinity. Poor water management and inadequate water-table control significantly contribute to these problems. In response to this challenge, the government has given a high priority to installing subsurface drainage systems to conserve the productivity of agricultural areas.

When the government became convinced that providing agricultural lands with field drainage would increase crop yield and prevent waterlogging and soil salinity, a national program was initiated. It was started in the southern part of the Nile Delta where salinity and high water table problems were predominant. A separate authority for drainage was established in 1959, as a department of the Ministry of Irrigation, to take responsibility for implementing drainage projects throughout the country. In 1970 an area of 950,000 fed (399,159 ha) in the southern part of the Delta was provided with covered drains, 11 drainage pumping stations were constructed, and the main open drainage systems in the area were widened and deepened to allow field drains to be installed.

In 1973, World Bank programs were extended to cover areas in Upper Egypt that had begun to suffer from waterlogging and salinity. A second agreement was signed with the World Bank in 1973 for a loan to install covered field drains in an area of 300,000 fed (126,050 ha) in Upper Egypt, to install four pumping stations, to reclaim 22,000 fed (9,243 ha) suffering from salinity and alkalinity problems, to rehabilitate the main drains, and to implement a bilharzia control program in an area of 900,000 fed (378,151 ha) in Upper Egypt.

Open drainage system

The most affected irrigated lands were divided into several drainage units to be served by independent pumping stations. The main open drains projects started in 1933, and consisted of a huge system of open drains and pumping stations. The system is divided into:

- Open and covered drains (collectors and laterals).
- Open collector drains that comprise both branch and sub-branch drains.
- A carrier network of main drains, which receives water from the collector system and conveys it to the Nile, or discharges it into the coastal lakes or the Mediterranean Sea.
- Pumping stations, which transfer drainage water to coastal lakes or to the Mediterranean Sea.

The Ministry of Public Works and Water Resources has established comprehensive drainage programs ranging from the construction of open collector drains and additional pumping stations to the maintenance of the drainage system and weed control. These programs resulted in improvement of drainage conditions in the areas involved.

A 1977 survey of pumping stations showed a total of 80 pumping stations serving an area of about 4,172,000 fed (1,813,913 ha) in the Nile Delta and Upper Egypt. From 1977 to 1987, more pumping stations were constructed, bringing the total to 129, with a capacity of 2,459 m^3/sec and serving an area of 6,592,450 fed (2,769,936 ha).

In the late 1970s, the Drainage Research Institute (DRI) took the lead in establishing a network of measuring stations at key points along the main drains in the Nile Delta. The measurement network is composed of 22 drain catchments, each of which consists of a single or multiple drainage zone.

Subsurface drainage

The intensive land drainage program initiated in 1970 included:

- Construction of open collector drains.
- Remodeling of the existing open drains.
- Construction of additional pumping stations.
- Installation of field tile drainage.

As of the end of 1988, about 3.2 million fed (1.34 million ha) in the Nile Delta, and Middle and Upper Egypt were provided with subsurface drainage and an improved open drainage system. Data on the status of land drainage projects up to year 2000 and a map of the areas involved are presented in the main report.

Time sequence data on water quality

Nile water quality

Salinity. Generally, the water of the River Nile is of good quality, with total salt content not exceeding 350 ppm and an average adjusted SAR of 4.5. The average salinity and chemical composition of irrigation water at various locations along the main canals in the three major regions of the Delta are given in the main report. The data illustrate that the salt content in the irrigation canals in the Delta is 0.35–0.7 mmhos/cm. The dominant cations are calcium and magnesium throughout the year, and the prevalent anions appear to be bicarbonate in winter and sulfate in summer.

Environment. The River Nile is considered the source of life for Egyptians. It is put to multiple uses, such as domestic, commercial, agricultural, industrial, and navigational activities. Different types of waste material enter the river, affecting its water quality. Water quality monitoring programs have existed since 1976. Their main objective is to serve and evaluate Nile water quality and the potential effects of pollutants with respect to different water uses. The historical data show that the quality of Nile water has deteriorated at some locations. The situation is probably getting worse with time, as the discharge of waste increases. The monitoring stations along the River Nile are reviewed in the main report. Priority was given to 13 major sites, according to proximity to barrages, and heavy pollution. The results of this monitoring program are summarized later in this section.

Average Water Quality Index (AWQI). The Average Water Quality Index is defined as a rating reflecting the composite influence of a number of parameters on overall water quality. The Average Water Quality Index along the River Nile from Aswan to the Delta Barrage is given in the main report. AWQI varies from site to site according to the specific water quality parameter contribution. For example, dissolved oxygen and coliform are important contributing factors at some sites.

Water quality parameters and standards from Aswan to the Delta Barrage. The most important parameters affecting water pollution indicators and the source of the recommended standards are listed in the main report. They vary along the course of the River Nile from Aswan to the Delta Barrage:

- Dissolved oxygen (DO): The DO levels fluctuated along the river between 3.1 and 9.5 mg/l.
- Chemical Oxygen Demand (COD): The concentration varied between 5 and 25 mg/l. About 65% of the sites were below the standard value of 0 mg/l.
- Biochemical Oxygen Demand (BOD): The concentration varied between 0.4 and 4.7 mg/l. The concentration of BOD was below the standard value (6 mg/l).
- Total phosphorus (TP): The concentration of TP was below the standard value of 0.1 mg/l at all sites.
- Fecal Coliform Count: The most probable number (MPN) varied between 14 and 12000 MPN/100 ml, exceeding the standard value (2000 MPN/100 m) at 4 sites only.
- Total Coliform: *Total coliform counts fluctuated between 76 MPN/100 ml and the* standard value (10,000 MPN/100 ml), exceeding the latter at only five sites.
- Ammonia (NH_3): The concentration of NH_3 fluctuated between 0.01 mg/l and 0.6 mg/l. The concentration was below the standard value (0.5 mg/l), except at one site, where it exceeded the standard value by 20%.
- Surfactant: Concentrations of surfactant were mainly between 0.008 and 0.06 mg/l. A value of 0.18 mg/l was observed at one site, still below the standard of 0.5 mg/l.
- Nitrate (NO_3): The concentration of NO_3 along the river was very low, below the standard value of 45 mg/l. It fluctuated between 0.81 and 3.8 mg/l.
- Organic nitrogen: *Organic nitrogen concentrations along the river were very low.*

Water quality parameters and standards along the Rosetta Branch. In order to evaluate water quality along the Rosetta Branch, the Water Quality Department of the Nile Research Institute, as part of its monitoring program, collected samples in 1990/91. These samples were analyzed following physio-chemical parameters, including organo-chlorinated pesticides and biological characteristics along the Rosetta Branch, at agricultural drains, and industrial effluent outfalls. The following parameters were evaluated:

- Nutrients: nitrogen (total organic, ammonia, nitrite, and nitrate) and phosphorus (ortho).
- Organic pollutants: BOD, COD, surfactant (S), oil, and grease.
- Major ions: TDS, Cl, *sulfate, calcium, magnesium, sodium, and potassium.*
- Organic micro-pollutants: phenols, surfactant, and organochlorine pesticides.
- Bacteriological and biological: total coliform, fecal coliform, algal density, and chlorophyll "a."

The results of this study are:

- Generally the water in the Rosetta Branch has a pH between 7 and 9, and an alvalinitu value between 150 mg/l (during winter) and 270 mg/l, downstream from the Rahawy Drain discharge point. The total solids range from 246 mg/l (May 1991) to 410 mg/l (winter closure). The TDS concentration has a steady value of 500 mg/l.
- Surfactant: Surfactant concentrations along the Rosetta Branch vary according to season.
- Organic pollutants: In general, although the Rosetta Branch receives effluent from various sources, it shows considerable self-purification capability, resulting in water of good quality. This was indicated by BOD and COD, where values are matched with the value of dissolved oxygen concentration along the branch. The dissolved oxygen content in water upstream of the Delta Barrage is 8.2 mg/l in winter and 11.5 mg/l in summer.
- Nutrients: The nitrogen concentration of different components along the Rosetta Branch is given in the main report. Generally, ammonia and organic nitrogen concentrations are at low levels at the Delta Barrage. They increase immediately downstream from the Rahawy Drain, then gradually decrease further downstream. Nitrate concentration ranges between 2 and 7 mg/l along the branch; reaching 12 mg/l at Kafr El Zayat.
- Pesticides: The total organochlorine concentration is higher upstream from the Delta Barrage than upstream from the Edfina Barrage. The value of organochlorine residues should not exceed 0.1 mg/l in water samples. Pesticide residues along the Rosetta Branch are listed in the main report.

A similar study was carried out to evaluate River Nile water quality based on pesticide residues along the Rosetta Branch. The organochlorine pesticide residues were monitored in water samples collected from two sites upstream from the Delta barrage and upstream from the Edfina Barrage. Samples were collected before, during and after the winter closure, and three months later. Samples were analyzed for 15 organochlorinated pesticides, DDT complex, HCH isomers, oxychlordane, endrin, heptachlor epoxide, and dieldrin residue. The results show that the highest levels of organochlorine pesticide residue were found after the termination of the winter closure.

Biological Index of the River Nile: The degree of eutrophication and pollution along the Nile was evaluated. The biological evaluation included the compound eutrophication index, trophic state index, autotrophic index, Wiener index, Saprobic index, Saprobic quotient, and the concept of the indicator species. These biological approaches rely mainly on the species composition of phytoplanktons, the distribution of individuals among species, chlorophyll "a" concentration and the dry weight of the organic matter. The study was carried out from autumn 1987 to summer 1988. Water samples were collected from 16 different sampling stations, three located upstream and thirteen downstream from Cairo. The biological approaches revealed a severe deterioration in water quality progressing from upstream to downstream. From a biological point of view, the water of the study area is typically eutrophic, with pollution ranging between P mesosaprobic and oligosaprobic conditions. For a more detailed description of that study, refer to the original report.

Drainage water quality

Salinity status of drainage water. Agricultural drainage water in Upper and Middle Egypt is discharged into the River Nile. Thus it mixes with Nile water and becomes a part of the flow to the Delta. This slightly affects the quality of Nile water, as salinity increases from 250 ppm at Aswan to 300–350 ppm near Cairo. The amount of drainage water from Upper and Middle Egypt is relatively small, estimated at approximately 2 BCM per year. The drainage system in the Delta is extensive, serving an area of 4.72 million fed (1.98 million ha) out of Egypt's 7.2 million fed (3.02 million ha) of agricultural land. The length of the main open drains in the Delta is approximately 1,600 km. The drainage water in these drains is of low quality, and in the past the drains discharged into the sea or the coastal lakes. However, there are now few drains which discharge their water into the two branches of the Nile.

Preliminary investigations show that a substantial proportion of the drainage water flowing to the sea has acceptable salinity and can be reused for irrigation. However, its inclusion requires careful and detailed evaluation of quantity and quality. The Drainage Research Institute of the Water Research Center was entrusted with carrying out a long-term monitoring program to determine the time-dependent variables of drainage flow in the Delta. A network of fixed measuring stations at key points along the drainage system was established in the late 1970s. Since then, the network has been maintained and upgraded to furnish reliable measurements. The measuring sites are located at drainage catchment outlets (whether a pumping station or a gravity outlet), at pumping stations which lift water from branch drains into main drains, at intermediate check points along the main drains, and at reuse pumping stations. The current monitoring network consists of 90 measuring stations distributed all over the Delta.

An important parameter for evaluating the suitability of drainage water for agricultural uses is salt content. Annual variations are primarily dependent on water use policies and management of the main supply system. The strict control and reduction of releases associated with drought in the Upper Nile basin have resulted in an increase in salt content in drainage water and a reduction in drainage discharges, i.e., the reduction in drainage water quality due to the rationalization policy introduced in 1987/88 has resulted in an increase in salinity. Drainage water salinity varies from one month to another, and is influenced by the cropping system and the irrigation system and its loss into the main drains. The monthly variation of drainage water salinity is illustrated in the main report. The monthly distribution of drainage water flow into the sea or coastal lakes, and the amount reused in each Delta region from 1984/85 to 1989/90, are presented in the main report.

Drainage water pollution: Sometimes, waste generated domestically or industrially in villages or towns finds its way to the open drains. The drainage water in certain locations is highly polluted (Bahr El Baqar main drain). Simple tests, such as biological oxygen demand, chemical oxygen demand, and some microbiological examinations, have been carried out by the Drainage Research Institute to ascertain the type of pollutants and their amount in drainage water. The source and degree of pollution in some locations in the Nile Delta are given in the main report.

Land ownership

Egypt has about 6 million fed (2.52 million ha) of fully irrigated Old Lands. One of the most important characteristics of ownership and tenure distribution in Egypt is its fragmentation. A review of the distribution of land ownership in 1990 showed that about 95.7% of the owners own less than 5 fed (2.1 ha) and about 56.3% of the total area. Only 0.4% owned more than 50 fed (21 ha), representing about 15% of the total area.

Land tenure

Review of the distribution of land tenure in 1982 showed that about 91.1% of the holders hold less than 5 fed, and they hold about 52% of the total area. Only 0.2% of the holders hold more than 50 fed, and the area they hold represents about 12.7% of the total area. Compared to 1961, a recent survey shows that the average size of land holdings is still decreasing due to continuing fragmentation.

Types of land tenure

The three main types of land tenure in the Egyptian agricultural sector are: owned tenure, rented tenure, and shared tenure. The data from the 1961, 1981, and 1990 surveys illustrate the following changes:

- There has been a continuous increase in the relative importance of owned tenure land (both number and area), representing 68% of the tenures and holdings and about 75% of the area in 1990.
- There has been a dramatic decrease in the relative importance of rented tenure land, from 31.9% in 1961 to approximately 14.6% in 1990. However, there has been no significant change in the percentage of area held, 19.5% in 1961, and 16.36% in 1990.
- The relative importance of shared tenure decreased in both number of tenants (from 30.2% to 13.8%) and area held (from 37.7% to only 2.39%).

Dominant cropping systems

Agriculture in the Valley and Delta is dependent on irrigation from the Nile, with water available year-round. Consequently, continuous cropping is the general practice. The dominant rotations are three-year and two-year cotton rotations. Crops included in these rotations are cotton, berseem, food legumes, wheat, barley, rice, maize, and oil crops (peanut, sesame, sunflower, soybean) in summer.

The sugarcane rotation is also very important. The area cropped to sugarcane is about 113,000 ha, with an average yield of 100–120 t/ha. Main producing governorates are Qena, Aswan, and Minya. The crop is usually planted either in October (autumn planting) or February–April (spring planting). The cane crop is obtained 12–14 months after planting, followed by 4–5 ratoons taken at 12-month intervals. Thus, the crop is on the land for 5–6 years, after which the land is often planted with winter (mainly wheat) and summer (mainly cotton) crops for one or two years, then replanted with a new sugarcane crop.

Livestock

Egypt has a large livestock population. The livestock holding is almost 2.4 head per ha. According to the census adopted by the Ministry of Agriculture and Land Reclamation

(1982), the total number of cattle and buffaloes is 5.28 million, while sheep and goats number approximately 6.0 million. A survey conducted by MALR in 1988 showed that there have been some changes, with the buffalo population increasing by 20%, and the cattle population decreasing by 7%.

Most of the cattle population are in the Delta (60%), whereas only 38% are in Middle and Upper Egypt. The buffalo population exhibits the same trend, and is concentrated in the Delta, with only 39% in Middle and Upper Egypt. About 93% of the cattle in Egypt are owned by small farmers. The average herd size is between 1.5–2.5 head. Buffalo ownership is similar.

Resource Utilization and Management

Cropping systems

Cotton, maize, and rice are the country's major summer crops. They are harvested in October and November. There is usually limited time to get land prepared for winter crops. Accordingly, zero or minimum tillage systems prevail, with no appreciable reduction in winter crop yield. However, the impact of these tillage systems on soil-borne and seedling diseases that may threaten production of winter crops has not been well-studied. Therefore, it is important to assess the effect of soil tillage systems on soil-borne diseases, which have plagued faba bean in recent years, especially in Middle and Upper Egypt.

Recently, there has been a trend for intercropping, where a secondary crop is grown with the main crop to improve land and water utilization:

- Sugarcane/soybean.
- Maize/soybean.
- Sugarcane/faba bean (or lentil).
- Sugar beet/faba bean
- Mixed cropping.
- Faba bean/fodder beet.
- Berseem/barley.
- Lentil/faba bean.

Current and future trends:

- Maize/early maturing soybean.
- Sequential multiple cropping.
- Catch cropping.
- Leaf-feeding insect-resistant soybean after wheat.
- Maize/early maturing disease-resistant faba bean/cotton.

The benefits that can result from the cropping systems mentioned above are: i) more efficient use of farm resources; ii) greater resource efficiency from farm waste and by-products; iii) increased land utilization; iv) stabilization of farm income; v) risk minimization; vi) minimizing environmental pollution through reducing N fertilizer rates and insecticide use; vii) maximizing faba bean area and production to meet increasing demand; and viii) increasing soybean and faba bean production as current demand exceeds local production.

Animal feed sources

Forage crops

Two of the principal summer and winter crops are cotton and wheat. Both affect forage production. Until recent years, these two crops were not financially attractive to the farmers due to poor profitability. As a result, farmers have increased their enterprises where government control is lowest, notably in forage production. With farmers looking to their herds as a good source of income and a secure, inflation-proof investment, forage crops show high profitability. In recent years, pricing policy reforms have remarkably increased the profitability of wheat and cotton, and this has had a negative impact on the area cropped with the main winter forage crop, berseem. The average yield varies between 14–19 tons of green material/cut/ha for multiple cut berseem. A short season yields between 24–28 t/ha.

Comparing berseem production with the nutritional requirements of Egypt's livestock in winter shows an excess of protein and a shortage of energy. Annual berseem production is 64.55 million tons of green material (55.95 million tons from the multiple cuts and 8.7 million tons from the short season).

Fodder beet could have a place in the forage system. Dry matter yield of fodder beet is similar to that of berseem (approximately 14 t/ha), but fodder beet exceeds berseem in the amount of energy obtained. Moreover, fodder beet is more palatable, and thus increases the intake of dry roughage. It can be transplanted later in the season than berseem. One of the major constraints to fodder beet expansion, however, is the problem of storing the crop after harvest. Using fodder beet for silage may offer a solution to this problem.

Summer forages are relatively few, as land is fully committed to human crop requirements. The available data estimate the total area under summer forages at 83,073 ha. The main summer forage crops are sorghum and sorghum hybrids. The total production of green material is estimated at 3.6 million tons. The area under alfalfa, mainly in reclaimed lands, is approximately 5,000 ha, producing 3.2 million tons.

Compound feed

Animal and poultry feed. Recent reports by the Ministry of Agriculture and Land Reclamation (1990) estimated the production of compound feed mix at 2.5 million tons. However, available manufacturing capacity is 4.5 million tons.

Feed is the most expensive input in animal and poultry operations. Feed represents 60–70% of the total running cost. Increasing feed production in Egypt is constrained by limited cultivable land, and it is important to intensify land use to meet the needs of the ever-increasing human population, as well as animal feed requirements.

The policy of the government is to focus on:

- Increasing green fodder per unit area.
- Increasing maize production to reach self-sufficiency.

- Searching out new feed resources for feed compounds, and ensuring the production of high quality feed compounds.

The estimated capacity of poultry feed manufacturing facilitates is approximately 3.5 million tons annually. For the last three years production figures have been 2.2–2.5 million tons of compound feeds. Poultry feed compounders use a limited number of ingredients: yellow maize, soybean meal, and concentrate formula premixes.

Fibrous agricultural residues. The total national production is estimated at about 15.7 million tons annually for cereal straw, berseem hay, maize stover, maize cobs, sugarcane tops, rice husks, and rice straw. Other fibrous residues are sugar beet tops, in those parts of the Delta where the crop is grown, and cotton hulls from the ginning of cotton.

Some of these residues are included in the concentrated compounds to produce complete feed compounds for ruminants. The use of fibrous agricultural residue is limited to 4.5 million tons, due low nutritive value and poor farmer knowledge.

Biotic and abiotic stresses

Food legumes

Productivity of faba bean, lentil, and chickpea is constrained by various biotic and abiotic stresses in different farming systems. Yield potential of these crops is seldom achieved due to unsuitable cultivars and inadequate crop management to cope with these stresses.

Major biotic stresses include disease, insect pests, and weeds (parasitic and non-parasitic), while major abiotic stresses include extremes of soil moisture, high temperature during the reproductive stage, and soil fertility imbalances (nutrient deficiency, toxicity, and salinity). The seriousness of these stresses is often associated with farming systems characterized by specific agro-climatic conditions.

Given the irrigated farming system (mostly flood and furrow irrigation) and the relatively hot dry environment in Egypt, foliar diseases are usually less important than soil-borne diseases in cool-season food legumes, except in areas of high relative humidity and wetness, such as the North Delta. In this hot environment, aphid, leaf miner, white fly, and seed beetle are important production constraints. Viruses are of major concern because of high aphid activity.

The damage caused by chocolate spot and rust diseases in the North Delta would be increased if faba bean were sown early in October, as pathogen spread and development is enhanced by vigorous vegetative growth. However, in Middle and Upper Egypt, planting faba bean on November 1 was found to produce the best results. Planting either on October 15 or on December 1 decreased seed yield by 17.6 and 55.3%, respectively. Moisture condensation around faba bean plants in dense stands usually encourages foliar disease, resulting in low yields.

Chickpea cultivation is concentrated in Upper Egypt, mainly Assiut Governorate (75% of the total crop area), with only 25% in the Delta. However, foliar diseases (Botrytis gray mold, rust, and to a lesser extent ascochyta blight) are constraints to high production in the Delta in certain seasons. Seedling and root-rot diseases are important because of the damage they cause, particularly in Middle and Upper Egypt.

Yield reduction due to weed competition ranges between 24 and 30% in faba bean. In Egypt, as hand labor has become expensive and scarce, chemical weed control becomes necessary and practical. Broom rape is also a serious parasitic weed of faba bean, lentil, and, to a lesser extent, chickpea.

Principal production problems and constraints for soybean are: i) competition with maize, rice, and cotton for arable land (soybean has higher production cost and lower net return per ha than maize); ii) lack of varieties with proper maturity for cropping systems; iii) damage by mites and leaf-feeding insects, primarily cotton leaf worm; and iv) the need to reduce N fertilizer input costs.

Cereal

Constraints to wheat and barley production are mainly high temperature—especially in Upper Egypt during grain filling—aphid infestation, planting old local varieties, late planting, limited access to advanced production technology, inadequate irrigation, and disease. Weeds constitute one of the major constraints to cereal crops, especially wild oat, which causes appreciable reduction in grain yield in most cereal fields. In Egypt, as hand labor has become expensive and scarce, chemical weed control has become necessary and practical.

New, rust-resistance wheat varieties have been developed, but the appearance of new virulent pathotypes makes the effective life of a new variety very short. Therefore, the development of new, resistant genotypes should be continued.

Stem rust has been severe in Middle Egypt, mainly on durum wheat. Leaf rust infection is higher than stem rust in northern areas (Beheira and Nubaria). In the Delta, leaf rust and stem rust are widespread, while some infection with stripe rust has been observed at Gemmeiza and Sakha.

Barley Yellow Dwarf Virus (BYDV) has been a serious problem in wheat and barley fields during recent years. This virus is considered one of the most destructive wheat and barley diseases. Aphid is the most destructive pest attacking wheat in Egypt. It causes serious damage by sucking the plant sap and transmitting viral diseases such as BYDV. Four species of aphid are found in Egypt: *Rhopalosiphum padi, R. maidis* F, *Schizaphis graminum* R, and *Sitibion avenae* Fab. The Russian wheat aphid has also been found in wheat and barley fields. Losses in grain yield range from 4 to 23% due to aphid infestation.

Estimated losses in wheat yield due to aphid infestation were 7.5–23% in Middle and Upper Egypt, where the highest infestation occurs. Current aphid control in wheat fields is dependent mainly on chemical insecticides, regardless of their direct and indirect impact on the environment, particularly the harmful effect on natural enemies (predators). A sharp decline in the number of predators (40–48%) and parasitism (66%) has been observed after spraying. An integrated pest control program is needed for aphid control in wheat fields.

Barley is vulnerable to many foliar diseases such as leaf rust, powdery mildew, net blotch, and leaf stripe, which substantially reduce the yield of the susceptible varieties. The severity of the disease and yield loss vary from one year to another depending on the prevailing climatic conditions and pathogens in a given area.

Net blotch causes considerable damage, especially in the humid areas of the Nile Delta. It occurs in practically all fields throughout the Delta during late February and March, although it is rarely found in southern regions. Powdery mildew is found extensively in the Delta and Middle Egypt, decreasing to the south. Leaf rust occurs annually, especially in the northern parts of the Delta where high humidity is favorable for disease development.

Covered smut, on the other hand, is a seed-borne disease and very destructive because of the potential use of infected seed. Infection can range from a trace to 5%, depending on grain infection, soil temperature and moisture. Barley leaf stripe, also a seed-borne disease, has been observed on some barley varieties.

Recently, BYDV—which can be vectored by several species of aphid and is generally present throughout the dry areas but varies from year to year depending on conditions—has been observed in barley fields. The disease can be recognized by the presence of yellowing and stunted plants.

Infestation of barley with the maize leaf aphid, *Rhopalosiphum maidis* (Fitch), is common in the northern parts of the country. In Middle Egypt, *R. padi* and *R. maidis* account for 85% of aphids on barley, while the green bug *Schizaphis graminum* (12%) and *Sitobion avenae* (3%) are present in fewer numbers. It has been possible to identify some genotypes that exhibit resistance to aphid build-up.

Irrigation practices

Until the last 20–30 years, the *tambour* and *shadouf*, both small water lifting devices inherited from the ancient Egyptians, were still in common use in Egypt. Both devices are operated by hand. For larger areas, *sakias* (water wheels), operated by farm animals, were in common use. Some are still in operation.

Two important facts are highlighted in this section:

- The on-farm irrigation system in Egypt is as old as the country itself.
- Lifting of water is a traditional process, the possibility of wasting water after exerting such an effort either by human or animals is slim.

When meat and dairy prices increased, farmers realized that animals were worth more if not worked, and many changed from *sakias* to small diesel pump. Other reasons for the change were: irrigation time was shortened, competition between manufacturers of diesel pumps brought prices down, and the credit system enabled farmers to pay for pumps in installments.

The number of irrigations the farmer applies is generally consistent with the number specified by the irrigation authorities. The only difference is in the designated planting and harvesting dates, which vary considerably between farmers from one location to another, and even from one farmer to another in the same locality.

The gap between the last irrigation of one crop and the first irrigation of the next also varies between groups of farmers in different localities and between individual farmers in the same place. While some farmers use intercropping in order to make use of every single day of the year, other farmers have long gaps between their crops. Even though these irrigation gaps are prolonged, the individual crops receive appropriate final and initial irrigations when considered separately.

The irrigation gap represents a period of general decline in irrigation demand, when large volumes of water are released. Much of this water flows directly to the drains, unused.

Irrigation planning should, therefore, be based on the entire cropping pattern rather than on individual crops. Abstraction normally starts at 4:00 a.m. in summer and 8:00 a.m. in winter. Irrigation ends at 1:00 p.m., except during periods of peak demand when farmers in some locations—especially those at the tail ends of the canals—are forced to irrigate at night. As soon as irrigation ceases, canals refill, and any excess water flows into the drains unused.

The amount of water applied during an irrigation depends largely on whether or not it is the first or a subsequent irrigation. The first irrigation after a long dry period requires 150–200 mm of water. Subsequent irrigations, which only replace depleted moisture, require 70–100 mm. Puddling of rice fields requires 250 mm of water.

Each irrigation usually recharges the soil moisture profile or exceeds it. The presence of prolonged irrigation gaps, and the difference between initial and subsequent irrigations indicates a need to determine irrigation requirements over the entire crop rotation rather than considering the irrigation demands of individual crops. Over-irrigation, defined as the application of more water than a crop requires, occurs for one or more of the following reasons:

- Farmers irrigating poorly leveled land apply more water than necessary to ensure that high spots receive adequate amounts.
- The uncertainty of delivery schedules.
- A lack of knowledge about actual soil moisture.
- Poor management of water, especially during night irrigation.
- Softening of the top soil layer in order to easily remove the remains of crops after harvesting.

Despite the above factors, which favor the development of low application efficiency, the actual efficiencies measured in the Egypt Water Use and Management Project (EWUP) areas were mostly in the 60–90% range. This was attributed to the low infiltration properties of the soil. In sandy soil, the application efficiency is low. Figures ranging between 14 and 40% were reported by the EWUP. In some areas where the groundwater table is shallow, the estimated consumptive use of applied water is high, indicating a substantial contribution of groundwater to crop requirements. It was reported that the average application efficiencies in Upper Egypt, Middle Egypt and the Delta are in the range of 72, 75, and 75%, respectively. These figures were obtained from intensive experiments carried out at research stations.

The Irrigation System Efficiency Indicator, as given by the Integrated Soil and Water Improvement Project (ISAWIP) at the farm level for the area served by Bahr El Saghir Canal (80,000 fed, or 33,613 ha) is 53–58%. The margin of efficiency in El Nazl pilot area (6,800 fed, or 2,857 ha), within the same research project, is 53–60%. However, these figures should be treated with the utmost caution, since efficiency depends on the definition, which is still a matter of controversy among researchers and executives working in the fields of irrigation and agriculture. Also, on-farm efficiency depends on the location of the field with respect to the feeding canal. Tail end fields are expected to have higher efficiencies because of the tight water supply. Areas which lie at the tail end of the overall irrigation system (i.e., the most northerly part of the agricultural area, near to the coast) are considered tail end areas. On-farm efficiency is a function of surface runoff and deep percolation, if evaporation on the farm level is neglected. In the ISAWIP area, runoff and percolation account for 49% of the amount of water delivered at the farm gate, 34% for percolation and the remaining 15% for surface runoff. However, the water which percolates out of the soil is not considered a loss because it also represents the leaching component of the farm delivery requirement.

Operation

Flow in any distributary canal is assumed to be based on crop needs as determined by: i) the cropping pattern; ii) the water requirements of each crop; iii) the area served; iv) soil type; and v) the expected conveyance, distribution, and on-farm losses.

In practice, water delivery to distributary canals is based on the surface elevation on the downstream side of the off-take structure control gate. Regulation of the flow to distributary canals is usually related to the available head in the district branch or main canal.

The internal distribution within irrigation districts is accomplished by maintaining water levels in the branch and distributary canals. Most of the first order and main canal intake structures, and those of the main distribution sites between governorates, are calibrated, and the water flowing through them is measured. During on-periods, water flows through the canals 24 hours per day. With no gates on the farm outlets, water flows from the canals into the *mesqas* continuously, day and night. Daytime irrigation is preferred by farmers, thus during the night water either flows through the system to the drains or is stored in the channels.

Water balance studies in the EWUP project show high losses to drains: 30–45% of the water delivered for irrigation at Abyuha (Minya) and 46–58% at Abu-Raya (Kafr El Sheikh). It should be noted here that following the crisis situation of 1988, when the water level in the High Aswan Dam Lake fell to its minimum, deliveries were tightened, night irrigation was increased, and losses to the drainage system were considerably reduced.

On-farm crop management

A general survey and calculations for the ET of all crops in three main regions of Egypt were carried out. Data collected from the actual field research showed that:

- Total annual ET of crops in Egypt is about 28 bcm.
- Total crop area in 1990/91 was about 11.6 million fed (4.87 million ha).
- Total water requirements of crops are about 47 bcm.

Wheat. High-yielding varieties consume more water than other wheat varieties. Proper leveling, with slope and long furrow techniques, showed practical advantages, especially in saving land and labor, increasing yield and in water application efficiency.

It is very important to obtain the maximum grain and straw yields with the least amount of water. Wheat needs 4–5 irrigations, including irrigation at sowing, to obtain the best result. In the Delta, rainfall and groundwater may save one irrigation. Six irrigations are acceptable in Middle and Upper Egypt. The suitable irrigation interval is 3–4 weeks. Four-week intervals are suitable in the Delta, while three-week intervals are favored in Middle and Upper Egypt and at flowering and grain filling. Seasonal, monthly and daily average ETs for wheat at the three regions were estimated.

Barley. Barley ET was calculated using the Blaney and Criddle formula at 1,165, 1,444, and 1,702 m^3/fed for the Delta, and Middle, and Upper Egypt, respectively. Studies clarify that water-use efficiency is significantly affected by different irrigation regimes: values decrease with increasing drought stress. Barley genotypes differ significantly in water-use efficiency. Giza 124 and Giza 123 are recognized as having higher water-use efficiency.

Faba bean. Faba bean varies in its water need throughout the growing season and according to temperature. It needs 4–6 irrigations including irrigation at sowing. Five irrigations are best. The life watering, i.e., the first irrigation after planting, is given after four weeks in Upper Egypt, while five weeks is preferred in the Delta and Middle Egypt. The other irrigations are applied 3–4 weeks apart. Faba bean ET values are 1218, 1470, and 1747 m^3/fed in the Delta, and Middle, and Upper Egypt, respectively.

Lentil. When soil moisture content reaches 70% of field capacity, plant height and number of branches/plant increase along with it. It is clear that increasing available soil moisture increases yield. Water-use efficiency decreases with increasing soil moisture stress. A regime of 2–3 surface irrigations is best to obtain maximum yield.

Soybean. Irrigating every 10 days increases plant height, number of pods/plant, number of seeds/plant, seed weight/plant, 100-seed weight, seed yield/fed, and seed oil content. Protein content decreases. The irrigation interval for soybean is 10–14 days for best yields.

Chickpea. Seasonal ET values of chickpea are 1402, 1442, and 1607 m^3/fed in the Delta, and Middle, and Upper Egypt, respectively.

Berseem clover. The second most important winter crop in Egypt is berseem, which occupies the largest area. Berseem needs considerable water throughout its growing season, especially at germination, tillering, and at high temperatures (in spring). It needs 8–10 irrigations, including one 8–10 days before cutting and one 6-8 days after cutting. The life watering must be approximately 12 days from sowing. The more water at sowing, the lower the germination percentage. ET values of berseem are 2,000, 2,352, and 2,772 m^3/fed for the Delta, and Middle, and Upper Egypt, respectively.

Irrigation improvement and water conservation

Land leveling and long furrow technique. Using long furrows to control irrigation and leveling the land to a slope of 0.1% showed practical advantages, especially in land and labor saving. One of the greatest advantages is the potential for fully-mechanizing all-crop production operations. Water use by faba bean is 1,213 m^3/fed, with 2,420 m^3/fed of water applied. Compared to small basins, faba bean yield increases by 24% when long furrows are used.

Water use by wheat is 1,508 m^3/fed, while the amount of water applied is 2,420 m^3. Compared to traditional methods, wheat yield is increased 17% by using long run irrigation. For both crops, irrigation efficiency reaches 65%, compared with 50–60% in the traditional method.

Soil and fertilizer management practices

Wheat

Application of chemical fertilizers to wheat is an important component in the technology package recommended to farmers. The fertilization rate has increased from 106 kg N/ha in 1970 to 180 kg N/ha in 1993 for improved varieties. Data obtained from several on-station and on-farm trials conducted to establish fertilizer recommendations for wheat in Egypt, show that:

- Optimum economic yield is produced by applying 144–180 kg N/ha, 36 kg P_2O_5/ha and 58 kg K_2O/ha if the soil is poor in available K.
- Wheat responds to higher rates of N fertilization in southern Egypt as opposed to the Delta.
- Durum wheat and triticale respond to higher N rates than bread wheat.
- With regard to the method of application, application of N and P fertilizers, either placed together and below the seeds, or with the seeds, does not differ widely.
- Splitting the amount of applied N into three equal doses (at planting, tillering, and booting) was found to be most effective.
- Positive response to foliar application of micronutrient solutions (Fe, Zn, Mn, and Cu) is obtained when wheat is planted in micronutrient-deficient soils.

Barley

Compared to other cereal crops, little research has been conducted on barley fertilization in the Valley and Delta. The main findings can be summarized as:

- The recommended economic N rate is 72–96 kg N/ha, however barley yield increases as the rate of N increased up to 144 kg N/ha.
- No appreciable response was reported for P and K fertilization for all tested varieties.

Faba bean

As an important food legume, attention was given to mineral fertilization of faba bean. The results of several field trials can be summarized as:

- The recommended fertilizer levels are 36 kg N/ha and 36–72 kg P_2O_5/ha.
- No definite response to K application was observed.
- A significant increase in seed yield was recorded due to application of Zn, Fe, and Mn as a foliar spray in poor soil.
- Foliar application of micronutrients resulted in higher yield increases than soil application.

Chickpea and lentil

Chemical fertilization of chickpea and lentil was given little attention. The major findings are:

- Nitrogen application at the rate of 36 kg N/ha with *Rhizobium* inoculation significantly increased chickpea seed yield.
- Although the recommended package for lentil production is 36 kg N/ha plus 72 kg P_2O_5/ha, lentil responded to fertilization at higher doses of P in Upper Egypt.
- Foliar application of micronutrients resulted in higher chickpea yield in deficient soils.

Forage crops

Berseem (clover): Because berseem is the main forage crop in Egypt, its response to chemical fertilizers has been the main subject of several studies. The major findings are:

- A high response for P application was observed, as the soil test for P-Olsen was low.
- Although the forage yield of berseem was significantly increased by P fertilization up to 108 kg P_2O_5/ha, the difference between 72 and 108 kg P_2O_5/ha was not significant.
- Application of 50 kg K_2O/ha generally increased forage yield of berseem in potash-deficient soil.
- Combined application of P and K fertilizers resulted in increased yield.

Forage sorghum: The main findings regarding response of forage sorghum to macro- and micronutrients are:

- Forage yield of all tested varieties of sorghum was increased by N fertilizer application up to 324 kg N/ha (135 kg N/fed).
- A significant increase in forage yield was reported due to foliar spray of micronutrients.

Legume seed inoculation, organic and biofertilizers

Inoculation: Due to their ability to fix atmospheric nitrogen, legume crops have the advantage of minimum need for chemical N fertilizers. The amount of fixed N depends on several factors, such as crop species, soil properties, and inoculation with the effective strain of rhizobia. The main findings of the research on inoculation and N fixation are:

- Nitrogen fixed by faba bean was estimated at 90–145 kg N/ha.
- Significant increase in seed yield was obtained due to seed inoculation.
- Application of high rates of N (96 kg N/ha) reduced fixed N in faba bean.
- Foliar application of faba bean with nutrient solution (NPKS) enhanced the absorption of fertilizer and soil N by the roots and reduced the amount of N fixed.
- High water table, and soil salinity and alkalinity are unsuitable environments for faba bean production and nodulation.
- Nitrogen fixation by chickpea was estimated at 14–28 kg N/ha.
- Nitrogen fixation by lentil was 53–83 kg N/ha, depending on variety.
- Inoculation of soybean resulted in an increase in seed yield up to 160% over the control.
- Inoculation of soybean without N fertilizer gave higher seed yield and N uptake compared with uninoculated soybean fertilized with 144 kg N/ha.

- High soybean yield was recorded following inoculation and application of micronutrients.
- Nitrogen fixation by inoculated soybean was 157–200 kg N/ha.
- Nitrogen fixation by berseem was affected by inoculation treatment, soil type, and number of cuts. N fixation was estimated to be 236 kg N/ha in berseem *miskawi* (five cuts), and 68 kg N/ha in berseem *fahl* (one cut).

Organic and bio-fertilizer application: Organic manure is considered a source of nitrogen. Farmyard manure, compost, and green manure are non-proteid organics, while concentrated organics such as oilseed cakes, pigeon refuse, and dried blood are proteid organics. The availability of nitrogen in organic manures depends on their C/N ratio. The narrower the ratio, the greater the availability. Concentrated organics release their nitrogen more readily than bulk.

Studies comparing the impact of organic manure and chemical fertilizers show that the value of organics on clay loamy soil is inferior to ammonium sulfate. Farmyard manure and green manure had the lowest values. On sandy soil, the value of various organic fertilizers was, in general, better than ammonium sulfate. This is probably due to the desirable effect of organic manure on the physical properties of sandy soil. Addition of plant residues such as wheat or maize straw as an organic fertilizer for both clay and sandy soils was investigated. Studies on the effect of green manure, farmyard manure, composted bean straw, and composted rice straw on the chemical and physical properties of various soil types show that organic matter content, total nitrogen content and cation exchange capacity were increased due to organic manuring. Addition of fresh and composted town refuse increased N content in maize plants. The residual effect of organic fertilizers increases compared with chemical fertilizers.

Utilization of biofertilizers such as nitrogen-fixing bacteria, phosphate-dissolving bacteria, VA mycorrhizal fungi, *Azolla*, and blue-green algae has recently received great attention in Egypt as possible partial substitutes for chemical fertilizers, and for their potential to sustain crop production and soil fertility. Nitrogen fixation through legume/*Rhizobium* association has been well-established by several studies conducted to evaluate the ability of winter and summer food legumes, as well as forage legumes, to fix nitrogen. Inoculating cereal crops with asymbiotic nitrogen fixers such as Azotobacter and Azospirilla proved to be effective in increasing wheat, barley, and maize yields, in addition to improving the nutrient status of the crops. Significant increase in wheat yield due to inoculation with Azotobacter and Azospirilla has also been reported. *Azolla anabaena* symbiosis and blue-green algae were found effective in rice fertilization. *Azolla* not only fixes N_2, but also reduces losses due to chemical fertilizers.

Testing soil to estimate fertilizer requirements

The idea of using soil testing as a way to predict fertilizer requirements in Egypt has been around for a long time. Different methods of chemical analysis have been evaluated to find out which one shows the highest yield response to a given nutrient. But little attention has been given to the initial fertility of the soil, and its actual fertilization needs. The packages of fertilizer recommendations available to farmers in Egypt are based on field trials carried out throughout the crop belt under different agro-climatic conditions.

For more efficient fertilizer use, specific recommendations based on soil tests, plant analyses, and field trials substitute for general recommendations.

Approximately six thousand soil samples were recently collected from the cotton areas in the Valley and the Delta. They were analyzed for macro- and micronutrients, and specific fertilizers were recommended for a basin area of 4.0 ha. This approach will be followed for other main field crops. The critical limits used in these studies were set according to previous research.

Cropping structure and changes

The Old Lands in Egypt totaled approximately 6.17 million fed (2.59 million ha) in 1992. The cropped area was about 12.5 million fed (5.25 million ha) in 1992. Cropping intensity was approximately 2.1, reflecting the extensive use of irrigation and the favorable climate. A review of the changes in the cropping structure of the Old Lands during the last four years (1989–1992) suggests that:

- The area planted to wheat increased from 13.6% in 1989 to 15.6% in 1992, whereas berseem and faba bean did not significantly change from 14.2% and 3.4%, respectively.
- The area planted to the following crops decreased: soybean from 0.8 to 0.45%, lentil from 0.2 to 0.1%, and chickpea from 0.2 to 0.1%.
- The area planted to barley increased from 0.2 to 0.7%.

Target crops

During the last ten years (1983/84–1992/93) the area planted to the target crops has changed as follows:

- The area planted to wheat in the Old Lands increased from 1.32 million fed (0.554 million ha) in 1982/83 to 2.188 million fed (0.9193 million ha) in 1992/93 (a 65.7% increase).
- The faba bean area decreased from 0.389 million fed (0.163 million ha) in 1982/83 to 0.231 million fed (0.097 million ha) in 1992/93 (a 40% decrease).
- The lentil area increased from approximately 15,000 to 19,000 fed (6,302 to 7,983 ha), a 26.6% increase.
- The barley area increased from 0.121 million fed (0.05 million ha) to 0.248 million fed (0.104 million ha) in 1991/92, and decreased to 0.118 million fed (0.049 million ha) in 1993.
- The soybean area decreased significantly, from 0.147 million fed (0.026 million ha) in 1983 to 44,000 fed (18,487 ha) in 1993.
- The clover area decreased from 1.866 million fed (0.784 million ha) to 1.678 million fed (0.705 million ha) in 1992/93 (10% decrease).

Productivity and Profitability

Crop yield per unit area

The high population growth rate has resulted in a decrease in per capita cropped area from 0.097 ha in 1960 to 0.050 ha in 1990. Therefore, it is essential to increase production per unit area per unit time. One approach is to improve cultural practices to enhance crop productivity and consequently increase crop production to cope with the population increase.

Food legumes

Cool-season food legumes (faba bean, lentil, and chickpea) are important crops that have the potential to meet the increasing demand for food. These crops are generally included in the crop rotation. Because of their ability to fix atmospheric nitrogen, they have succeeded in keeping the soil fertile and productive. The area cropped to food legumes is 150,000–170,000 ha annually, of which faba bean represents about 80%. Productivity of faba bean gradually increased from 2,254 kg in 1982 to 2,944 kg in 1990, then declined to 2,305 kg in 1991 and 1,313 kg in 1992. This decline in average yield resulted in an appreciable reduction in self-sufficiency, from 100% in 1990 to 75% in 1991 and only 60% in 1992. This deficit was made up through imports. Yield losses were due mainly to an epidemic viral disease in Middle Egypt.

Although average lentil seed yield has increased by 52%, and total production by 80% during the past decade, Egypt is still dependent on imports. This is because of the limited lentil acreage (about 6,300 ha annually). Chickpea acreage (5,500–6,300 ha) and production (11,000–12,000 tons) fluctuations are relatively small. Egypt is considered self-sufficient in chickpea.

Although soybean is a relatively new summer legume crop, average seed yield has increased rapidly during the last decade to approximately 3 t/ha. Productivity of soybean faces several problems, such as its proper place in the cropping system and its high demand for N fertilizers.

Cereals

National wheat consumption in 1984 reached about 8 million tons (80% imported). The average grain yield of wheat is 5.8 t/ha for the Old Lands and 4.2 t/ha for the New Lands.

Increased wheat production on the national level can be achieved through vertical and horizontal expansion. Cultivating saline soils (about 30% of the total area) could effectively increase the area under wheat in Egypt. Maximizing the yield per unit area is of great importance as well. Therefore, applying improved cultural practices to the adopted high yielding varieties is recommended.

Barley is the main crop grown on a large scale along the north coast of Egypt. It is considered a suitable crop that can be grown over a wide range of soil variability and under adverse conditions such as heat stress, low soil fertility, salinity, etc.

In the Old Lands, barley is mostly used for livestock and the malt industry, which consumes about 20,000 tons annually. The barley area in the Valley is gradually decreasing, especially where soil and irrigation are feasible. It can be grown with other strategic crops, such as wheat, to overcome the problem of wheat shortage in Egypt. The main barley area is in the coastal region and newly reclaimed lands.

Since the total cropped area in Egypt is limited, it is essential to increase production per unit area per unit time. Wheat and barley can be increased under irrigation where favorable climatic and soil conditions exist. Increases are also expected from the use of improved genotypes, and there is still room for yield increases through the application of recommended technology packages. It is anticipated that if proper technology is applied, and constraints facing cereal production are minimized, 20–25% yield increases could be gained in the farmers' fields.

Cultural practices for wheat and barley, including land preparation, seeding rate and density, fertilizer application, sowing methodology, pest and weed control, as well as disease and aphid occurrence, are discussed in detail in the agronomy report.

Returns of target crops

Average net return per feddan for some cereals, food legumes and forage crops in Egypt have been calculated for the period 1982/83–1992/93:

- Wheat: The average net return per feddan increased from LE 105 in 1982/83 to LE 644 in 1992/93. The highest recorded yield was LE 868 per fed, in 1989/90.
- Barley: Net return per feddan fluctuated between LE 24 (the lowest return) in 1982/83 to LE 232 (the highest return) in 1991/92. It declined to LE 49 in 1992/93.
- Faba bean: Net return per feddan increased from LE 100 in 1982/83 to a high of LE 452 in 1989/90. Lowest return was LE 31 in 1991/92, increasing to LE 244 in 1992/93.
- Lentil: Net return per feddan increased from LE 121 in 1982/83 to a high of LE 748 in 1989/90, decreasing to LE 274 in 1992/93.
- Chickpea: Net return per feddan increased from LE 176 in 1982/83 to a high of LE 644 in 1990/91. A very low net return (LE 29) was recorded in 1992/93.
- Soybean: Net return per feddan was only LE 7 in 1982/83, reaching a high (LE 378) in 1990/91 and decreasing to LE 138 in 1991/92.
- Berseem: Net return increased from LE 299 in 1982/83 to a high of LE 1,039 in 1991/92. It declined to LE 699 in 1992/93.

Comparison of net returns for the target crops show the following:

- During 1982/83–1987/88, berseem, chickpea, and lentil had the highest net returns per feddan, whereas soybean and barley had the lowest net returns.
- During 1988/89–1992/93, wheat, berseem, lentil, and chickpea had the highest net returns per feddan, in that order, whereas barley, soybean, and faba bean had the lowest net returns.

Water-use efficiency

Water-use efficiency (WUE) is the yield per unit of water used for irrigating the crop, expressed in kg/m^3. The following studies were conducted on the water-use efficiency for the target crops:

Water-use efficiency of wheat

The highest WUE for wheat grain and dry matter production was recorded with an 80% soil moisture deficit. Delaying the sowing date to December increased water-use efficiency. Water-use efficiency ranged from 115.3 to 137.3 kg grain/inch ET over an average of two growing seasons at different locations. Irrigation at 50% from available soil moisture (ASM) is best for wheat yield and water-use efficiency. On the other hand, irrigation with field capacity plus 20% ASM gave higher WUE values without decreasing wheat grain yield. The highest water-use efficiency in wheat was obtained when soil moisture depletion was 30%.

Water-use efficiency of barley

Water-use efficiency was significantly affected by irrigation treatments. Values decreased with increasing drought stress. Barley genotypes differed significantly in water-use efficiency. CR 366, Giza 124, and Giza 123 are recognized as barely varieties that have the highest values for water-use efficiency.

Water-use efficiency of food legumes

A value of 1.13–1.47 kg seeds/m^3 (WUE) was obtained for faba bean. For soybean, irrigation at 60% soil moisture depletion produced the highest water-use efficiency. Frequent irrigation at 25% depletion from ASM decreased water-use efficiency compared to other irrigation depletion treatments.

Animal products

Animal products, such as red meat, including beef and veal, camel meat, milk and dairy products, and poultry and eggs are discussed in detail in the agronomy report. Beef and veal dominate the meat sector in Egypt. They provide nearly 85% of red meat consumption. The consumption of mutton is estimated at 1.5 kg/capita/year (15.1% of total red meat consumption). The consumption of this meat is limited to some areas, i.e. Sharkia and Beheira in the Delta and Qena in Upper Egypt. Most of the camels for slaughter are imported from Sudan (about 75,000–80,000 head/year).

In 1980, milk production was about 1,860,000 tons, while in 1989 it reached 2,173,309 tons. Cow milk constitutes about 42% of total milk production, and buffalo milk 57%. Annual milk yield of native cows is 925 kg, and 1,550 kg for buffalo.

During the early 1980s, the Egyptian government encouraged egg production. This resulted in expansion through the development of large commercial enterprises. The layer industry, however, faces constraints, as does the broiler industry. Egg production declined sharply in 1988 following the elimination of the subsidy on imported maize. Nevertheless, a number of broiler operations converted to layer during 1989 as a result of relatively better returns. Prior to 1980, the public sector was responsible for about 75% of egg production. Today, large operations of 15 million eggs and above are responsible for 58.9% of estimated capacity. Operations of 1–15 million eggs are estimated at 19.5%, while those of less than one million represent 21.6%.

Although animal production levels are low, prices have continued to increase, giving reasonable margins to the farmers. Forage crops continue to be highly profitable. In recent years, pricing policy reform has increased profitability of wheat and cotton, and this has had a negative impact on the area cropped with the main winter forage crop, berseem. Compound feed distribution in recent years has been controlled by the Ministry of Agriculture. Quotas are set each year for the following categories:

- Quarantine.
- State companies.
- Large and private owners who own a minimum of 10 head and insure their animals.
- Enterprises and owners who deliver their milk to Misr Dairy Company (public sector).
- All poultry enterprises, based on the number of flocks owned.

The quota system was adopted because of the subsidy given to the feed industry. The system, consequently, has given very little opportunity to small holders to benefit from the subsidies offered unless they formulate a cooperative to fulfill the minimum head requirement.

It was thought that strong cooperatives would exist and a national recording system could be adopted to help build a strategy to improve Egypt's livestock productivity. Apart from the old quota system, the government has taken action to regulate the livestock/poultry feed industry. A Ministerial Decree issued in 1984 allowed the private sector to invest in the feed industry, avoiding the government monopoly of this industry. The decree also regulates the formulation, raw materials, and nutrient required for any specific type of production. as well as quality control.

Consequently, most raw materials are available in the free market, except for cotton seed cake, which goes to government-owned factories. Animal and poultry feed prices are uncontrolled. The most efficient factories can obtain raw materials, manufacture them, market them, and the better the quality the greater the market. The feed formulation industry has produced many innovations and technological improvements due to high competition among producers.

The new free system of feed distribution applies for ruminant and poultry feed compounds. For ruminants, a sum of 900,000 tons is allocated to producers participating in the National Project for buffalo veal development, and those farmers who deliver their milk to Misr Dairy Co. The remainder are in the market on a competitive basis.

Threats to Sustainability

Loss of land

The Old Lands have been decreasing in area as a result of urbanization. It is estimated that the most fertile Old Lands, particularly those that are near cities, towns, and villages, annually lose approximately 20,000–30,000 fed (8,403–12,605 ha).

Low land/population ratio

Rapid population growth in the country leads to a low land/population ratio. In 1990, this ratio was about 0.05 ha per capita, compared with 0.097 ha/capita in 1960.

Land holding fragmentation

The trend towards land holding fragmentation (declining holding size) has resulted in decreasing the shift towards subsistence farming.

Changes in water quality and quantity

The water of the River Nile is of good quality, with total salt content not exceeding 350 ppm and an average adjusted SAR value of 4.5. However, different types of waste material are disposed of in the river, affecting water quality. The historical data show that Nile water quality has been deteriorating in some locations.

Drainage water is also polluted with waste, generated domestically or industrially in villages and towns, which finds its way into the open drains. Therefore, drainage water in certain locations is highly polluted.

Good quality drainage water that can be used for irrigation, either separately or mixed with freshwater, results from large-scale on-farm operation and tail end losses. If these losses could be prevented, the cost of pumping from the drainage system to the irrigation system would be saved. If these losses are reduced due to improvement projects, the area served by drainage or mixed water will suffer severe water shortages. Improvement projects not only reduce the quantity of drainage water but also cause deterioration in the water quality. Sustainability of some of these projects is questionable.

Rising water table

Excessive water applied to slowly permeable clay soils ponds on the surface, preventing seed germination and damaging mature plants. Some farmers use less caution when surface drains are available. The major damage in this case is soil leaching and the increase in water table elevation, which could negatively soil nutrients, rooting depth and crop yield.

Inadequate drainage systems

Specific drainage problems have been identified in different locations. The characteristics of each area are classified as follows:

- Heavy clay soils with highly saline and poor internal drainage. The sodicity hazard in these soils is high, and their permeability is very low. These areas are estimated at 500,000 fed (21,008 ha).
- Unstable silty clay soils characterized by unstable subsoils. The area is about 150,000 fed (63,025 ha), located on the fringes of the Valley and Delta.
- Areas under artesian pressure, where the piezometer pressure of groundwater within the aquifer is very high. These areas are located in the north of the Delta and near the Ismailia Canal.

Saline soils

The high water table and lack of drainage in several areas of the Delta and the Valley cause soil salinity. Large areas of the North Delta are characterized by a salt crust. They were classified as saline, highly saline, and very saline soils. In salt-affected soils at Mashtul, which is described as poorly drained land, soil salinity was as high as 10 mmhos/cm. In fact, more than 2.0 million fed (0.84 million ha) of Egypt's agricultural land still needs better drainage to control waterlogging and salinity, including 500,000 fed (210,084 ha) of heavy soils in the northern part of the country.

Fertilizer abuse and water quality

Egypt is a heavy user of chemical fertilizers. Egyptian agriculture consumes about 10 times as much of all nutrients per hectare as the world average. Increasing the production area, increasing the rate of fertilization, and low recovery of fertilizers by the plant are the main reasons for this excessive fertilizer waste. With increasing concern about environmental pollution, attention has been given to the adverse environmental impact of N fertilizers. Although it has been reported that nitrate concentrations along the Nile are below the standard values (45 mg/l), nitrate concentrations were found to be as high as 1,038 ppm in a well for drinking water in Sharkia.

Pollution from fertilizers and pesticides

Drainage water is a collection of waters that: i) pass on top of the soil as surface runoff; ii) pass through the soil until they reach the field drain; and iii) flow upwards from shallow groundwater aquifers to field drains by capillary action. This water is, therefore, loaded with salts, fertilizers, and other chemicals such as pesticides, insecticides and herbicides. Sometimes raw sewage and industrial waste water are disposed of in the drainage system, adding another pollution dimension. Drainage water reuse must therefore be treated with care to prevent soil, crop and general environmental pollution.

Animal and crop integration

Feed is the most expensive input in animal and poultry operations. Feed represents 60–70% of the total running cost. The increase of feed production in Egypt is constrained by limited cultivable land and the challenge of intensifying land use to meet the needs of the ever-increased human population.

The use of fibrous agricultural residues to produce feed compounds for ruminants is limited to 4.5 million tons per year from a possible 15.7 million tons. This is due to constraints such as low nutritive value, lack of information, and the economics of collecting such residues from small holdings.

Major Constraints

Major constraints in socioeconomic, agronomic, soil, and water management studies are presented in detail in the individual reports of each component. Following is a general summary of the various constraints confronting resources and crop production in the Old Irrigated Lands.

Biological and Technical Constraints

Production of field crops, such as food legumes and cereals, is threatened by various stresses and technical limitations in various farming systems. Yield potential is seldom achieved, due to unsuitable cultivars and inadequate crop management. The following are some technical constraints:

- Poor soil fertility, associated with salinity and alkalinity problems, represents a major limiting factor for the productivity of most field crops. About 500,000 fed (210,084 ha) of heavy soils, located in the northern part of the country, are highly saline, with poor internal drainage properties. The sodicity hazard of these soils is high and their permeability is low. Reclamation requires improvement of their physical and chemical properties through leaching, amendments, subsoiling, and deep plowing with good, appropriate drainage.
- The major maintenance problems in unlined canals are weeds, seepage, and unstable cross-sections. Removal of weeds and general cleaning and maintenance of private *mesqas* is traditionally the responsibility of the farmers. However, in view of the excessive weed growth in some cases and the blocking of canal cross-sections caused by sediment, garbage material, and debris in others, especially those running through or beside villages, farmers are unable to cope with this situation.
- Seepage of water from both sides of the canal to adjacent strips, and the over-topping of water above the banks of the canals, impede operations due to flooding.
- Inequity of water distribution between the heads and tail ends of distributary canals and *mesqas*.
- Poor maintenance of canals and *mesqas*.
- Inefficient control of water due to manual operation of gates and leakage from closed gates.
- Excessive freshwater loss to drains due to over-irrigation, poor land leveling, etc.
- Poor plant stands associated with hand seeding. The resulting low and uneven plant density cannot make efficient use of fertilizers.
- Poor weed control in the field.
- Poor management practices such as:
    - Poor seedbed preparation at planting.
    - Uneven seed depth and cover.
    - Late planting in some locations.

- Primitive methods of harvesting, threshing, transportation and storage which might cause heavy yield losses.
- Insect damage, especially aphid, to food legumes, wheat, and barley. Storage insects lead to grain loss and bad seed quality.
- Disease damage in some field crops.

Institutional and Policy Constraints

- The fixed irrigation intervals of the water rotation system are often too short or too long, and are generally inflexible. This system causes over-irrigation in some areas and crop water stress in others.
- The gap between research and extension still exists.
- The necessary quantity and quality of inputs are not available when needed.
- Lack of dynamic administrative and management systems.
- Division of various research and production efforts on the same crop between various institutes and sections.

Extension Constraints

Although there are constraints in any research program, the main problem is how to transfer the already available research results to the farmer. Extension programs in Egypt face a variety of constraints:

- Lack of communication between research and extension.
- Inadequacy in delivering research results quickly and effectively to extension specialists and dissemination to farmers.
- Isolation of extension agents from each other.
- Farmer suspicion towards government personnel.
- Shortage of well-trained extension workers.
- Engagement of extension personnel in many other governmental activities.

Further Research

To improve resource management of the Old Lands, several research topics have been suggested for the different components.

Socioeconomic

- The effect of the agricultural policy reform program on the availability of inputs, credit and marketing system of agricultural products.
- The role of different institutions in resource management and utilization.
- Evaluating various technology packages, including water inputs for different locations and crops.
- The impact of different types of agricultural technology on unemployment in the agricultural sector.

Agronomy/Systems

- It is very important to further study the effect of soil tillage systems on soil-borne disease, which has been a serious problem in cereal and faba bean in recent years, especially in Middle and Upper Egypt. The effect of soil tillage systems on *Orobanche* infestation in faba bean should also be studied.
- More studies are also needed on the population dynamics of pest species and their natural predators. Weather data and IPM should be considered.
- More attention should be given to viral disease in wheat and barley (Barley Yellow Dwarf Virus), and faba bean (Necrotic Yellow Virus and Bean Yellow Mosaic Virus).
- The leaf miner (*Liriomyza trifolii*) causes appreciable yield losses in faba bean, therefore studies should focus on this pest.
- Additional yield increases could be obtained by improving on-farm activities such as cultural practices, soil management and drainage system efficiency, etc.
- Results of the Forage Research Section show that dry matter yield of fodder beet is similar to that of berseem (about 14 t/ha); however, fodder beet exceeds berseem in the amount of energy obtained. Fodder beet is more palatable and therefore increases the intake of dry roughage, and can be transplanted later in the season than berseem. However, one of the major constraints to fodder beet expansion in Egypt is storage of the crop after harvest. Making fodder beet silage may offer a solution to this problem.
- The utilization of agricultural fibrous residue is constrained by its low nutritive value, which physiologically limits the use of amounts large enough to satisfy the animal's needs. Therefore, more research on improving the nutritive value of agricultural fibrous residue is needed. Only 4.5 million tons are currently used.
- Efforts are being made to evaluate some early maturing (80–90 days) soybean cultivars, recently developed to be used in an intercropping system with other summer crops.
- Cropping intensification: The newly developed short season soybean varieties that mature in 95 days or less can be planted at the end of March or in early April—after

either berseem (two cuttings) or winter vegetables such as potato—and are harvested in June in time for maize planting or rice transplanting. This new cropping system should be evaluated in different places in the Old Lands.

- Early maturing faba bean cultivars that are resistant to chocolate spot and rust diseases with high yield potential have been developed. These cultivars could be planted in October after the maize harvest and harvested in late March in time for cotton planting on the same faba bean ridges, without land preparation.

Soil Management/Fertility

For better management and more efficient use of fertilizers, the following possible research issues are suggested:

- Modeling of fertilizer recommendations for various crops based on soil tests, plant tissue analysis, and field trials under similar conditions.
- The current fertilization package should be reassessed due to continuous changes in soil fertility and the release of new crop varieties with different plant types and yield potential.
- A fertilizer program should be introduced based on the rotation used rather than individual crops.
- Utilization of bio- and organic fertilizers as a partial substitute for chemical fertilizers, to improve soil productivity and conserve the environment.
- Estimating the carry-over effect of phosphatic and organic manures.
- Long-term research to assess the impact of fertilizer management on soil parameters and crop production.
- Fertilizer management of the salt-affected soils which dominate the northern part of the Delta.
- The impact of heavy nitrogen fertilization on water quality.
- The interaction between fertilizer management for various crops and other cultural practices, in particular water management.

Water Management

Several study topics still need further research. Among these topics are:

- Potential evapotranspiration studies should be directed towards the assessment of crop consumptive use under water shortage and low water quality conditions. The effect of such conditions on crop yield should be investigated.
- Crop water consumption should be correlated with simple parameters such as pan evaporation.
- Crop water consumption should be determined according to the stage of growth. Stages where plant stress is required should be emphasized, provided this stress does not affect crop production.
- Conveyance and distribution efficiency and on-farm irrigation efficiency should be defined and values for each part of the country determined.

- Measurement of water quality at all levels should be practiced. The use of water levels in the distribution system should be slowly withdrawn and replaced by actual flow measurements. Research in this area should be intensified.
- Continuous monitoring of irrigation-water quality at all levels of the distribution network should be carried out. Establishment of a water quality network should be part of research activities.
- The extent of non-official reuse of drainage water should be identified through research.
- Reuse of drainage and underground water needs more intensive study.
- The unequal distribution of water between the upstream and tail end of the system and the individual canals should be rectified.
- Ways and means of encouraging farmers to practice night irrigation are needed.
- The transfer of the activities of the Irrigation Improvement Project (IIP) from the pilot project to a national project is required. Evaluation of the results of the pilot project should be carried out so that the drawbacks may be avoided in the implementation of the national project.
- Indicative cropping patterns based on the free choice of farmers should be investigated and scenarios established that consider the delicate situation of water availability.
- Strategic planning on the long-term distribution of water resources should receive primary attention. Strategic irrigation planning, including irrigation methods and systems, change of cropping patterns, change of crop varieties, and use of up-to-date techniques (genetic engineering, tissue culture, greenhouse cultivation, etc.) should be included.
- Use of lysimeters in the determination of actual water requirements of different crops and crop factors still needs further research, especially in the area of restricted irrigation water supply and low-quality irrigation water.
- Irrigation studies on chickpea are poor and need further research.
- Drip and sprinkler irrigation studies are important and need further research.
- The agro-meteorological data is still inadequate, due to the shortage of weather stations and their proper maintenance.

Recommendations

To identify problems in sustainable resource management and to design multidisciplinary research activities to tackle these problems, the following recommendations are made.

Soil Management/Fertility Studies

- To achieve more efficient use of fertilizers, specific fertilizer recommendations should substitute for general recommendations. These specific recommendations should be based on soil testing, plant analysis, and results obtained from fertility trials conducted under similar conditions.
- Because newly improved cultivars of target crops have been released, fertilizer recommendations should be reassessed.
- Biofertilizers and natural organics should be used as partial substitutes for chemical fertilizers.
- Fertilizer management in salt-affected soils should be addressed.
- Long-term research is needed to assess the impact of fertilizer management on soil parameters and crop production.
- The interaction between fertilizer management for target crops and other factors affecting crop production (time of planting, tillage, rate of seeding, irrigation, pest control, etc.) need to be studied.

Water Management Studies

Several study topics are needed for more efficient use of water management. Some of these topics are listed below:

- ET and IRR estimations for cultivated crops must be rechecked.
- Drip and sprinkler irrigation systems are important and in need of study in the Valley and Delta.
- Lysimeter applications were deficient in the present study.
- There is a shortage of agro-meteorological data in the present study, due to the shortage of weather stations and proper maintenance.
- Irrigation improvements to save water and sustain high yields are needed.
- Studies of alternative cropping patterns should be focused on.
- Reuse of drainage and groundwater needs more intensive study.
- Irrigation studies on chickpea are very poor and need further work.
- Removal of weeds and general cleaning and maintenance of private *mesqas* for more efficient use of water are topics in need of urgent attention.

Agronomy/Systems Studies

- It is very important to further study the effects of soil tillage systems on soil-borne diseases, which have posed a serious threat to cereals and faba bean in recent years.

They also affect the *Orobanche* infestation in faba bean, especially in Middle and Upper Egypt.

- More studies are needed on the population dynamics of pest species and their natural enemies in relation to weather data and IPM.
- More attention should be given to viral diseases in wheat, barley, and faba bean.
- Fodder beet could have a place in the forage system. It was found to be more palatable than berseem. However, one of the major constraints to fodder beet expansion in Egypt is storage of the crop after harvest. Making fodder beet silage may offer a solution to this problem.
- Some crop rotations are suggested for study. These rotations are presented in detail in the Agronomy report.
- The newly developed short-season soybean cultivars might help to grow two crops during the summer season instead of one. Moreover, they will minimize the competition which currently exists with other summer crops.
- Some leaf-feeding, insect-resistant soybean cultivars have been developed, and can be planted in June after harvesting wheat and barley. This will minimize or eliminate the need for excessive amounts of insecticides currently used in the farmers' fields.

Socioeconomic Studies

- The effect of the agricultural policy reform program on the availability of inputs, and the credit and marketing system for agricultural products, should be studied.
- The impact of different types of agricultural technology on unemployment in the agricultural sector should be studied.
- Newly recommended technology packages, including improved cultivars and various cultural practices, should be evaluated.
- New agricultural technology is a major management resource. New technologies developed by some leader farmers, and adopted by them, are one important resource. These technologies can be easily transferred.
- It is expected that some institutions, especially rural institutions, will have a significant role in agricultural resource management and utilization.