# Integrating national agricultural research imperatives and capacity building for food security in Egypt

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# Integrating National Agricultural Research Imperatives and Capacity Building for Food Security in Egypt

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**Abstract.** In Egypt, the increase in population and total demand for agricultural products necessitate increasing use of technology due to limited natural resources (water and land). New technologies are required in all agricultural sectors based upon maximization of crop returns (plant and animal). This could be achieved through increasing productivity and minimizing post-harvest losses. While demand-side policies are imminent concerns of many policy makers, supply-side capabilities must be the longer term, preeminent focal point. In order to capture the benefits of Research and Development within NARS, there is need for the emphasis on the adoption of existing technologies, as well as the adaptation of newly developed technologies. The need for strong linkage between research and the analysis of future market requirements, must be emphasized. Solving food security problems depends on available technologies and the rate at which they evolve.

**Key words.** Egypt – NARS – Food Security – Technology

***Titre. Intégration des impératifs de la Recherche agricole nationale et des capacités de réalisation de la sécurité alimentaire en Egypte.***

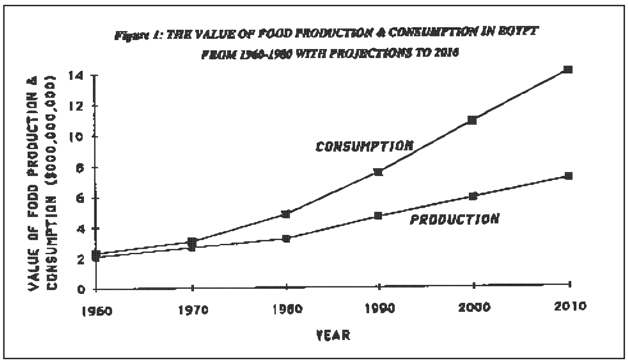
***Résumé.*** *En Egypte, la croissance de la population et de la demande en produits agricoles nécessite une utilisation de plus en plus importante de la technologie en raison des limitations des ressources naturelles (eau et sols). Les nouvelles technologies sont nécessaires dans tous les secteurs agricoles basées sur la maximisation des recettes (productions animales ou végétales). Ceci peut être obtenu en augmentant la production et en minimisant les pertes après-récolte. Alors que des politiques de la demande sont les préoccupations les plus urgentes des décideurs, les capacités d'offre doivent être l'objectif principal de long terme.*
*Pour bénéficier des résultats de la recherche et du développement du SNRA, il faut mettre l'accent sur l'adoption de technolgies existantes, et sur l'adaptation de nouvelles technologies. Le besoin d'une liaison forte entre recherche et analyse des nécéssités du marché doit être souligné. L'obtention de la sécurité alimentaire dépend des technologies disponibles et du rythme auxquelles elles évolueront.*

***Mots clés.*** *Egypte – SNRA – Sécurité alimentaire – Technologie*

## I. – Introduction

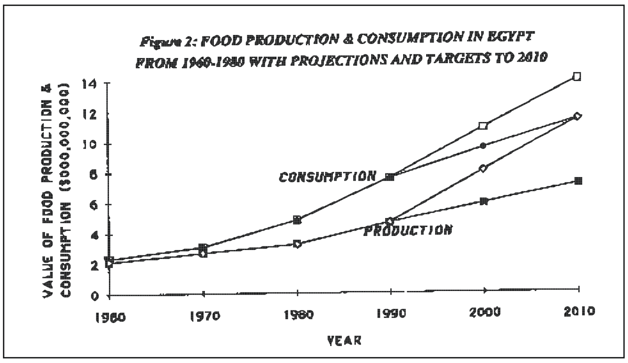
The major issues facing the world in the 90s are interrelated, and the dynamic shape of mankind's future will be determined not by any single issue but by the interactions of a number of issues. Food security represents a major elemental goal in any practical enterprises towards providing economic and political stability in developing, and also many developed, countries. An increase in population translates into demands for more food, fiber, energy and other raw materials. The commonly driving practical solutions to these major problems is greater investments, improved technologies, human expertise and intensified cooperation. The interrelationships are global in character, and hence they can best be understood and then ultimately resolved within a global framework. While the framework necessitates a global character, within this there must be a wide variety of integrated regional and national responses. Clearly, agricultural capabilities are the mainstay of developing economies. Establishing priorities, effective mechanisms and management of sustainable National Agricultural Research programs are of paramount importance.

During the coming decades, the increase in population—and consequently the increase in total demand for agricultural products—and the constraints of limiting natural resources of water and agricultural land, necessitate increasing dependency upon technology. New technologies are required in all agricultural sectors based upon maximization of crop returns (plant and animal) per unit of land and water. This could be achieved through increasing productivity and minimizing post-harvest losses. While demand-side policies are imminent concerns of many policy makers, supply-side capabilities must be the longer term, preeminent focal point. In order to capture the benefits of Research and Development within National agricultural research systems (NARS), from an overall technological perspective, there is need for the emphasis on the adoption of existing technologies, as well as

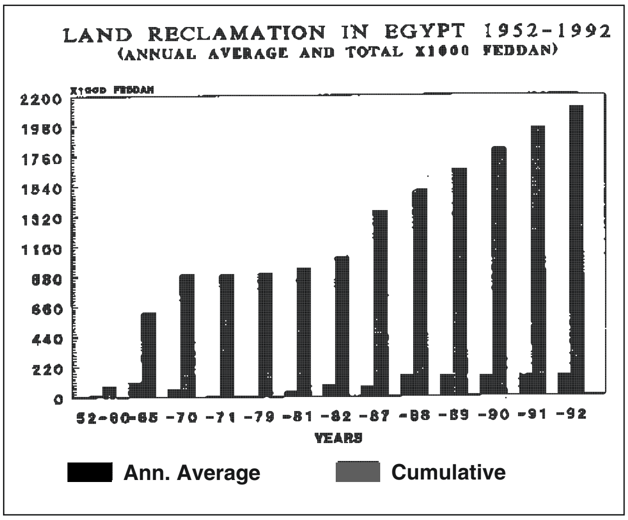



the adaptation of newly developed technologies. In this context, the need for strong linkage between research and the analysis of future market requirements, must be emphasized. Solving the food security and crop production sustainability problems depends on the technologies that are available and the rate at which they evolve.

## II. – Dichotomy of Production-Consumption Patterns




A limited arable land base coupled with an ever growing population at an annual birth rate of 2.7% are the main features impacting the food production-consumption gap in Egypt. Egypt's population will grow to about 70 million by the year 2000. In the once highly fertile Nile Valley the population is about 1,300 people per km², among the world's highest densities. Even with an intensification rate of 200% which would increase the agricultural land base from 7.4 million feddan to 14 million cropping acreage, production of food would only satisfy 50% of the requirement for a current population of 59 million. The value of food produced and consumed in Egypt for the last three decades is presented graphically in *Figure 1*. From this graph it is clear that the actual rate of increase in consumption for the period 1960–1990 has far outdistanced agricultural production. Assuming a continuation of the present rate of increase in both production and consumption, the gap will widen. Assuming that productivity increases consistent with the Government of Egypt's agricultural strategy for the l990s, including shifts to higher valued crops for export, and that social education programs favorably impact on the society's eating habits to reduce consumption, parity in production-consumption may be achieved by the year 2010 *(Figure 2)*.




## III. – Land and Water Resources

To bridge the food gap and to fulfill a goal of self reliance, expanding the land base and optimizing agricultural outputs are urgently needed. The period from 1950–1970 witnessed an increased awareness and interest by the Government of Egypt in land reclamation. During this period approximately 900,000 feddans were reclaimed; with nearly 800,000 feddans of this total reclaimed during the period of 1960–70 *(Figure 3)*. Activities waned during the period of 1970–78, when only 21,000 feddans were reclaimed. Lands reclaimed during this 28-year period are referred to as "old" new lands. During the 1st five-year plan developed by MALR for the period 1982–1987, the GOE reclaimed 577,700 feddans, of which nearly one-half was reclaimed in the Western Delta. The 2nd five-year plan (1987–92) engaged the reclamation of 150,000 feddans/year for the period. The post-1978 reclaimed lands are termed "new" new lands. The Land Master Plan has identified 2.56 million feddans as potentially reclaimable, of which 1.86 million feddans have been targeted as immediate priorities.

Land *per se* is not the critical constraint to development in Egypt, but rather water resources to reclaim the vast desert resources available. Egypt, presently, has about 1,000 cubic meters of water per person. This value approximates the reasonable threshold for development. This ratio is projected to decline to 350 cubic meters per person by the year 2025. Fresh water is a finite resource, essential for agriculture, industry and human existence. Without fresh water of adequate quality and quantity, sustainable development is not possible. Competition for fresh water resources among all end-users will clearly intensify. This underscores the need to better use and manage available natural resources today, if development in Egypt is to proceed in a sustainable fashion for the future. This means we must apply all our inventiveness to develop and exploit new powerful, efficient and appropriate technologies. Meeting this objective will require the continued commitment and increasingly active contribution of science, research and education.

## IV. – Overall Egyptian NARS' Strategy

The Government of Egypt's overall concern for food self-reliance and its strategic goals for the country's agricultural sector are as follows:

– Improve the efficiency in the use of Egypt's limited land and water resources, relative to a rapidly growing population through greater specialization in products in which the country has and can maintain a dynamic comparative advantage;

– Enhance sustainability of resource use patterns and protection of the environment;

– Increase the number of workers employed in the private sector (e.g., agro-industry, added value production, etc.);

– Contribute to more equitable income distribution, poverty alleviation, and fulfillment of basic needs of the population; and,

– Expand foreign exchange earnings from agricultural exports.

The Ministry of Agriculture and Land Reclamation (MALR) has emphasized within the third five-year research plan (1993–1997), the need for optimization of crop returns per unit of land and water consumed.

## V. – Institutional Infrastructure

Within MALR, the Agricultural Research Center (ARC) is the principal agency responsible for technology generation; with 16 research institutes, 7 central laboratories, and 37 research stations it represents the largest, most complex infrastructure dedicated to research and development in the agricultural sciences *(Table 1)*. The Desert Research Center under the auspices of MALR has 5 stations with the responsibility for conducting research relevant to rainfed production areas. The Water Research Center (within the Ministry of Public Works and Water Resources) with its 11 institutes and a training center is involved in water resources/irrigation/drainage research related to agriculture. The NARS research network also draws heavily upon Universities under the Minister of Education and the Supreme Council of Universities which provides nearly one-half of the professional resources in the Agricultural Sciences. In addition, the National Academy of Scientific Research and Technology and the National Research Center, under the Ministry of Scientific Research and Technology are also engaged in agricultural research through their specialized irrigation, food and agriculture divisions. The professional personnel engaged in agriculture research and development within the public sector is nearing 10,000 researchers *(Table 1)*. Finally, the private sector is increasingly contributing to agricultural research, particularly in relationship to seeds, tissue culture and agrochemicals. The public agencies, while presently engaged in diversified research activities, the private sector efforts in adaptive research will likely proceed to expand into a larger share of the overall research effort, as policies are developed to encourage and better integrate their efforts within the NARS context.

**Table 1. Current Numbers of Professional Researchers within Major Egyptian Research Organizations in the Agricultural Sciences**

| Agricultural Research Organization | Highest Advanced Degrees Awarded (# Individuals) | | | |
|---|---|---|---|---|
| | Ph.D. | M.Sc. | B.Sc. | Total |
| ARC | 2042 | 995 | 533 | 3570 |
| DRC | 155 | 56 | 16 | 227 |
| WRC | 71 | 62 | 41 | 174 |
| NRC | 383 | 213 | 122 | 718 |
| IO & Fisheries | 111 | 57 | 122 | 290 |
| Agr. Colleges (14) | 2707 | 698 | 369 | 3774 |
| Vet. Colleges (8) | 726 | 221 | 128 | 1075 |
| Others | 66 | 37 | 14 | 117 |

Source: MALR, ARC, Information & Documentation Center, Manpower Study for Agriculture.

## VI. – Ecoregional Research and Linkages with National Agricultural Research Systems

### 1. Establishment of Agro-ecological Zones

The diversity of agro-ecological zones and the diversity of farming systems which they contain underscores a need to strategically diversify and simultaneously focus research activities to include the full range of ecological settings. Decentralization, accompanied by enhanced coordination, by fostering greater collaborative effort with appropriate National Research programs represents a cost-effective strategy. The establishment of Research and Extension (R&E) Centers in each of the five targeted zones is a prerequisite to meeting priority needs without diluting NARs resources, both human and financial. The zones were selected on the basis of the unique edaphic features of the environment and to simultaneously capture the diversity of production management systems operating within Egyptian agriculture. Each zone is served by a center of excellence for applied/adaptive research activities to identify improved germplasm, cultural practices tailored to the advanced genetic stocks tolerant of the deliver of such "technological packages" to a widening array of comparable agro-ecological zones. One of the main operational objectives of the R&E Centers is to collaborate with, and foster cooperation among other National, Regional and International Institutions in the testing, adoption and demonstration of improved crops, farming and livestock systems. The satellite research centers primary focus would be directed towards representative production systems with targeted crops and farming systems which could serve as models, to better characterize and improve their efficiencies and sustainability. Research Outcomes at the central sites could then be more readily applied to similar agro-ecological settings. An integrated extension "outreach" coordination system would then focus upon the joint research program implemented at the core R&E sites with involved scientists. Four Councils have been established to enhance and coordinate agricultural development, one in each of the agro-ecological zones.

### 1. Interlinking Needs Assessments

NARs can achieve greater impact, coherence of activities, and greater resource-use efficiencies by formally strengthening linkages between researchers in the academic (University) community, researchers in established research centers, the private sector and allied resources in other Ministries. This provides greater access to and generation of data-bases characterizing features of the climate, soil and water, land use patterns and practices, cropping systems and efficiencies, and erosion and land degradation. Linkages would likewise offer greater precision in needs assessment, characterizing and understanding farming systems, the impact of adopted technologies and their interaction with microclimate variations. This approach importantly provides a higher probability of success in identifying comparable agroecological areas for additional outreach of new technologies. The above referenced Councils include representatives from the private sector, Universities, Agricultural Research Organizations in the Ministry, and is the formal linkage mechanism for implementation.

## VII. – Research targets and impacts: Past, Present and Future

### 1. Mission Oriented Technology Development

Major challenges confront the research system in delivering solutions to current and pending problems. The challenges derive from the need to develop new technologies which are consistent with the arable land and water constraints facing Egyptian agriculture; technologies which are appropriate, fitting into the socioeconomic fabric of the agricultural sector and contributing significant financial benefits to the end-users to ensure their widespread and rapid adoption. Technological challenges of the future would include the following:

– enhanced research work targeting, e.g., the development of new varieties, improved varieties and better crop rotations which are aimed at maximizing returns to first water, and then land, towards achieving improved overall natural resource management and foster new developments;

– research effort directed towards improved agro-management practices, in particular development of short duration varieties to enable more intensive land utilization, increased coverage of high yielding, pest resistant varieties to reduce costly chemical pesticide dependency and insure greater stability of production, improved fodder crops, efficient crop and animal by-product utilization, improved on-farm irrigation and drainage systems, post-harvest activities and agroindustries which address the concerns of producers, handlers and consumers preferences in both domestic and export markets;

– research effort directed towards improving animal production systems, including enhanced aquaculture and fisheries development;

– the need to strengthen analytical capabilities for research adoption, in particular assessing the economic and financial viability of research findings and of public policy implications for the sectors continued development;

– the development of high calibre research managers to assess and focus cost effective research activities towards their development potential;

– technology generation, and most importantly, the on-site adaption of existing technologies to the needs of the new lands in a manner which recognizes the special needs of the socioeconomic background of the intended end-users (smallholders and new graduates);

– need for adaptive research in improved irrigation technologies for both the old and new lands, with a view to identify the most appropriate on-farm irrigation technologies for the different categories of farmers, as well as the wide range of local conditions;

– research work on farm mechanization with a view to addressing the needs of small and medium size farms, developing appropriate capital intensive technologies for a smallholder dominated agricultural sector is important in view of an uncertain future availability of labor where and when the crops need harvesting;

– water saving technologies, including recycling agricultural drainage and industrial waste water in a cost effective fashion, which may include drought/saline tolerant crops, is an urgent need;

– development of biotechnologies to develop new, improved crop plants to overcome production constraints in a fashion which is environmentally sound, safe and sustainable;

– research into value-added agricultural products and commodities, including relevant food processing technologies, anticipating the likely emergence of new consumer preferences and markets;

– developing extension, education and outreach tools, and mechanisms for information transfer to end-users. Technology transfer is a pivotal point in the whole research delivery process;

Past efforts in hastening closure of the food gap in Egypt can be gleaned from the data in *Table 2*. Relative food production capabilities during the decade of 1980-1990 has risen nearly 50% since 1980. This is nearly double the change observed worldwide or in Africa as a whole.

**Table 2. World Food Production Indices***

| | World | Africa | Egypt |
|---|---|---|---|
| 1980 | 99.08 | 99.33 | 99.03 |
| 1982 | 106.17 | 103.56 | 108.63 |
| 1984 | 111.56 | 102.92 | 120.68 |
| 1986 | 116.22 | 116.60 | 139.74 |
| 1988 | 118.75 | 123.90 | 147.60 |
| 1990 | 125.62 | 127.66 | 155.40 |

* 1979–81 = 100
Source: Adapted from *FAO-Production Yearbook*, vol. 45 (1992).

When the food production index is adjusted for population growth, Egypt retains a 21% increase per capita *(Table 3)*, which contrasts favorably with the 6% increase on a worldwide basis, or the approximately 5% decrease per capita for the African continent from 1980 to 1990. The Egyptian situation provides strong encouragement that the NARS system is contributing to the reduction of the food gap.

**Table 3. Comparative Food Production Indices* Adjusted for Population Growth**

| | World | Africa | Egypt |
|---|---|---|---|
| 1980 | 99.09 | 99.35 | 99.04 |
| 1982 | 102.56 | 97.69 | 103.17 |
| 1984 | 104.06 | 91.54 | 108.81 |
| 1986 | 104.68 | 97.73 | 119.80 |
| 1988 | 103.25 | 97.82 | 120.57 |
| 1990 | 105.53 | 94.90 | 121.17 |

* 1979–81 = 100
Source: Adapted from *FAO-Production Yearbook*, vol. 45 (1992).

Comparison of average yields of selected, major crops attained in Egypt with yields of the same crops worldwide, in Africa and the USA is provided in *Table 4*. The data indicate that Egypt has achieved a yield advantage per unit area both worldwide and over the African continent: the yields recorded for one-half of the crops are greater than those reported in the United States. This strongly suggests that both the technological management packages developed in Egypt and expansion of arable lands through land reclamation activities are contributing to the enhancement of food production capabilities seen in *Table 2*.

## 2. Using Modern Technology in Crop Production

The ARC in Egypt is focussing efforts into exploiting three high-technology systems to enhance agricultural development. The first system uses Landstat technology for proper management of natural resources (El-Beltagy, 1992). The second system uses computer expert systems as tools to optimize productivity by improving crop management capabilities in an outreach-friendly mode. The third system is genetic engineering to harness advances in biotechnology to support agriculture.

**Table 4. Comparison of Average USA and Egyptian Crops Yields in 1990 (MT/ha)**

| Crop | World | Africa | USA | Egypt |
|---|---|---|---|---|
| Maize | 3.72 | 1.60 | 7.44 | 5.78 |
| Wheat | 2.59 | 1.55 | 2.66 | 5.20 |
| Sorghum | 1.40 | 0.77 | 3.96 | 4.60 |
| Rice | 3.53 | 2.00 | 6.20 | 7.26 |
| Barley | 2.50 | 0.88 | 3.02 | 2.43 |
| Soybeans | 1.91 | 1.06 | 2.29 | 2.60 |
| Sesame | 0.38 | 0.34 | 20,, | 1.22 |
| Peanuts | 1.16 | 0.80 | 2.23 | 2.38 |
| Potatoes | 15.16 | 9.94 | 32.86 | 20.48 |
| Tomatoes | 23.80 | 18.63 | 55.16 | 27.14 |
| Onions | 14.69 | 12.32 | 42.75 | 52.45 |

* 1979–81 = 100
Source: Adapted from *FAO-Production Yearbook,* vol. 45 (1992).

## 3. Landstat Technology in Agriculture

Landstat imagery is becoming an extensive tool in agriculture, land-use planning and environmental planning. Its utility will continue to be enhanced as the technology advances and as users gain experience with this relatively new tool. The Landstat system not only gathers the data, but also puts them into digital form for computer analysis. The Geographic Information System (GIS) is the fundamental technology for merging various independent spatial data-maps into a form that represents usable information. This system can provide precise monitoring of:

– settlement and urban encroachment on fertile agricultural lands;

– crop area estimation for individual crops;

– early detection of plant diseases, water and nutrient stress;

– land degradation through over-grazing or pollution.

## 4. Computer Expert Management Systems

The development of computer expert systems for improved crop management integrates state-of-the-art human experience of subject matter specialists with that of computer science to form a knowledge based system which is readily available to outreach personnel and farmers for diagnosing and advising on practical problems related to crop management. The Computer Expert System also represents a dynamic tool in education and research. Developed in a user friendly format, it can assist the farmer in making agro-management decisions in irrigation practices, nutrition and fertilization, and pesticide intervention for insect, weed and pathogen control. By using an expert system, workers can improve their performance to an expert's level, improving not only their efficiency and effectiveness, but also increasing yields and improving the quality of agricultural products. Application of a properly developed expert system represents a powerful tool to optimize the use of water and land resources for improved crop production potentials. Development of these "expert" tools was initiated in the ARC three years ago with the formation of the Central Laboratory for Agricultural Expert Systems.

## 5. Genetic Engineering of Crop Plants

Partnerships between traditional plant breeding methodologies and contemporary molecular genetic engineering technologies have been established through the agricultural Genetic Engineering Research Institute (AGERI) and ARC University plant breeders to alter the genetic make-up of important crop species to impart resistances to limiting environmental constraints to productivity. This includes host plant resistances to disease and insect pests, and various water related economies of the plant. A major domain for genetic engineering research is directed to salinity and drought tolerance, which are considered among the most serious problems to agriculture in Egypt and developing countries. Adapting crops to more marginal environments represents another tool to maximize management/utilization of available water and desert land resources.

The successful establishment of AGERI has positioned the MALR to realize a new, evolving partnership between the public and private sector; one that will allow the country to fully benefit from biotechnology in agriculture. This in turn will place Egypt in the best position to optimize its domestic self-sufficiency in food, feed and fibre and maximize its capacity to be competitive in the international marketplace, where foreign exchange revenues from its exports will become increasingly important, and where it will have to satisfy increasingly demanding environmental standards that are emerging as the new global code of environmental conduct.

Through the development and transfer of technologies the current five-year plan of MALR is targetting specific crops for increased yield efficiency per unit area as shown in *Table 5*.

**Table 5. Yields (tons/feddan) of Selected Crops and Target Productivity at the End of the Third Agricultural Research Five-Year Plan**

| Crop | Actual production | | | Target production | |
|---|---|---|---|---|---|
| | 1987 | 1992 | % Gain | 1997 | % Gain |
| Fiber | | | | | |
| Cotton | 0.97 | 0.93 | - 4.3 | 1.28 | 37.5 |
| Flax | 2.74 | 2.74 | 0 | 3.80 | 40.0 |
| Teel | 1.25 | 1.15 | - 8.0 | 1.25 | 9.0 |
| Cereals | | | | | |
| Wheat | 1.98 | 2.21 | 11.6 | 2.51 | 14 |
| Corn | 1.18 | 0.86 | - 26.7 | 1.08 | 25.0 |
| Sorghum | 1.75 | 2.20 | 25.7 | 2.80 | 27.0 |
| Rice | 2.45 | 3.10 | 26.5 | 3.50 | 13.0 |
| Oils | | | | | |
| Peanuts | 0.77 | 0.98 | 27.6 | 1.13 | 15.0 |
| Sunflower | 0.86 | 0.90 | 4.7 | 1.00 | 15.0 |
| Sesame | 0.46 | 0.52 | 12.1 | 0.59 | 12.5 |
| Legumes | | | | | |
| Broadbean | 1.05 | 1.15 | 9.6 | 1.44 | 25.0 |
| Lentil | 0.68 | 0.72 | 5.9 | 0.96 | 33 |
| Chickpea | 0.72 | 0.75 | 4.4 | 0.86 | 15.0 |
| Fenugreek | 0.81 | 0.83 | 1.5 | 0.90 | 10.0 |
| Lupine | 0.76 | 0.83 | 8.3 | 0.90 | 10.0 |
| Soybean | 1.18 | 1.20 | 1.7 | 1.44 | 20 |
| Mungbean | — | 0.80 | — | 0.90 | 12.0 |
| Sugar | | | | | |
| Sugarcane | 40.33 | 42.3 | 4.9 | 44.0 | 4.0 |
| Sugar beet | 17.27 | 18.5 | 7.1 | 21.0 | 14.0 |
| Onions | | | | | |
| Summer | 7.96 | 8.10 | 2.3 | 9.80 | 20.0 |
| Winter | 8.31 | 9.70 | 16.7 | 11.6 | 20.0 |

Feddan = 4200 $m^2$

## VIII. – Human Resource Development

The key to successful ventures in increasing food production capacities in an economically efficient and sustainable fashion, is intricately dependent upon the professional competence and motivation of the individuals shouldering the myriad of tasks that are required. The importance of human resource development can not be overstated. Simply put, a dedicated well-trained individual will always find a way to get the job done, irrespective of the institutional setting. In contrast, even in a well defined, modern institutional structure, an individual may have little impact if they do not have the capability or motivation to implement the program (WASH, 1990). Human resource development includes training and education, opportunities to assume greater responsibilities, advancement and a reward system for positive feedback. It represents a key element in capacity building, which is often overshadowed by other aspects of capacity building, such as research institution building and institutional development. People oriented skills in management and communication also play an increasingly important role. To facilitate the integration of activities, regional committees (based upon the earlier mentioned agro-ecological zones) have been established to oversee the integration of research, training and extension. These committees have formulated policies for enhancing the development and delivery of technological packages for the major crops, animals and other agricultural systems in the zones; including the design and implementation of appropriate training programs for subject matter specialist and end-users.

The key to the whole enterprise of land reclamation and desert development is the rate at which technologies are developed, verified, transferred to and accepted by the end-user. From a technical viewpoint, the introduction of appropriate advanced agromanagement packages including crop selection, on-farm irrigation management, fertigation techniques, integrated pest management and harvesting, handling and packaging technologies are required. Similarly, technology packages for aquaculture systems, fisheries and animal-related sector are needed. Research missions, including trained personnel, monies and facilities must assume a greater responsiveness to problem solving, and continuity to the research-development-delivery conduit.

## IX. – Economic Self-Sufficiency

The current 5-year plan for agricultural research within the NARS context is aiming at achieving self-reliance based upon the optimal utilization of natural resources; land, water and the prevailing environment in a sustainable fashion. The goal of the GOE is to achieve economic self-sufficiency, not self-sufficiency on a commodity basis. To achieve this, increased attention is being given towards the agricultural system delivering agricultural products that have a competitive, economic advantage in the export market. The selected products thus generated may have higher economic value, by allowing a more favorable trade-balance, and securing agricultural products that can not be grown economically in Egypt to secure the populations requirements for food, fiber and energy.

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