Economic Incentives to Promote the Abatement of Nile Pollution (Draft)

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Abbreviations

bcm	Billion cubic meters
CAPMAS	Central Agency for Public Mobilization And Statistics
CIDA	Canadian International Development Agency
DRI	Drainage Research Institute
DRTPC	Development Research and Technological Planning Center
ECEP	Energy Conservation and Environment Protection Project
EEAA	Egyptian Environmental Affairs Agency
EP3	Environment Pollution Prevention Project
IFPRI	International Food Policy Research Institute
GAMS	General Algebraic Modeling System
GOSD	General Organization for Sanitary Drainage
IIP	Irrigation Improvement Project
IMS	Irrigation Management System
lcd	Liter per capita per day
LMP	Land Master Plan
MFF	MPWWR and Ford Foundation
MALR	Ministry of Agriculture and Land Reclamation
MOH	Ministry Of Health
MOP	Ministry Of Planning
MPWWR	Ministry of Public Works and Water Resources
NGO	Non-Government Organization
NSC	National Specialized Councils
PPM	Particle Per Million
PRIDE	Project In Development and the Environment
RNPD	River Nile Protection and Development Project
TDS	Total Dissolved Solids
TIMS	Tabbin Institute for Metallurgical Studies
TSS	Total Suspended Solids
UNDP	United Nations Development Program
USAID	United States Agency for International Development
WECD	World Commission on Environment and Development
WHO	World Health Organization
WMP	Water Master Plan

Introduction

The abatement of Nile pollution is a serious concern in Egypt's development [1] Four factors support this assertion. (i) demand for water exceeds available freshwater; (ii) water demand is increasing over time; (iii) opportunities to increase the water supply are limited; and (iv) although reuse of returning water to counteract the growing water shortage is a viable option, it is not used often enough. The government has tried to improve water quality for reuse while avoiding adverse impact on the environment.[2] But recent studies indicate that efforts made so far to protect water quality have not achieved the desired goals Hazards associated with the degraded quality of returning water necessitate the search for policy instruments to boost the effectiveness of water quality management. This paper is a contribution to that search.

This paper recommends the adoption of positive economic incentives for the design of quality management policy and demonstrates the effectiveness of improving the quality of returning water. It relies on local and international research findings for its recommendations for modifying existing production techniques to eliminate or at least reduce polluted inputs or processes and to find an economic use for emitted pollutants to transfer it to an economic "good" The approach depends on motivating firms to adopt the proposed modifications, leaving the responsibility of policy execution and information dissemination to the government.

Three sources are identified as the main water polluters: municipal waste, agricultural drainage and industrial effluent. Municipal waste, which is disposed of at community expense, is recommended for use as an input in the manufacture of organic fertilizers and compost. The benefits accrued from processing municipal waste are multiplied many fold when the products are used as a substitute for chemical fertilizers in agriculture

In the agriculture sector, improving the notorious non-point pollution can be accomplished by replacing chemical fertilizers with organic and biofertilization techniques. These three fertilization techniques are modeled and tested using a regional LP model Improving industrial emissions can be accomplished by adopting the "pollution prevention" principle as applied by the ECEP/EP3 project.

Research has proven the willingness of polluters to adopt measures that improve their own profit and reduce pollution emissions. These measures have a number of common characteristics desirable in policy design: they are sustainable, as they meet the "win-win" criteria, do not require a tedious—sometimes impossible—definition of rights and liabilities, and they are immune to loopholes and lobbying.

This paper comprises three sections in addition to the introduction . The first discusses water pollution as a public health hazard that aggravates water shortage. The crucial role played by returning water in meeting the water need is explored, as well as its damaging effects. The relative importance of reusing returning water to meet the increasing water need and the efforts exerted to conserve the quality of returning water are presented, and the failure of those efforts is demonstrated. The second section paves the way to a new policy by discussing the factors undermining the existing policy. The application of this new policy to emissions from municipal, agricultural and industrial activities is discussed In the final section, policy implications are explored

Water Shortage and Pollution

Water Shortage

Available water in Egypt is barely enough to meet need. The 1990 water budget (Table 1) shows that the quantity used exceeded the available fresh water by about 6 bcm. The deficit was met by: reusing drainage water, pumping out seepage from the irrigation–drainage network (groundwater), and recycling a limited amount of sewage water

The gap between available fresh water and the amount needed is expected to grow as a result of the rising needs of the various sectors of the economy, coupled with limited opportunities to increase the fresh water supply. Egypt's water need is rising because of an ambitious land reclamation program, a growing population, an expanding industrial sector, and steady rural and urbanization development. In the land reclamation sector, 3 4 million feddans have been identified as reclaimable (LMP 1986:vi). Of this area, about one million feddans had been reclaimed by 1992 (MALR 1993:28); the remainder (about 2.5 million feddans) can be reclaimed if 13 bcm is provided for irrigation [3,4]

Municipal water use is another component of water demand. It includes all types of public and private day-to-day use of treated water. An increase in municipal use results from population growth, rise in national income (which enables the government to provide unserved areas with treated water), increased hygienic awareness, and the price of water Municipal supply in 1990 (3 1 bcm) represented only about 70 percent of the national target of 206 lcd The current government plan is to raise per capita water use to 269 lcd, an, at the same time extend treated water supply to 85 percent of the population by 1996/97 (MOP 1992 202). If by the year 2001 the population receives 269 lcd, municipal water use is expected to reach 6 7 bcm [5] This implies that 3 6 bcm, in addition to the amount demanded in 1990, must be allocated to meet municipal demand in the next century.

Table 1: 1990 Water Budget

Item	Quantity (bcm)
Available: Fresh	
Nile	55.5
Aquifer	0.5
Subtotal	56.0
Available: Recycled	
Groundwater	2.6
Drainage	4.7
Sewage	0.2
Subtotal	7.5
Total	63.5
Uses	
Irrigation	49.7
Municipal	3.1
Industrial	4.6
Navigation	1.8
Hydropower	1
Evaporation	2
Total	62.2
Surplus	1 3

Source: Abu Zeid and Rady 1991:50-52 (Tables 9, 10, figure 10), 62 (Table 12). Hydropower is added from Abu Zeid 1990.

Table 2: Water need at the beginning of the 21st Century.

Item	Quantity (bcm)
New Lands	13
Municipal use	4
Industry	5
Total	22

The volume of water required for industrial use depends on the rate of growth in that sector, the change in the composition of the industrial base, the prevailing technology, and the price of water. The volume of industrial water use is expected to reach 9 7 bcm by the year 2000 (WMP 1981-b:2 1) Thus, an additional 5 bcm will be needed to cover the expected increase in industrial use

In sum, about 22 bcm has to be made available at the beginning of the next century in order to satisfy the projected increase in water demand (Table 2). Hence, demand for returning water is expected to rise, yet—as will be shown in the next section—its poor, degraded quality forms a major obstacle for its utilization.

Water Pollution

Degraded water quality has a severe impact upon economic development in Egypt. It affects people's lives, agriculture production, industrial output, and competitiveness in international markets. It devastates the output of the country's human resources: it shortens life expectancy, decreases the number of working days because of increased sick leave and lowers productivity. WHO estimates 60,000 Egyptians/year die from water-borne diseases. In Lake Manzalla, life expectancy of lakeside residents is 40 years compared to 60 in the rest of the country; the standard of living for fishermen has dropped as a result of a 90 percent decline in the fish take over the past 10 years. In Lake Maryut, mercury levels in some fish exceed 1,000 ppm, compared to the WHO standard of 1 ppm. In Cairo, microbiological diseases are common: diarrhea, infectious hepatitis, typhoid fever, schistosomiasis and many others. These diseases cause up to 10 percent of all deaths among the general population and 30 percent of deaths among children (PRIDE 1994:1).

Irrigation with degraded water undermines the production of the agriculture sector for the following reasons: (i) it has a direct adverse effect on crop yield; (ii) it lowers quality, thus dampening prices, and (iii) if repeatedly applied, polluted water will temporarily or permanently destroy soil fertility as a consequence of salt build up and/or conglomeration of soil particles because of oil constituents. In the industrial sector, the use of degraded water raises maintenance costs because of higher rates of corrosion.

Egypt's competitiveness in international commodity and tourism markets may be damaged by a poor reputation in environmental issues Consumer rejection of adulterated products is surging and tourists fear water-borne diseases. Unless a good quality water environment is preserved, Egypt's exports will suffer

Opportunities to Improve Water

Water Availability

Egypt is almost totally dependent on Nile water, which varies in quantity due to weather variations in its basin.[6] Normally, Egypt's share of Nile water is 55 5 bcm annually, according to the 1959 agreement This limitation on Egypt's share leaves three options to increase water availability: Upper Nile projects, water conservation and water reuse

Limitations of upper Nile conservation projects. Such projects can provide Egypt with up to 9 bcm annually [7] However, a number of factors make those projects a relatively less attractive option. Such projects are subject to political negotiation and environmental concerns. Furthermore, their cost is high relative to reuse and conservation options (estimated at LE 300-350 million/bcm; Abu Zeid 1992.8). Moreover, the completion of such projects depends mainly on political stability in their locations; for example, the first phase of the Jonglei project was never completed. Therefore, a prudent planner should search for more reliable alternatives. That leaves conservation and reuse as the two options under the full control of Egypt.

Water conservation. The MPWWR (Ministry of Public Works and Water Resources) has emphasized conservation at many levels in the irrigation hierarchy. At the national level, it has adopted a tight water policy that comprises. (i) the elimination of special water release for the purpose of generating hydroelectric power; (ii) construction of the Isna Barrage to prevent water releases used to reduce the head increase resulting from river bed erosion, (iii) prolongation of the winter closure period, (iv) minimizing water releases through the Rosetta branch; (v) modification of current cropping patterns to reduce the irrigation requirement (Abu Zeid and Rady 1991:47-48 and Abu Zeid 1990), and (vi) constructing civil works necessary to reduce losses of rainwater in Sinai and the northwestern coast (EEAA n.d.42).

At the farm level, efforts are being made to improve the overall irrigation efficiency, which is currently in the vicinity of 50-55 percent. Towards that end, MPWWR has implemented a large USAID-funded scheme known as the Irrigation Management Systems Project (IMS). The purpose of the project is to rehabilitate the irrigation–drainage system, and to enhance its management. An improvement in irrigation efficiency by 10 percent is expected to reduce the Old Lands irrigation requirement by about 3 bcm [8] Another area for conservation is the reduction of waste in the municipal network which has been estimated at 50 percent (Chemonics 1992-c)

Water reuse. Reuse is another alternative to increase water supplies. There are four sources of water reuse: sewage discharge, seepage from the irrigation-drainage network (groundwater), drainage water, and industrial effluent.

An estimated 18 bcm of Nile water is returned annually. In 1990, 4.7 bcm was recycled, with the remaining 13 3 bcm discharged into the sea (Abu Zeid 1992-b 6) An additional 2 3 bcm can be recycled, thus raising the reuse of drainage water to approximately 7 bcm and reducing the release to the sea to about 6 bcm. This will: (i) get rid of water with salinity greater than 2000 ppm; (ii) sustain the Delta salt balance; and (iii) prevent sea water intrusion beneath the North Delta soil (Amer 1992:1-2).

In 1990, the amount of extracted groundwater was estimated at 2.6 bcm. This amount can be increased to 4.9 bcm, which is believed to be equal to the rate of recharge (Biswas 1991:38) This is 2.3 bcm above the 1990 level. One interesting feature of groundwater extraction is its positive impact on the agriculture sector as a result of a lowered water table (MFF 1988·14 and Biswas 1991:38)

The reuse of treated sewage water for agricultural purposes has been practiced in Egypt since 1915 in Al-Gabal Al-Assfar. Pending the completion of sewage plants nationwide, about 64 percent of the water withdrawn for municipal use will be recovered through the sewage system.[9] Irrigation with treated sewage water is advantageous because it is nutritionally richer than fresh water. Moreover, dried sludge can be sold as organic fertilizer. Plans exist to use 5 bcm of treated wastewater annually for agriculture and forestation (EEAA n d·42).

As mentioned above, by the year 2000 industrial water demand is expected to reach 9.7 bcm, with a consumptive use is only 0.4 bcm (WMP 1981-b:2.1) The rest (9.3 bcm) will be returned to the Nile system. Approximately 7.4 bcm can be collected for reuse, accounting for 20 percent waste in the network

To sum up, the supply of fresh water in Egypt is fixed. The options available to increase it at low cost and with a reasonable degree of certainty are conservation and reuse. The first is beyond the domain of this paper. Due to the significance of the role water reuse can play in closing the demand gap (Table 3) the second will be focused on in this paper.

Table 3: Summary of potential water available for reuse.

Item	Quantity (bcm)
Drainage water	7 0
Groundwater	4.9
Sewage discharge	5.0
Industrial effluent	7 4

Environmental Conservation Efforts

The Egyptian government has followed a number of paths to address the critical situation of the environment. enacting necessary laws, establishing specialized institutions, implementing technical projects jointly with foreign partners, and encouraging the public sector to participate through forming NGOs. Over the past four decades the government has enacted a set of laws that addresses various environmental issues. This set includes· Law 93/1962, organizing the discharge of effluents and the sewer system; Law 57/1978, regulating swamps and concomitant pollution issues; Law 48/1982, concerning issues pertaining to water surfaces; and Law 4/1994, with its executive regulation published one year later as Prime Minister Decree No. 338 /1995. Law 4/1994 and Law 48/1982 are the most relevant to this paper; a glimpse of their contents is provided in Box 1

On the institutional front, the government, in addition to encouraging NGOs, has established two highly specialized institutes to look after the Egyptian environment EEAA, and the Environment Protection Fund, both of which were established by Law 4/1995 One of the early achievements of EEAA was the preparation of an environment protection plan for the period 1994-2008, at a cost of LE 5 8 billion (estimated in 1992 pounds). The plan aims at protecting Egypt's environment (water, air, and soil) by adopting protective measures against further degradation and improving the present situation. The plan is to be carried out in two five-year plans (1994–1998 and 1999–2008). Of special interest are the measures to protect the water (EEAA n d·1,3,6,42)·

- Industrial wastewater treatment projects for approximately 100 factories will be implemented, at company expense.
- River cruise ship waste will be treated before discharge.

- Pilot and trial projects to create and test inexpensive techniques for wastewater treatment will be developed.
- Administrative and technical staff will be trained to run and maintain wastewater treatment systems.
- Whenever possible, chemical fertilizers will be replaced with organic waste

Box 1: A summary of Laws 4/1994 and 48/1982.

Law 4/1994 (This law is complementary to Law 48/1982.)

Article 1: provides thirty eight environmental definitions.

Articles 2-13: reestablish EEAA which was previously created by republican decree The EEAA is in charge of enacting public environmental policy in coordination with other concerned institutions, cooperating with other regional and international organizations, monitoring the environment, issuing environmental criteria to control pollution and degradation, proposing environmental laws, and performing related studies.

Articles 14-18: establish an Environmental Protection Fund, which receives funds from the government donations and fines. It provides incentives to firms or individuals who make significant contributions to environment conservation.

Articles 19-28: are concerned with land and wild life protection. One of the articles requires establishing a tree nursery in each village in Egypt on an area of 1000 m3. Another requires firms to keep environmental records, are designed by EEAA.

Articles 29-33: address transportation and handling of hazardous material and waste.

Articles 34-47: provide criteria for air protection.

Articles 48-75: describe off- and on-shore marine pollution.

Articles 76-77: handle international environmental certificates.

Articles 78-83: prescribe administrative and judicial procedures.

Articles 84-104: state penalties, the severest is imposed on handling hazardous material and waste, a fine up to LE 40 000 and a minimum 5 years imprisonment (Article 88)

(Source. A R.E. 1995)

Law 48/1982

- The law comprises twenty articles which start by defining water courses to be the Nile, all its branches, all drains, lakes, swamps, and aquifers.
- A permit has to be secured from MPWWR for any discharge into a water course.
- MOH is in charge of monitoring water quality. MPWWR can request MOH to run tests on effluent at the expense of the polluter.
- Buildings are prohibited on water course banks, but MPWWR may make exceptions.
- MALR is not to allow the use of chemicals which may, directly or indirectly, pollute water courses.
- The law establishes the Water Surfaces Police to monitor law enforcement.
- The maximum penalty is one year imprisonment plus a fine not less than LE 500. The penalty is doubled if the violation is repeated

(Source. A.R E. 1994)

Another example of the activities of EEAA is the ongoing preparation of "An Industrial Pollution Abatement Project," with World Bank assistance.[10] The project, which will last three years (the grace period provided by Law 4/1994), is designed to help EEAA to build an effective institutional capacity to monitor pollution and enforce environmental laws

The project is also concerned with helping Egyptian firms adjust their processes so as to comply with Law 4/1994

An additional joint project, titled "River Nile Protection and Development Project," is being implemented by MPWWR and CIDA. The second phase of the project was initiated in 1993, and will end in 1997. Its purpose is to "protect and develop the River Nile system and to consolidate efforts towards strengthening issues related to strategic research and planning, soil and water quality monitoring, barrage safety and monitoring, and hydrographic survey, data management and mapping" (RNPD).

In spite of the efforts that have been made to stop water pollution, recent reports indicate that the objectives have not been achieved Evidence of failure is provided in the next section.

Water Quality

A decade after the issuing of Law 48/1982, industrial effluent, sewage discharge, and agricultural drainage are still dumped into the Nile. Several studies shed light on the critical situation of water quality A comparatively optimistic report asserts that the river's assimilative capacity exceeds the present discharge of organic, nutrient load and biodegradable organic matter However, inorganic salts, nutrients, pesticide residues, and oils have been steadily increasing in the Nile water, and it's fish, since the construction of the Aswan High Dam (El Gohary 1993:26).

The NSC (National Specialized Councils) estimates industrial pollutants dumped into the Nile as 1151 t/d of dissolved solids (TDS), 296 t/d of suspended solids (TSS), 168 t/d of oils, and 1 65 t/d of heavy metals. Following is a detailed summary of industrial pollutants (NSC 1992.229-43):

- The first Nile reach (from Aswan to Isna) receives effluent from the Kima fertilizer factory, Kom Ombo sugar factory, the paper factory and Sebaiaa Phosphate Port
- The second reach (Isna to Nag Hammadi) receives discharges from sugar factories in Armant, Quos, Deshna, Nag Hamadi, and the Aluminum Factory.
- The third reach (Nag Hamadi to Assiut) receives the effluent of different Sohag factories: Onion dehydration, Coca Cola, oil and soap.

- The fourth reach (Assiut to Kourimat) receives chemical waste of highly concentrated soluble material from fertilizer and phosphate factories, in addition to the Minya oil and soup factories.
- The fifth reach (Kourimat to the Delta) receives the most hazardous pollutants, from the factories in Hawamdia, Tebeen, Helwan, Torah, and Shoubra El Khima. Moreover, pollution in this reach is aggravated by Nile cruise ships. This reach is the source for Cairo's municipal water
- The sixth reach (Rashid Branch) has two main sources of pollution: Rahawy drainage, whose water is a mixture of sewage and drainage discharge, and effluent from Kafr El Zayat industrial region.
- The seventh reach (Damietta Branch) gets the effluent of Talkha Fertilizer Factory which is the main source of pollution. A purifying unit has been installed in the factory at a cost of LE 5 million to improve the quality of the discharge

Out of 20 cities and towns equipped with water treatment plants only nine have reliable sewage treatment systems The villages in the Egyptian rural areas are without sewage systems. Sewage services cover 80 percent of the population in urban areas and only 5 percent in rural regions (PRIDE 1994:1). Sewage water collected from major areas in Egypt exceeds the capacity of the treatment stations. Another minor, yet active, type of pollution is caused by the 173 Nile cruise ships that discharge untreated waste directly into the river. Such sewage water is loaded with nitrogen, and microbial and viral infection.

Agricultural drainage is loaded with residues of toxic chemicals used to fight insects, plant disease, chemical nutrients added to enhance plant growth, and soil particles The negative impact of contamination with toxic chemicals on public health requires no elaboration. Eutrophication caused by nitrogen, potassium and phosphate stimulates rapid growth of aquatic micro- and macrophytes and encourages algal bloom. Sedimentation causes situation of water conveyance facilities. Together they raise turbidity, boost the maintenance cost of waterways and establishments, and alter the water habitat. Residues reach the main Nile course itself via 72 drains spread between Aswan and the Delta barrage (NSC 1992:234,237) This does not include drainage in regions north of the Delta barrage.[11]

The above brief review poses important questions. Given all the efforts made, what are the factors that have weakened their effectiveness, and what can be done to reverse this trend?. The answers to these questions are tackled below

Toward a More Effective Economic Policy

Why the Current Policy Has Failed

The failure of the attempts to effectively improve water quality can be attributed to a number of reasons.

- Laws 4/1994 and 48/1982 assume that polluting firms possess identical marginal abatement cost and, consequently, that they will have the same response to a policy tool Obviously, this is not necessarily true. The reaction of firms will naturally vary widely depending on several factors, such as production technique, scale, etc
- The procedure followed to formalize a policy legally is lengthy and complex, that makes it rather rigid when adjusting to the ever dynamic economic variables. What may be a prohibitive penalty one day could be rendered obsolete if its real value is eroded by economic change. For example, the maximum penalty imposed by Law 48/1982 is one year imprisonment plus a fine not less than LE 500. This penalty sanctions what the legislator considered at the time of preparing the law the severest offense. Over time, the real value of this penalty, and its prohibitive power, has eroded and rendered it ineffective, especially when weighed by the probability of being caught.
- In many cases, polluters are persuaded to maintain the status quo because the cost of investing in new environmentally conservative techniques or in the purchase of more expensive cleaner inputs required to reduce emission brings about a drop in profit
- The difficulties involved in defining relevant rights and liabilities provide plenty of room for lobbying and the exploitation of loopholes to undermine strict application of laws and regulations.
- Governmental budget constraints may limit the ability of environmental authorities to sustain continuous and alert monitoring of the extensive Nile network, along with active police support backed by prohibitive judicial penalties.
- A government becomes lenient in law enforcement if the application of a policy results in closing down an operating firm, rendering its workers unemployed.
- Responsibility of environmental supervision is lost among five government organizations that have direct responsibility for sampling industrial effluent· GOSD, the Ministry of Health, the General Organization for Industrialization, the General Organization for Greater Cairo Water Supply and MPWWR (El Gohary 1993 ii)

The inefficiency of government actions in addressing environmental issues has been explained (WCED 1983 301)

> "The nation state is insufficient to deal with threats to shared ecosystems Threats to environmental security can only be dealt with by joint management and multilateral procedures and mechanisms "

Thus, the absence of collaboration between the State and other concerned parties underlies the government's failure to enhance environmental conservation The issue boils down to how to neutralize the factors undermining the efficacy of water quality management policies so as to improve the quality of returning water in a way that secures safe utilization This mission is the subject of the following section. It presents a policy model grounded on the utilization of positive economic incentives.

Features of the New Policy

A properly crafted economic policy, along with the necessary institutions (governmental and non-governmental), would be capable of internalizing the external diseconomies accompanying water pollution by inducing polluters to minimize or, if possible, abate pollution voluntarily with no, or minimal, coercion.

To appreciate this approach, one has to consider first the conventional economic framework that handles water pollution. It employs four elements. the river's assimilative capacity, the existing pollution levels beyond the assimilative capacity, the associated marginal social damage function, and the marginal social net benefit to be derived from pollution abatement. The intersection between the marginal social damage and net benefits guides policy makers to the appropriate level of pollution. Accordingly, permits (tradable or not), tax, or other prohibitive standards can be designed (see for example Pearce and Turner 1990, Baumol and Oates 1988, and Just et al 1982). Some of these tools are reviewed in Box 2.

In practice, the availability of the required information form a major obstacle to enlightened application of these tools. If one of the four essential pieces of information is not available, then conventional economic tools cannot be properly designed. Quantification of assimilative capacity and estimation of functions require considerable investment in data collection, processing, model building, and highly specialized manpower which are not generally available in developing countries. Indeed, this information is not available for the Nile river. Probably, these difficulties explain why economic tools have been neglected in quality management policy formation The availability of an array of techniques to substitute for polluting inputs make it possible to go around this obstacle. This way polluters reduce emission voluntarily.

Box 2: Summary of some international cases of pollution abatement.

River/State	Measures
Colorado River, USA	Pollution control is directly related to water rights via tradable water rights and discharge permits The latter considers the effect of returning effluent on water quality parameters (Teerink and Nakashima 1993).
The Andean Basin Peru	A new law proposes that existing users be granted tradable free water rights, to be recorded in a public water rights registry that indicates the quality and point of returning flow Non-allocated or additional water distributed by means of public auction. Water trade is subject to a minimum ecological water requirement (Thobani 1994)
Malaysia	Firms are required to treat their waste through a consortium or a private contractor, plus tax relief and industrial zoning
Japan	Financial support and tax exemption are provided for environment-related investment. Firms are expected to pay for the treatment of their waste through private contractors Water use permits are issued after establishing a proof that the use will not have adverse effects on water quality firms must advertise their intentions to allow parties that might be hurt to complain (Teerink and Nakashima 1993).
Yellow River China	Financially autonomous water institutions have been established to collect water fees (Gunaratnam et al. 1992) Land use and industrial zoning are employed Financial incentives are used to support investment in collective treatment plants (Brandon and Ramankutty 1993)

(Source: Tohamy 1995.)

To demonstrate the effectiveness of the proposed economic policy, the three most notorious water-polluting wastes are addressed below. These are municipal waste, agricultural drainage, and industrial effluent. These wastes are the main sources of chemicals and organic matter dumped in the Nile (other sources are power stations, which are responsible for thermal pollution and abuse of individual water courses) Due to innate differences, each source has been studied using a different framework. The municipal waste sector is a vital service sector. It is funded mainly by the government. To a large extent, it comprises similar firms with identical wastes that constitute a main environmental problem The second sector, agriculture, is a commodity sector which consists of hundred of thousands of farms engaged in the production of scores of agriculture commodities using, to a large extent, similar technologies. Hence, farms enjoy a considerable degree of homogeneity that allows them to be grouped for modeling Farms participate in the non-point pollution of the Nile. Pollutant sources are identical chemical fertilizers and pesticides Alleviating the pollution requires modifying related techniques The financial attractiveness of the proposed adjustments has been assessed using an LP model. Unlike the first two sectors, the third sector, industry, is characterized by a high degree of heterogeneity, even when broken down into sub-industries As heterogeneity does not allow proper aggregation, this report is confined to case studies available from the EP3/ECEP project.

Recycling Municipal Waste

In this context, municipal waste in this context includes sewage, town and rural area garbage, and farm waste. The total quantity of these waste is estimated at 50 million t/yr (Awadallah 1995). This represents a financial burden and, at the same time, an environmental problem. The financial burden is created by the cost of collecting, transporting, and treating this huge amount of solid and liquid waste Environmental problems are associated with different phases of handling waste. Time lapses during the process of garbage collection provide insects, microbes, etc with a shelter to multiply and spread Some garbage components are recycled, the rest are burned deliberately or by self-ignition In either case, burning garbage results in the emission of harmful gases Sewage may not be fully treated, or not treated at all before being dumped into the Nile.

A very simple, yet highly effective, approach can be adopted to reduce the financial burden of getting rid of waste and protecting the environment. Various types of waste (excluding glass and metals, which are already recycled) can be manufactured into cheap rich organic fertilizer and compost, as demonstrated by the analysis of the products of El Moqattum Waste Station (Awadallah 1995).

Several benefits can be driven from this approach. First, creating a demand for waste transforms it from the "bad" that everyone prefers to get rid of, to something that can be sold as an input to the organic fertilizer and compost industry Hence, there will be agents interested in collecting and selling waste.[12] Second, environmental concerns resulting from burning and dumping waste are relieved. Third, investment and employment opportunities will be created when such industries start Fourth, environmentally-clean inputs will be made available as substitutes for chemical fertilizers that leave residues that are carried with the drainage water to the Nile. The only demand for this product is the agriculture sector

Improving Agricultural Drainage

Agriculture is one of the main sectors of the Egyptian economy In 1991, it contributed 18 percent to the GDP. However, this figure does not reflect the real weight of the sector, for it does not take into account the vertical integration between the agricultural and industrial sectors Many of the inputs to the industrial sector are produced in the agriculture sector To be sure, in 1991 the food, beverages and tobacco industry generated 31 percent of the value added for manufacturing industries, while the textile and clothing industry yielded 16 percent (IBRD 1993:242,248, Tables 3,6).

The positive contribution of the agriculture sector is accompanied by negative external diseconomies in the form of toxic and harmful chemical residues entering the human food chain directly or indirectly. Those residues are generated by farmers' legitimate practices to secure good farm profit. The repellent impact of contamination with toxic chemicals on public health requires no elaboration. The two sources of chemical residue in drainage water are pesticides and chemical fertilizers It is the second source that is discussed here.

The objective of this section is to assess farmer willingness to adopt a set of new production techniques that have been tested in Egypt by specialized research institutes and proven suitable for Egyptian conditions. These techniques will lead to a reduction in the application of chemical fertilizers by replacing them with biofertilization or organic substitutes Thirty techniques are recommended by Awadallah and Siam. Awadalla focuses on testing the technical viability of recycling municipal waste to produce organic fertilizers and compost, and the impact of such techniques on farm income (Awadallah 1995).

Siam highlights many issues in his volume Demand for chemical fertilizers tend to be inelastic This position is supported by two studies in the Eighties and was also observed after the recent lifting of fertilizer subsidies. Although fertilizer prices rose by 300 percent between 1989–1992, its use dropped by only 16 percent (Siam 1995). The weak responsiveness of fertilizer demand to price increases is attributed to farmer ignorance of available substitutes. Lack of information is strengthened by artificially low relative prices for chemical fertilizers due to heavy subsidization, providing no incentives for farmers to look for alternative options.

Biofertilization is another issue covered by Siam. Significant savings in financial cost and application rates for chemical fertilizers can be obtained as a result of inoculation with nitrogen fixing bacteria or the introduction of microorganisms to modify soil pH so as to transform phosphorous in the root zone to a form that can be taken up by the plant (Siam 1995)

Both studies covered seven crops. wheat, broad bean, maize, barley, berseem, rice and sugar cane. One technique, representing conventional fertilization practices derived from the MALR Economic Bulletin, plus the thirty non-conventional techniques recommended by Awadallah and Siam, add up to the thirty one techniques used in the model. Willingness to adopt any of these techniques was assessed using a GAMS linear programming model.

The model simulated four scenarios, of which one pair represented the conventional fertilization technique (which relies heavily on chemical fertilizers) and the other introduced the thirty one fertilization techniques. In each pair, one scenario allocated land with no area restriction on any of the crops, while the other scenario restricted a crop area to 133 percent of its regional area in 1993.

Three indicators were adopted to assess the viability of the proposed techniques. net revenue, value added, shadow land price, and change in cropping pattern. Table 4 displays the first three indicators. Results show that clean agriculture scenarios are superior to the conventional method. They achieved greater values according to the three indicators. The total area of crops cultivated using the new techniques exceed 6 million feddans under the crop-area restriction and 1.2 million feddans under the free scenario

Table 4: Summary of the results of the four scenarios.

Crop Area	Free		Restricted	
Technique	Conventional	Clean	Conventional	Clean
Net revenue (billion LE)	30	32	8	13
Value added (billion LE)	39	41	15	20
Shadow Land Price	3,512	4,718	1,000	1,151
Upper Egypt (LE)	6,165	6,165	634	652
Middle Egypt (LE)	4,492	4,477	1,039	1,311
Lower Egypt (LE)				

Industrial Effluent

The industrial sector is a point-source polluter, thus it is easy to identify and measure emission per unit of time. One strategy to abate industrial pollution that is gaining worldwide acceptance is "pollution prevention." This strategy can be thought of as a pyramid of actions with the most preferable at the top and the environmentally less preferable actions arranged in descending order. An action is selected only when the others above it are not viable. At the top comes: (i) full prevention of pollution by changing a process or an input; (ii) source reduction, which alleviates the problem; (iii) internal recycling of waste either as a product or a material; (iv) external recycling of waste, either as a product or a material; (v) waste treatment by pyrolysis; (vi) incinerating waste with energy recovery; (vii) incinerating waste without energy recovery; and, if the above fail (viii) land fill disposal, (ix) air emission; and (x) discharge into water (adopted from Bush 1995 and De Neve 1995)

Many factories around the world have experience with pollution prevention. Smith & Wesson (USA) detail a number of examples of pollution prevention. The problems involved aging equipment and an inefficient cooling system with regard to heat treatment Moreover, the operation utilized high volumes of water A solution was found by using closed loop cooling. A cooling tower to continually recycle the water was installed at a cost of $79,887, which was recovered in 18 months. This achieved savings in water usage of 95 percent (Autorino 1995). Another dramatic example is given by 3M, where over a period of 14 years of pollution prevention (1975-1989), the company achieved savings of $500 million worldwide (De Neve 1995).

In Egypt, pollution prevention began recently with a project funded by USAID/Cairo and implemented—in cooperation with a number of factories—by four institutes the

Environment Pollution Prevention Project (EP3) based in Washington D.C., USA with a field office in Cairo, the Development Research and Technology Planning Center/Cairo University (DRTPC) which is working with a number of private sector factories, the Tibbin Institute for Metallurgical Studies which is helping some public sector factories, and the Federation of the Egyptian Industries, which is in charge of information dissemination and training. Apart from its favorable environmental impact, this project is distinguished by a number of interesting characteristics: it operates within the low-cost/no-cost range, it implements pollution prevention schemes at the factory level in full cooperation with its staff, it is process-specific, and serious attention is paid to information dissemination

Tentative results of the short-lived project are promising and in agreement with international experience, water savings of 220 thousand cubic meters were made in five of the factories participating in the project The cost of one cubic meter ranged from LE 0 75 to LE 1.65 per cubic meter for treated water. Water savings were associated with a reduction in effluent and material conservation of about LE 1.5 million. Pollution prevention in four factories reduced VOC emissions and achieved a saving of LE 1.3 million as well as improving product quality. Similarly, the burning of 2000 tons of *mazout* annually is saved in three factories. There has also been a positive impact on health and fire hazards.

The approaches applied to the factories under study were prevention, source reduction, internal recycling, and external recycling. These approaches brought about cost savings which translate into greater profit and value added. The approaches were employment neutral except in two cases: directing waste to external recycling, and replacing external recycling with internal recycling. Directing waste to external recycling creates job opportunities. However, replacing existing external recycling with internal recycling results in unemployment. The latter case was observed in one factory There, hard zinc, zinc ash and dust were previously taken by an external contractor for remanufacture Pollution prevention recommended internal recycling. As a result, some jobs concerned with the remanufacture of zinc were lost. The only advantage is that the remanufacturing subcontractor is operating in a heavily populated area in the slumps of Cairo, so the action is environmentally favorable. But the negative social impact has to be dealt with by arranging alternative training and employment opportunities

Policy Implications

This paper addresses one of the most serious constraints to sustainable development in Egypt, namely, water shortage and pollution Egypt is experiencing a rising water deficit The severity of the problem is the product of two factors. increasing need and limited opportunities to increase supply The factors increasing need are the growing population with its greater demand for new agriculture lands to meet its food requirements, and urbanization, which provides the necessary shelter for the growing population. Opportunities to get more water are very slim: upper Nile conservation projects are not reliable in the foreseeable future. So, thrifty use of fresh water and reuse of returning water are the only viable options However, the latter option requires safeguards for its use.

Returning water can be reused to alleviate the deficit, however, its degraded quality not only prevents its reuse but pollutes fresh water sources. Aware of this serious situation, the government has enacted what it thought to be an effective water environment law (Law 48/1982) Nonetheless, more than a decade has lapsed, and water quality is still a public hazard.

The failure to conserve clean water resources is due to the absence of economic incentives from the current environmental policy. The utilization of positive economic incentives to support Egypt's endeavor to secure and sustain a clean Nile is the focus of this paper The approach is to motivate a firm to reduce the level of its pollution emission as a part of its drive to increase profit This principle has been addressed with respect to the three most water-polluting activities in Egypt: municipal waste, agriculture, and industry In the case of municipal waste, the plan is to make use of waste in the manufacture of compost and organic fertilizers. Several benefits can result from such a scheme: (i) secure cleaner water environment, (ii) reduced need for burning waste; (iii) reduction of public expenditure for garbage collection and handling; (iv) investment and subsequent job creation in the area of waste processing and marketing of compost and organic fertilizers; and (v) the farming sector is provided with cheap a alternative to chemical fertilizers.

Manufactured organic fertilizers are not the only substitute for chemical fertilizers; biofertilization is equally important. In order to assess economic viability, thirty one options of chemical, organic, and biofertilization techniques were incorporated into an elaborate regional agro-economic LP model. The results indicate that organic and biofertilization are more profitable to farmers and generate greater value added at the national level

Unlike the first two sectors, studies in the industrial sector show that water conservation alone is not highly attractive, whereas a resource conservation package is. Hence, water conservation and reduction of industrial effluent should be explained to industrialists as a component of a broader resource conservation package

In the light of these findings, a policy principle and plan of action are proposed for the use of governmental organizations, international development agencies, and NGOs in Egypt and elsewhere. As a first principle, positive economic incentives have to be exhausted as tools to minimize Nile pollution before resorting to negative incentives and coercive instruments. To put this recommendation into effect, integrated, simultaneous action is required.

- The government and concerned agencies should invest in searching for more profitable and environmentally cleaner options so as to persuade firms to adopt them voluntarily.
- Similar investment should be directed to explore ways to reuse pollutants, creating a demand and, consequently, value added. Thus, dumping pollutants would represent a loss to the firm.
- Design a means to disseminate to target industries the information accumulated through the implementation of the first two items.
- Efforts being made now by government and non-government institutions need to be integrated in one comprehensive national framework to avoid duplication and conflict, and to enhance efficacy in environmental conservation.
- Intensive media campaigns should be launched to promote public awareness of short- and long-term environmental issues.

Apart from improvement in water quality, the implementation of the above recommendations will be helpful to the private sector, the government, and Egyptian society at large. First, they will help to prepare investors to face the new international market institutions which are growing sensitive to adulterated products. Second, concern about Egypt's share in the international goods and services markets holds true for local markets too With the liberalization of foreign trade, a segment of Egyptian consumers will shift to imported commodities if the quality of domestic products does not improve Product quality is a function of input quality especially water. Third, an unhealthy environment will have an adverse impact on Egypt's share in international tourism Fourth, public expenditure to finance policing and enforcement of environmental laws along with the concomitant tension can be reduced

In essence, positive economic tools provide a win-win environmental policy instrument that achieves Egypt's goal for a cleaner Nile

Appendix 1: The Agro-economic LP Model

Data Source

Data has been obtained from the most recent issue of the "Agricultural Economy Bulletin" series, which was published in mid-1995 and uses 1993 data. The bulletin is published annually by the Central Department of Agricultural Economics, the Economic Affairs Sector of MALR. Other than direct field surveys, this department is the formal data source for plant, animal and fish production in Egypt Its data are used and published by other government authorities as well as international agencies. The bulletin provides a wide coverage of demographic data, national aggregates, and governorate-level plant production data with crops broken down to varieties It lists areas under each variety, total production, yield, cost, revenue, and farm gate price.

Data manipulation included entering data on an Excel 5 worksheet, checking and evaluating manually. As a cross-check, the net revenues calculated by the GAMS program were compared with the published figures. In addition, some field operation data such as planting date, labor and water requirements were obtained from a recent study prepared by the IFPRI team.

The Decision Variable

To operate his farm, a farmer makes many decisions every day. Broadly, these decisions can be classified as long-term, seasonal and short-term. Long-term decisions involve investment in machinery, farm buildings, orchards and the like. This type of decision is governed by the farmer's expectations about the time profile of the cost and benefits streams as compared to other alternative options. At the other extreme, day-to-day decisions involve the utilization of labor, water and other inputs, and are dominated by seasonal decisions.

Given the production environment and constraints, a farmer makes two seasonal decisions· crops to be cultivated and the area of each crop. These are the two most important farm decisions. First, the size of farm income depends on how successful a farmer is in selecting the most profitable crops and in allocating his land resources among them. Second, the welfare of his family during the following season depends on that farm income. Third, return to his resources, whether land, labor or capital, is determined by the outcome of those decisions Fourth, the farmer's decisions affect, on aggregate, the returns to two of the most important natural resources in Egypt land and water.

Due to the importance of the farmer's decisions on the allocation of land resources, it has been adopted as the decision variable in this model. This decision is assumed to be guided by net revenue. Hence, a farmer maximizes total net revenue during the agricultural year (which begins in October).

Geographical Representation

Agriculture land in 1993 was estimated at 7.2 million feddans most of which (6.1 million feddans) was in the Nile Valley and Delta (MALR 1993:66, Table 38). As this area is spread across the twenty six governorates at varying degrees of intensity, it was necessary to aggregate it for modeling

One level of aggregation divides the agriculture land in Egypt into Old and New Lands. This practice is widely used in the literature on Egyptian agriculture Its main concern is to distinguish between the land brought under production before the heavy land reclamation programs started in the early Sixties and the lands reclaimed afterwards. Such aggregation is misleading. Confusion arises from the fact that some newly reclaimed land penetrates the Nile Valley and Delta governorates. The total of the newly reclaimed land in 1993 was estimated at 647,000 feddans, of which 60 percent lie in the desert governorates.[13] The rest (256,000 feddans) are scattered throughout the Nile Valley and Delta

Table 5: Old and New Lands in 1993.

Location	Area (thousand feddans)
Desert governorates	390.8
New Land in the Valley and Delta	256 1
Total New Land	646
Old Land in the Valley and Delta	5,884 9
Total agricultural area	6,531 8

(Source· MALR 1993.66, Table 38; areas of New & Old Lands in the Valley & Delta are calculated.)

Another aggregation has been recently adopted in a study prepared by the IFPRI team (Hazell et al 1994) The team divided the country into eight regions. five Old Lands regions and three New Lands regions. The Old Lands regions are divided, according to geographical considerations, into Upper Egypt, Middle Egypt, East Delta, Middle Delta, and West Delta. The division of the new land has a geographical dimension only in the sense that it is mostly located outside the Nile Valley and Delta Other than that, two main criteria are used in the classification: soil type and source of irrigation (Old Lands depend mainly on surface irrigation). Accordingly, New Lands have been divided into sandy soil with canal irrigation, clay calcareous soil with canal irrigation, sandy soil with ground water irrigation, and a generic region that encompass other soil types. Obviously, the IFPRI team focused on soil homogeneity and water sources in order to reduce discrepancies in the New Lands sub-model.

Many of the studies concerned with Nile pollution divide the River into seven reaches as mentioned above (NSC 1992:229-43). The main advantage of this division is that it allows environmental monitoring of water quality and assimilation capacity in each of the Nile reaches.

Regardless of the division, there are problems associated with water-related studies. These problems are caused by inconsistencies among the three sorts of official divisions prevailing in the Egyptian agriculture system: the administrative units, the irrigation commands, and the drainage commands The WMP team wrote a computer program that switches from one division to another. However, special agriculture data has to be collected at the village level in order to use that program effectively

Given the above, it has been found that the scheme most suitable for this study was to divide Egypt into three regions: Upper Egypt, Middle Egypt, and Lower Egypt (Delta) This leaves out desert regions. The Upper and Middle Egypt governorates do not have extensive drainage systems (except for Fayoum Governorate). Thus, drainage water is discharged in the Nile network and used in Lower Egypt. As for Lower Egypt, the non-point source pollution is not desirable there because it leads to pollution of the northern lakes and the Mediterranean. This scheme is consistent with the agricultural data set up However, the distinction between the newly reclaimed land in the Nile Valley and Delta and the Old Lands is overlooked. This simplification, despite overlooking desert regions, does not impair the analysis for several reasons:

- New Lands in the desert governorates are mainly irrigated from sources other than Nile water (MALR 1993 28-29, Table 15) [14]
- Except for the New Valley (which represents 0.7 percent of the agriculture area of Egypt), desert governorates do not have a drainage network (MALR 1993 30-31, Table 16), hence they do not contribute to Nile water pollution.
- The total area of desert New Lands is relatively small (about 9 percent)

Regional distribution of agricultural land is summarized in Table 6. Upper Egypt consists of four governorates: Aswan, Qena, Sohag, and Assiut There are approximately 1 1 million feddans of agriculture land in Upper Egypt, and approximately 18 percent of the agriculture area of the Nile Valley and Delta. Of these governorates, Aswan has the least share of agriculture land (2 percent) Middle Egypt comprises four governorates, Minya, Fayoum, Beni Sueif, and Giza, with a total agricultural area of 1.2 million feddans.

Table 6: Regional land distribution in 1993; area in thousand feddans.

Region	Area	Percentage
Upper Egypt	1,090.7	18%
Middle Egypt	1,237.1	20%
Lower Egypt	3,823.2	62%
Total	6,141.0	100%

(Source MALR 1993:66; Table 38.)
Percentage is calculated.

The agriculture area of the Delta represents 62 percent of the Nile Valley and Delta (about 3 8 million feddans). Administratively, it is divided into thirteen governorates, of which seven are basically urban or industrial centers (9 percent).[15] The agriculture land (52 percent) is concentrated in the other six governorates· Menoufia (5 percent), Sharkia (11 percent), Dakahlia (10 percent), Kafr El Sheikh (8 percent), Gharbia (6 percent), and Beheira (12 percent).

Cropping Pattern and Activities

Four categories of crops are cultivated in Egypt· winter, summer, nili, and perennials As indicated in Table 6, about 88 percent of the cropped area is under winter and summer crops

Table 7: Land allocation by season in 1993.

Season	Area (thousand fed)	Percentage
Winter	5,157	45
Summer	4,869	43
Nili	558	5
Perennials	835	7
Cropped Area	11,419	100

(Source : Calculated from MALR 1993:66, Table 38.)

In order to keep the model within a manageable size, and at the same time observe regional specialization, only key crops were included. The relative importance of crops in each season is evaluated in the light of the percentage of total area. Detailed tables are provided in the Agriculture Appendix with main crops shaded. Accordingly, a total of twenty two crops are selected for the study: ten winter crops, eleven summer crops, and one perennial crop.[16]

Selection of representative crops was based on the criterion that a crop occupy no less than 10 percent of the regional agriculture area. Twenty two crops met that criterion. Ten winter crops, occupying 93 percent of the national area under winter crops in 1992/1993, eleven summer crops, cultivated on 86 percent of summer land, and one perennial crop (sugar cane) were selected for study Altogether, the area of these crops adds up to 75 percent of the cropped area in Egypt.

Flexible Farming Options[17]

To approximate reality as much as possible, farmers were given six options: three planting dates and three irrigation levels. They could cultivate one crop on time, one month early or one month late. Delaying some summer crops one month is the same as cultivating them as nili crops. However, they are treated as summer crops in terms of input-output coefficients. Early cultivation is assumed to reduce yield by 5 percent but a one month delay will decrease it by 10 percent This assumes that the most suitable weather is always found around the normal planting date. In reality, erratic weather changes may make the yield of late cultivation better than that of the normal date. As this is a deterministic model such stochastic behavior is beyond its scope.

Table 8: Yield response to farming options.

Planting Date	High Irrigation	Medium Irrigation	Low Irrigation
Early	5%	11%	23%
Normal	0%	6%	18%
Late	10%	16%	28%

Irrigation options were to apply 100 percent, 85 percent or 70 percent of a crop's seasonal consumptive use. The impact of the variation in irrigation level was estimated using an FAO model (CROPWAT). Yield response to the level of water application was expected to be 0, -6 and -18 percent, respectively (Hazell et al. 1994 3-32, 3-33).

The combined effect of the two sets of options was assumed to be additive (Table 8).

Revenue

Published per feddan yield for each region was assumed to be the benchmark under the prevailing conditions in 1993 Whenever a regional average was not available, an area-weighted average was calculated. For each yield, eight additional values were calculated to adjust for planting dates and irrigation options using the variation shown in Table 7. The same procedure was applied to the by-product yield. Yields of the nine alternatives were multiplied by the corresponding average seasonal prices. Thus, the price advantage of early harvest was not accommodated Yield-related cost items were also subsequently adjusted.

Input Cost

Cost of production was divided into eleven items land preparation, seed and cultivation, irrigation, manure, chemical fertilizers, agriculture operations, pesticides and the like, harvest, on-farm product transportation, miscellaneous and rent.

Rent is a problematic issue. On the one hand, it is a fixed cost item since it has to be paid whether the land is cultivated or not. On the other hand, it is crop-specific. Its value is mainly determined by the crop that will be cultivated, suitability of land to that crop, crop duration, and other factors such as proximity to markets, irrigation sources, etc. Thus, rent is considered a variable cost item in this model. Market rent, not the official rent was used

The importance of the distinction between rent as a variable or fixed cost is in the distinction between "gross margin" and "profit." The first is "gross revenue" less "variable cost " The latter nets out other paid fixed cost items. Irrigation has been adjusted according to the irrigation options. Other inputs that were adjusted to yield changes are harvest, and transportation costs.

Resource Constraints

Monthly constraints are imposed on the total area under selected crops and on total labor requirements, these two constraints are imposed at the regional level A single constraint has been imposed on total national irrigation requirement.

Appendix 2: Mathematical Presentation of the Agro-economic LP Model

$$\underset{AREA}{MAX} \sum_{C} \sum_{D} \sum_{G} \sum_{R} NREVENU_{CDGR} * AREA_{CDGR}$$

$S.T.$

$$\sum_{C} \sum_{D} \sum_{G} LABOR_{MCDGR} * AREA_{CDGR} \leq TLABOR; \qquad \forall R,M$$

$$\sum_{C} \sum_{D} \sum_{G} LANDM_{MCDGR} * AREA_{CDGR} \leq TAREA; \qquad \forall R,M$$

$$\sum_{C} \sum_{D} \sum_{G} \sum_{R} IRIREQ_{CDGR} * AREA_{CDGR} \leq TWATER$$

$$AREA_{CDGR} \geq 0; \qquad \forall C,D,G,R$$

(1) *The "Free" Conventional Agriculture Model* (CONVAG).

C=crops, D=planting dates, G=irrigation level, R=region, M=month, NREVENU=per-feddan net revenue of crop C, AREA=area under crop C, LABOR=per-feddan labor requirement of crop C in month M, TLABOR=total labor in month M in region R, LANDM=land requirement of crop C in month M, TAREA=total agriculture area in region R in month M, IRIREQ=per-feddan irrigation requirement of crop C in region R, TWATER=total national water.

$$\underset{AREAX}{MAX} \sum_{C} \sum_{D} \sum_{G} \sum_{R} NREVENU_{CDGR} * AREAX_{CDGR}$$

$S.T.$

$$\sum_{C} \sum_{D} \sum_{G} LABOR_{MCDGR} * AREAX_{CDGR} \leq TLABOR; \qquad \forall R,M$$

$$\sum_{C} \sum_{D} \sum_{G} LANDM_{MCDGR} * AREAX_{CDGR} \leq TAREAX; \qquad \forall R,M$$

$$\sum_{C} \sum_{D} \sum_{G} \sum_{R} IRIREQ_{CDGR} * AREAX_{CDGR} \leq TWATER$$

$$\sum_{D} \sum_{G} AREAX_{CDGR} \leq TAREAS_{CR} \qquad \forall C,R$$

$$AREAX_{CDGR} \geq 0; \qquad \forall C,D,G,R$$

(2) *The "Restricted" Conventional Agriculture Model* (CONVAGX).

AREAX=regional area under crop C, TAREAS=1993 regional area under crop C multiplied by 133%; the rest is as in (1).

$$\max_{AREA} \sum_{C}\sum_{D}\sum_{G}\sum_{Y}\sum_{R} NREVENU_{CDGYR} * AREA_{CDGYR}$$

S.T.

$$\sum_{C}\sum_{D}\sum_{G}\sum_{Y} LABOR_{MCDGYR} * AREA_{CDGYR} \leq TLABOR; \qquad \forall R,M$$

$$\sum_{C}\sum_{D}\sum_{G}\sum_{Y} LANDM_{MCDGYR} * AREA_{CDGYR} \leq TAREA; \qquad \forall R,M$$

$$\sum_{C}\sum_{D}\sum_{G}\sum_{Y}\sum_{R} IRIREQ_{CDGYR} * AREA_{CDGYR} \leq TWATER$$

$$AREA_{CDGYR} \geq 0; \qquad \forall C,D,G,Y,R$$

(3) *The "Free" Clean Agriculture Model* (CLENAG).

Y=fertilization techniques; the rest is as in the above boxes.

$$\max_{AREAX} \sum_{C}\sum_{D}\sum_{G}\sum_{Y}\sum_{R} NREVENU_{CDGYR} * AREAX_{CDGYR}$$

S.T.

$$\sum_{C}\sum_{D}\sum_{G}\sum_{Y} LABOR_{MCDGYR} * AREAX_{CDGYR} \leq TLABOR; \qquad \forall R,M$$

$$\sum_{C}\sum_{D}\sum_{G}\sum_{Y} LANDM_{MCDGYR} * AREAX_{CDGYR} \leq TAREAX; \qquad \forall R,M$$

$$\sum_{C}\sum_{D}\sum_{G}\sum_{Y}\sum_{R} IRIREQ_{CDGYR} * AREAX_{CDGYR} \leq TWATER$$

$$\sum_{D}\sum_{G}\sum_{Y} AREAX_{CDGYR} \leq TAREAS_{CR} \qquad \forall C,R$$

$$AREAX_{CDGYR} \geq 0; \qquad \forall C,D,G,Y,R$$

(4) *The "Restricted" Clean Agriculture Model* (CLENAGX).

all notation is as in the above boxes.

End Notes

1 The word "Nile" in this text denotes the Nile, all its branches, the drainage network, and terminal lakes.

2 Actually, the pollution of one medium (water, soil or air) might lead to the pollution of another, acid rain is a good example However, this paper is confined to direct pollution of the water medium

3 Given an annual rate of reclamation of 150 thousand feddans, it will take about 17 years to reclaim 2.5 million feddans starting 1992

4 The estimation of per-feddan water requirement is a complex issue because it depends on a myriad of factors. No wonder then that estimates range from as low as 5000 to as high as 11200 m3/feddan of new land (WMP 1980:8 and LMP 1986 26; respectively). Provided that only modern methods of irrigation are allowed in the new lands, a conservative requirement of 5000 m3/feddan is adopted

5 The population forecast for 1996 and 2001 is 60 6 and 67 9 million (CAPMAS 1994.32).

6 Left aside is a gloomy hypothesis that a climatological change is shifting rainfall in the upper Nile region further to the south (Hulme 1990 59). This proposition is supported by a number of observations (a) data of the annual river yield over 116 years suggests a generally decreasing trend over time (Khouzam 1994), (b) another study using the same time series took the percentage of long-term mean as a reference point, it shows that the river flow was high during the period 1871-1905, less than the long-term mean during 1905-1965, and significantly lower during the post 1970 period (Abu-Zeid and Rady 1991). An alternative proposition suggests that river flows during the post 1970 period is just a reoccurrence of dry conditions which prevailed in the 19th century (Biswas 1991:70,72) In any case, refuting or confirming such hypothesis requires applying more sophisticated techniques to longer time series data

7 Water increment generated by upper Nile projects consist of 4 bcm from Jonglei Canal I, 3 from Jonglei II, 4 savings from Mashar Marches, 7 from Bahr El-Ghazal, that adds up to 18 bcm at Aswan to be shared equally with the Sudan (Abu Zeid 1992-b.4)

8 It is worth mentioning that the saved amount is one third the total water increment to be obtained from all upper Nile projects. Keeping in mind the high cost of upper Nile projects, conservation seems financially more attractive

9 The efficiency of the municipal network is targeted to reach 80 percent Assuming an equal efficiency rate for the sewage network, then recovery of the water allocated for municipal use will be 80%*80%*6 7 bcm = 4.3 bcm.

10 Extracted from a hand-out titled "An Invitation to Industrial Enterprises and Interested Banks" which was distributed at the conference on "The Role of Cleaner Production in Meeting the Challenges of a Changing World Economy," Taba, Egypt, July, 24-27, 1995

11 In addition to pollution from economic sectors at large, the individual man abuses water courses in her/his day-to-day practices: villagers use canals passing throughout or close to their villages for a variety of house and other uses such as drinking, cooking, washing dishes, clothes, animals, and equipment, and disposal of garbage or dead animals (DRI 1989:17,30-33)

12 This kind of business is already practiced in Egypt for the purpose of recycling certain garbage elements. Similarly, in the sewage sector some firms sell the sludge to farmers

13 Desert governorates are the New Valley, Mattroh, North Sinai, South Sinai, and the Red Sea.

14 A reservation on this statement may rise in the future with respect to El-Salam Canal which water will be used to irrigate about 400 thousand feddans in Sinai. Water of this canal is a mix of the Nile and drainage water.

15 Urban centers are Cairo (includes 0.08 percent of the valley and Delta agriculture area), Suez (0.17 percent), Port Said (0.09 percent), and Alexandria (1 8 percent). Minor agriculture governorates are: Qaliobia (industrial and urban center 3 percent), Ismailia (2 percent), and Damietta (1.8 percent)

16 That leaves less than 0 6 million feddans under orchids and palm trees.

17 These options are adopted from Hazell et al. 1994

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