Sustainable Solution for Unconventional Water in Arid Regions by Promoting Nature-based Techniques with Relatively Low Energy Demanding Solutions

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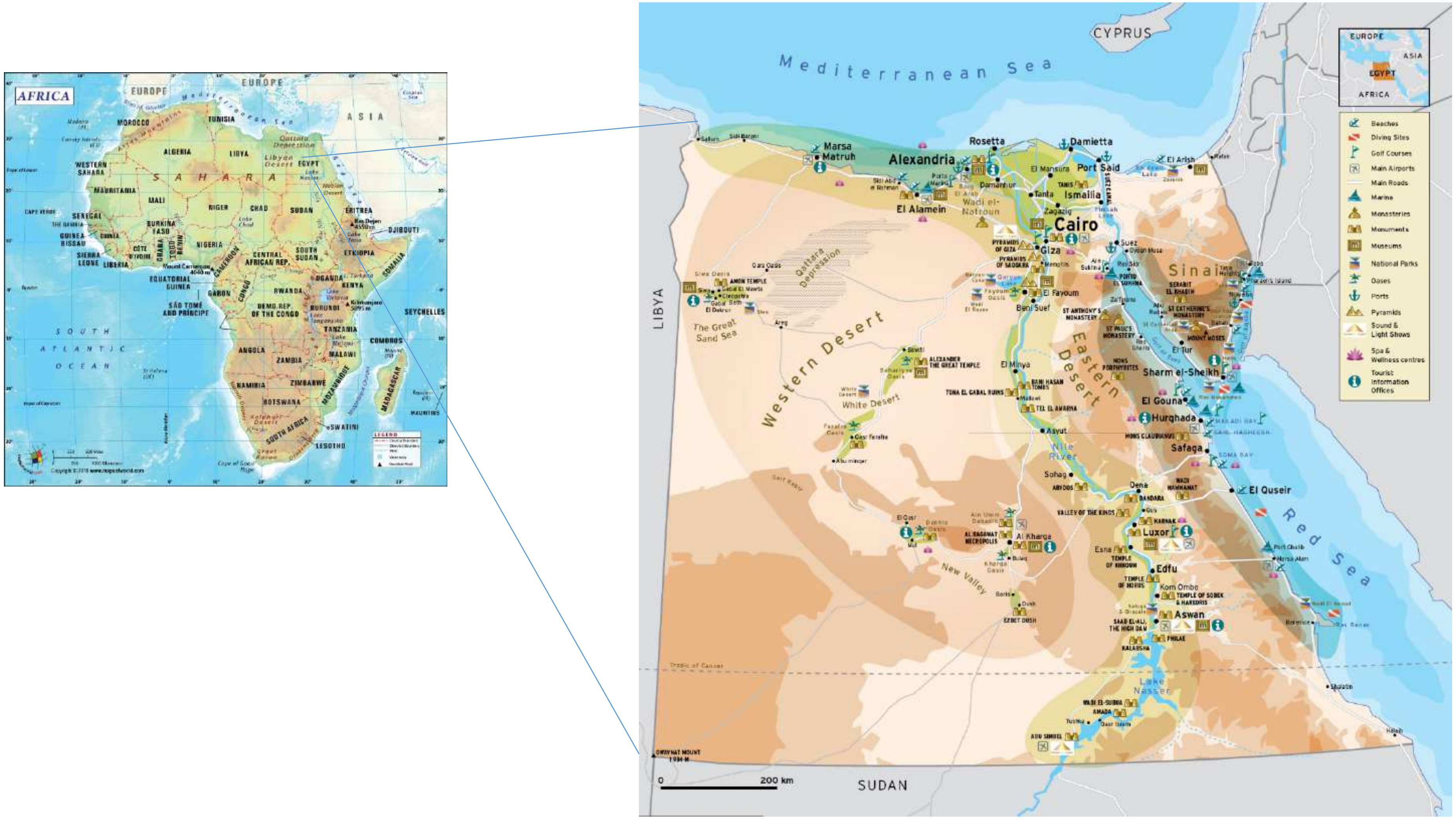
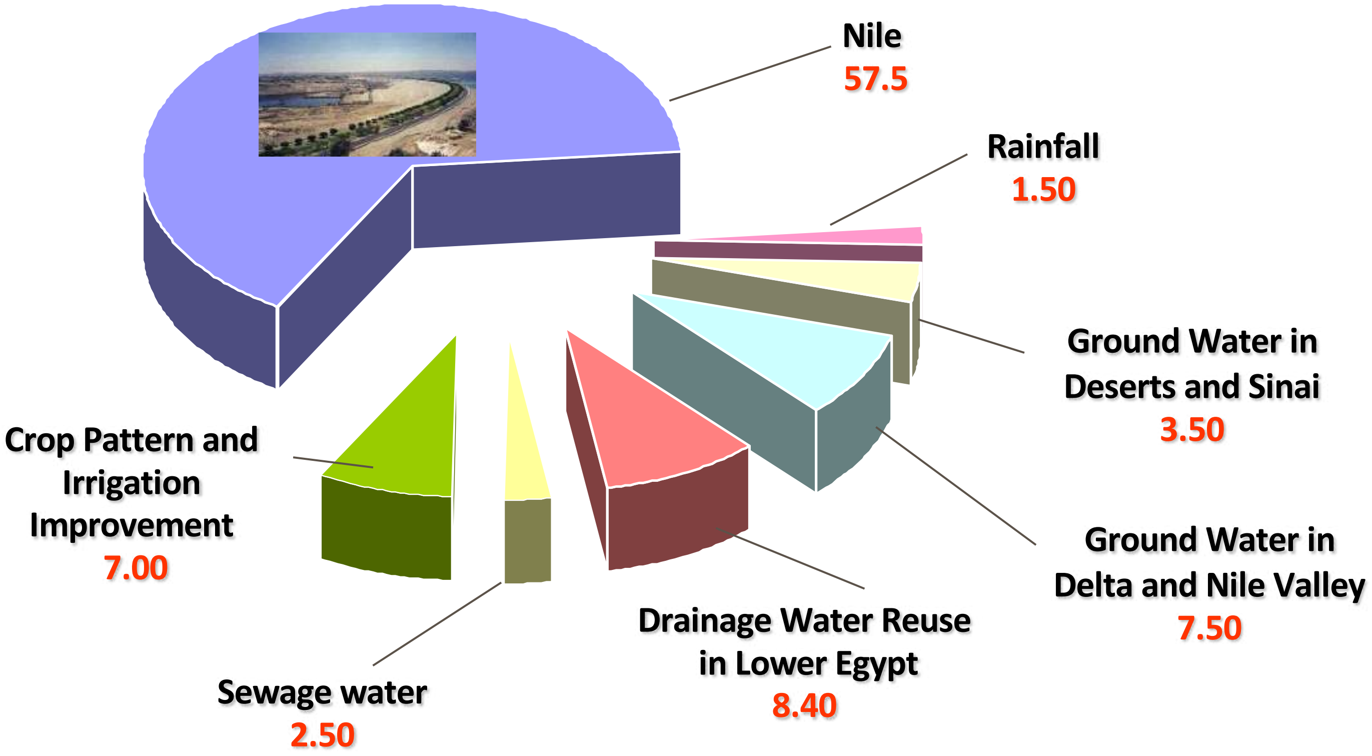


In Egypt, about 100 Mio inhabitants live in 222 cities and 4,617 villages. Apart from the regions close to the Nile river, the climate is arid and semi-arid.

Water Resources in Egypt, 2018

Demand: Agriculture (84.5%) Drinking (6%) Industry (9.5%)

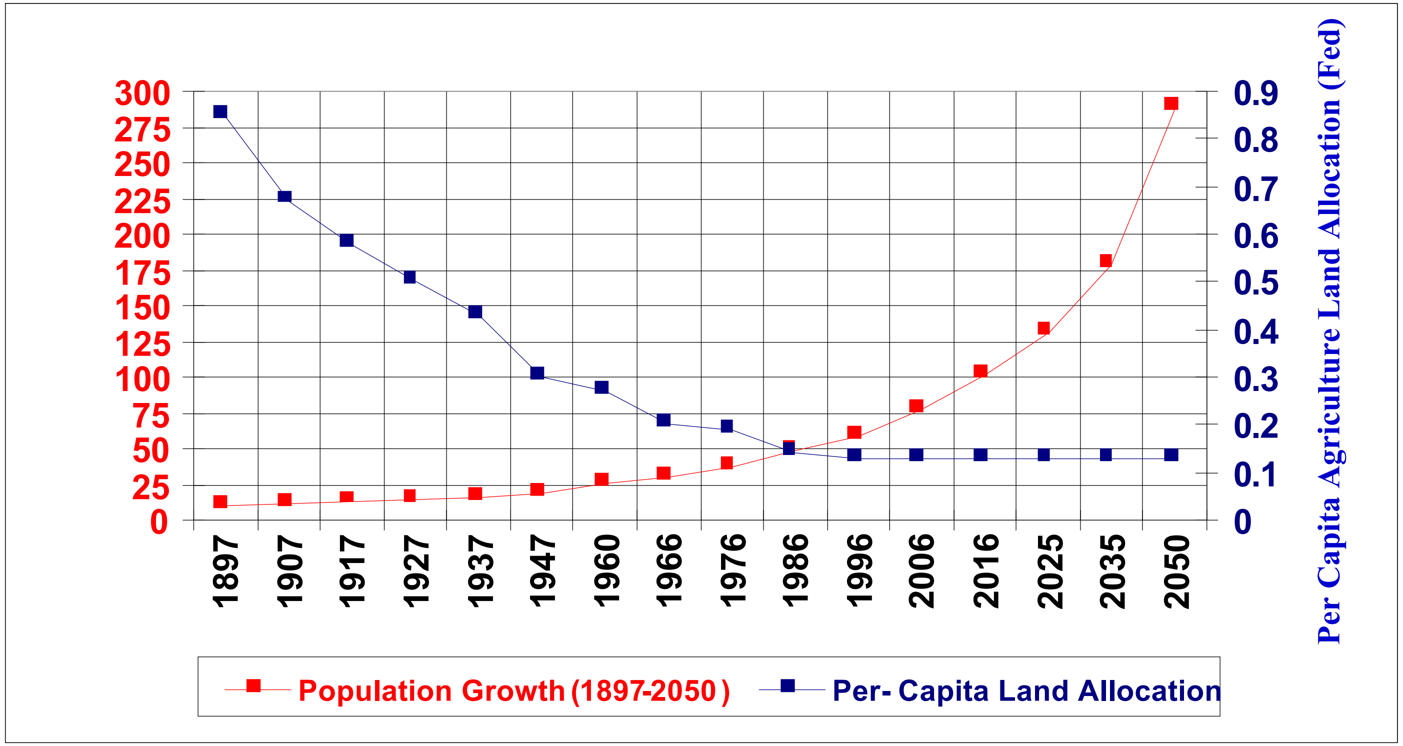
Resources:



Total 87.9 BCM

- Egypt is facing a major challenge of how to increase the rate of growth in agriculture production to generate and meet its future food requirements to cope with a very high annual rate of increasing in population (1.9%).
- The population which was about 20 million in 1952 is 100 millions in 2018 and is expected to be 150 million by the year 2025.

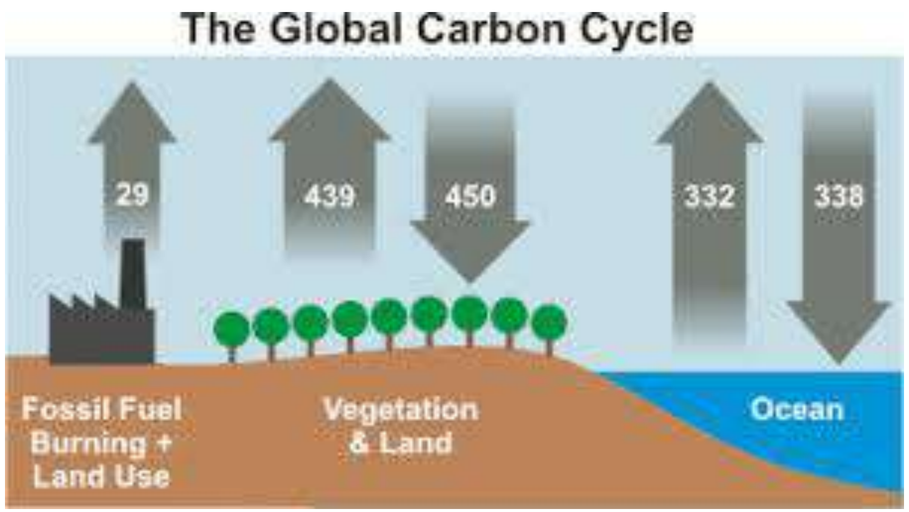
EGYPT: Population Growth & Per-Capita Land Allocation (1897 – 2050)

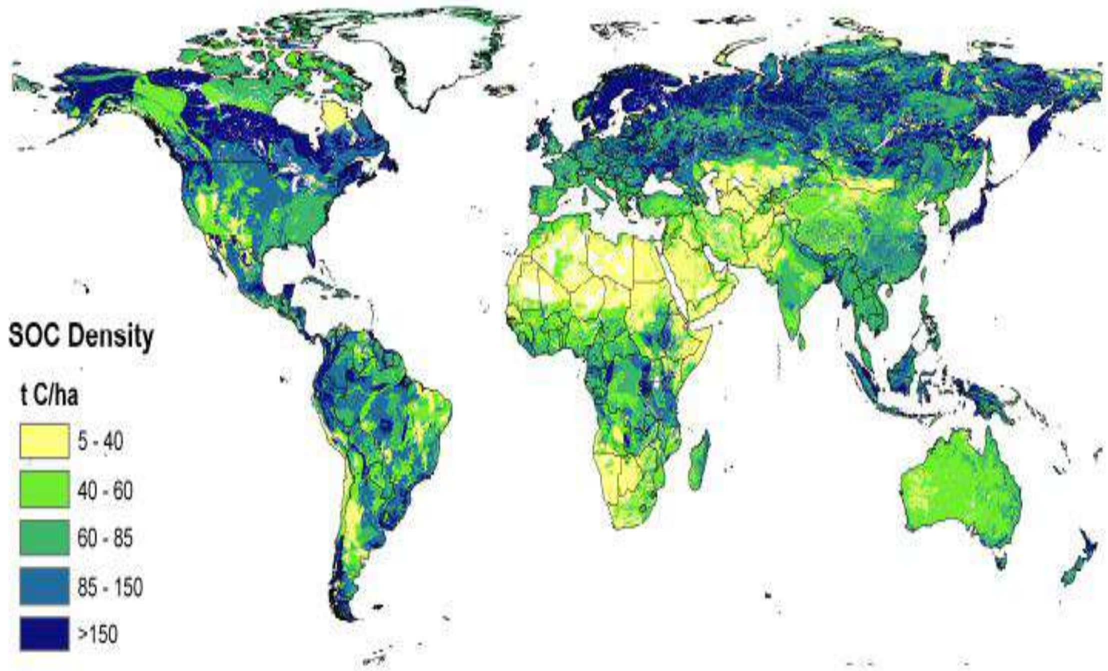


Should we blame the industry!!!

Or

Is there another main source for CO_2 emission!!





Spatial distribution of SOC density, 0-1 m depth (Mg C ha^{-1}) source (Gerard Govers et al., 2012.)

- Spatial distribution of SOC density (Batjes, 1996) at depth 0-100 cm vary depending on geographic location and climatic conditions. Northern Europe, Canada, Russia and several areas in the US and Central Africa are characterized by high soil organic carbon ratio where it ranging from 85 to 150 TC/ha.
- Moreover, South of Europe, Australia, and China are characterized by soil organic carbon ranging between 40-85 TC/ha.
- On the other hand, Middle East region and some areas in South Africa are characterized by low values of SOC less than 40 TC/ha that could be attributed to low primary productivity or the removal of plant organic matter at harvesting as well as low of precipitation rate and high temperature (Gerard et al., 2012).

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Effect of land-use changes and site variables on surface soil organic carbon pool at Mediterranean Region

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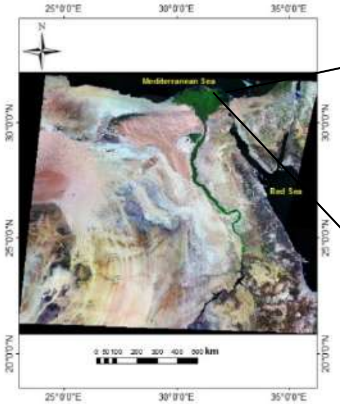
ABSTRACT

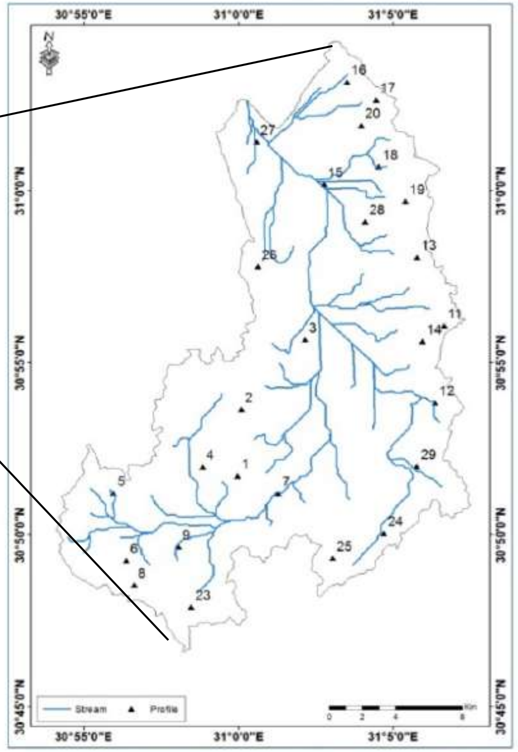
Soil organic carbon pool (SOCP) is affected by several factors particularly soil type, climate, topography, crop management, and anthropogenic factors. The study was carried out to clarify relationships between SOCP under different soil types and land-use changes in the Mediterranean region. Data of 26 pedons were investigated in Tanta catchment, middle Nile Delta, Egypt (30°45 N, 30°55 E), that the collected soil samples covered different soil types and land-uses. There were significant differences of SOCP among soils: loam and clay loams were rather similar. Clay soils were the most extensive and have mean SOCP of 4.08 ± 1.41 kg C m^{-2}. The highest SOCP of 7.07 kg C m^{-2} was in clay loam soil associated with bare soil, while the lowest of 2.57 kg C m^{-2} in sandy clay loam soil associated with bare soil. Losing cropland showed highest increase from 1990 to 2015 with increasing urban encroachment by 15.3%. The overall average results of SOCP in cropland area showed 53.85 Mg C ha^{-1} under different soils. Losing the arable lands to urbanization resulted in a decrease of 285.421 Gg C of SOCP. With the decrease in SOCP sequestrated within the soil surface, carbon dioxide would be emitted to the atmosphere. The emitted CO_2 resulted from losing the cropland equal to 1047.5 Gg CO_2. Land-use changes have marked impact on surface SOCP and C sequestration.

➢ ***The study was conducted to***;

1) identify the impact of land-uses changes, soil types and site variables on SOCP in the upper 30-cm soil surface in North Nile delta.

2) Assess the impact of soil organic carbon decrease on emitted carbon dioxide and hence the concentration of greenhouse gas (GHG) in the atmosphere.





Sample locations of the studied catchment area

- ***Land use & land cover changes***

❖ Enhanced Thematic Mapper (ETM+7) in May 1990 was used for mapping the historic land-use types, while Landsat TM and ETM+ data of Landsat 8 with spatial resolution 30 m in January 2015 for the same study area was acquired for analyzing the recent state.

❖ The changes of vegetation cover were monitored based on the Normalized Difference Vegetation Index (NDVI). The NDVI was established through analysis of ETM data in 1990 and 2015 as a ratio of the measured intensities of the near infrared (NIR) and the red (R) and spectral bands (Carlson et al., 1995) as follows:

NDVI = (NIR - R) / (NIR + R)

The NDVI for cultivated areas based on crop types, crop age, planting density and growing season.

➢ *Soil organic carbon pool calculation*

❖ Areal SOCP calculation was investigated as a function of soil organic carbon (SOC) concentration.

❖ For each soil pedon, SOCP at the top 30 cm depth was expressed in mass per unit area (kg C m^{-2}) by multiplying SOC percentage by soil bulk density (Mg m^{-3}), within the sampled soil depth (cm), and fine soil fraction < 2 mm in size (Tan et al., 2004b):

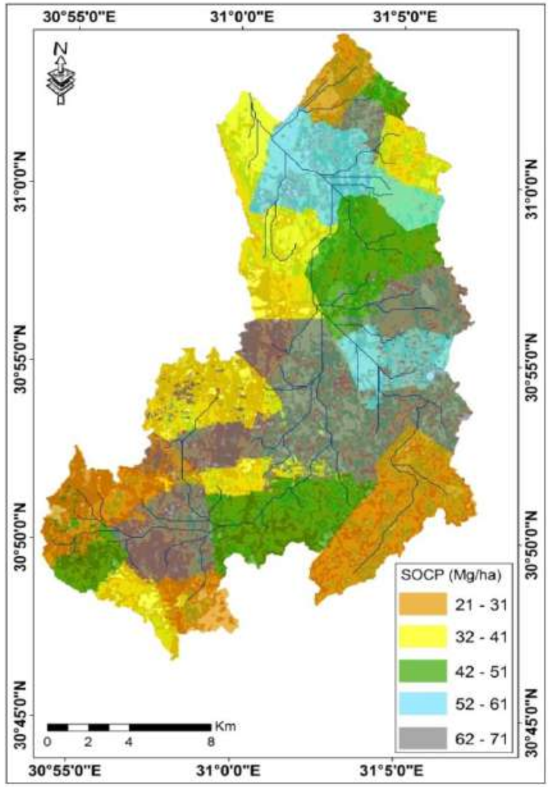
$$SOCP = [L * SOC * B.D * (1- F/100)] /10$$

Where: *SOCP* is soil organic carbon pool for the 30 cm depth (kg m^{-2}), *SOC* is soil organic carbon content (wt. %), *L* thickness of the soil layer in cm, *B.D* soil dry bulk density, (Mg m^{-3}), and *F* > 2 mm coarse soil fragment (wt. %).

❑ Based on the soil organic carbon sequestrated in soil surface, emitted carbon dioxide (CO_2) was calculated using the following equation of IPCC (2007):

Emitted CO_2 = Amount of Sequestrated Soil Organic Carbon X 3.67

Spatial distribution of soil organic carbon pool at the study area.

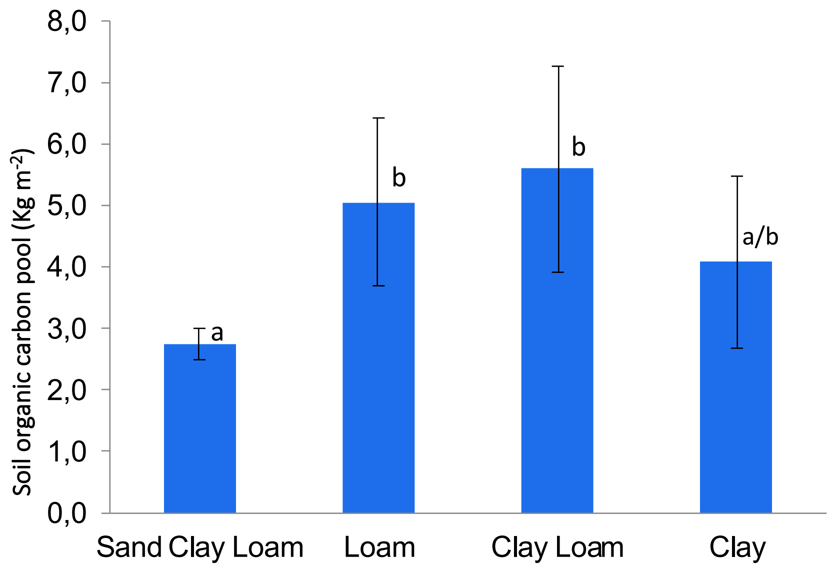


➢ The most representative area, having **higher *SOCP*** that ranges from **62 to 71 Mg ha^{-1}** (29.7 % of total area), is falling in the middle part which characterized by clay loam soil and dominated with cropland land-use in the catchment area.

➢ **Likewise**, areas of lower *SOCP* **(21-31 Mg ha^{-1})** overlapped with areas of bare soils that close to the urban area (city of Tanta) and characterized by sand clay loam soil and composed 19.7 % of the total area.

➢Conclusion

- The highest SOCP of 7.07 kg C m^{-2} was in clay loam soil associated with bare soil, while the lowest of 2.57 kg C m^{-2} in sandy clay loam soil associated with bare soil.
- Losing cropland showed highest increase from 1990 to 2015 with increasing urban encroachment by 15.3 %.
- The non-cultivated bare soils have been increased on small patches by 1.2 % as a result of land degradation in the Middle Delta. On the other hand, fallow soils increased with a noticeable percentage by 11.9 % (4127 ha).



- **Losing the arable lands to urbanization resulted in a decrease of 285.421 Gg C of SOCP.**
- **The emitted CO_2 resulted from losing the cropland equal to 1047.5 Gg CO_2.**

Nature Based Solutions

- Water Security requires an integration of traditional engineering solutions with nature-based solutions, which in essence is the conservation and enhancement of natural ecosystem or biophysical processes.

- Nature-based solutions, often referred to as “green infrastructure”, address water-related problems at multiple scales, and can work alongside gray infrastructure, resulting in reduced operation and maintenance costs of grey infrastructure and improved resilience of these systems.

➢ Objectives

1. Explore the value of nature based solutions for addressing water security challenges, both in developing and developed countries.
2. Discuss the benefits of the combined “green & grey” infrastructure approach in terms of water security, climate change mitigation and adaptation, human health and biodiversity protection
3. Discuss opportunities to mainstream investments in Nature Based Solutions for Water Resources Management

A common issue in rural areas in the south Mediterranean countries is the inefficient or completely absent sanitation, resulting in the contamination of the already scarce water resources and in insecurity in water and food supply.

The main purpose of the project is to provide a sustainable solution for polluted streams management in rural and remote areas under arid and semi-arid climatic conditions by utilizing natural-based treatment systems with domestic vegetation.

In the frame of the project, 8 institutions from 4 countries cooperated. It is intended to increase the public awareness about Constructed Wetlands (CWs) through intensive dissemination actions.

European Commission

ERANETMED

Technische Universität Berlin, Campus El Gouna, Dep. Water Engineering (public)

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University of Sousse, Institut Supérieur Agronomique de Chatt-Meriem (public),
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Mohammed V University, Faculté des sciences de Rabat-CERNE2D (public),
Agronomic and veterinary Institute Hassan II, Agronomy Department (public),
Institut Nationale de Recherche Agricole (public)

- Securing enough safe water for irrigation for food production.

- Protection of natural water resources from overexploitation (water reuse) and anthropogenic contamination.

- Improving life quality in rural areas and offering new jobs in the field of sanitation; supporting the local socio-economic growth; preventing urbanization.

- Additional economic benefits: production of agricultural and industrial raw materials for forage, personal care products, etc.

- **Contribution to climate change mitigation through C sequestration and minimum energy demands**.

- Turning arid areas into green areas - potential solution to desertification – improved productive and sustainable land management (SLM) practices.

- Increasing public, local/regional decision makers and other potential stakeholder awareness about natural treatment systems.

Unconventional water

Solution 1: **Afforestation using Treated Waste Water**

Using vegetation tolerant in high salinity and extreme environmental conditions.

In this way the polluted water source will be exploited further, considering that commercial products during treatment will be produced, thus increasing the socio-economic impact of the project and decreasing further the costs for treatment.
An innovative concept regarding the exploitation of the CWs vegetation will be developed, by examining several possible scenarios and by developing potential business models.

- The purpose will be examine in lab scale different domestic plant species and different CW configurations (e.g. horizontal or vertical subsurface systems, surface systems, different bed materials and depth, etc.) and to define the most efficient system for each region.

➢ Constructed wetlands CWs

- CWs are engineered systems designed to utilize natural processes within the ecosystem vegetation-soil microorganisms to achieve polluted water or WW treatment.

- A combination of physic-chemical processes and intensive biological activity in the soil, roots and plants transforms pollutants to non-hazardous byproducts or essential nutrients.

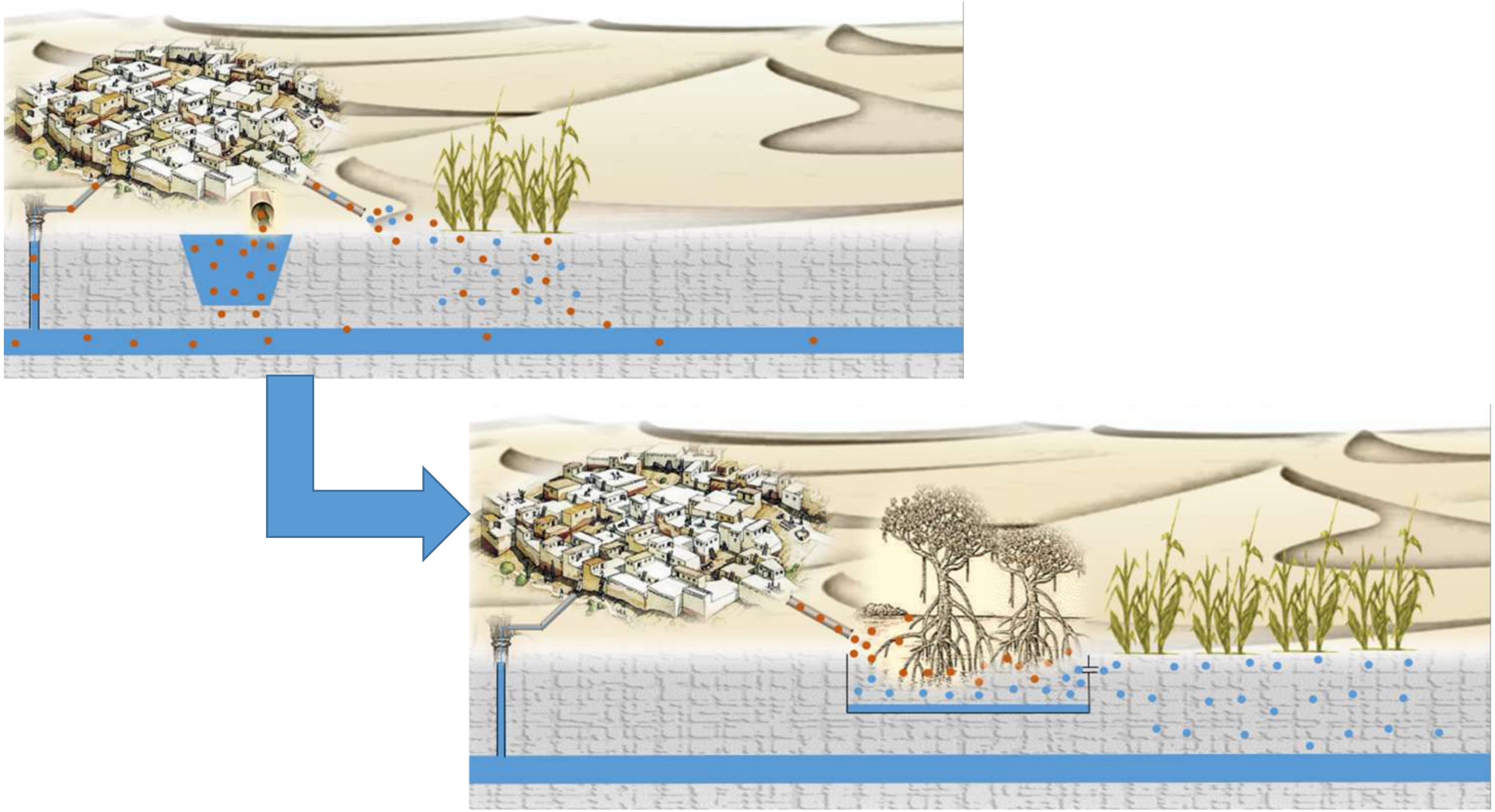
Natural wetlands have been used as WW discharge sites since long time, but the construction of wetlands for treatment started in the mid 1950's. CWs are proposed as a sustainable solution mainly because of the minimum energy input needed, relatively low construction and operational costs, easiness of operation and maintenance and good performance in most cases.

- Regarding energy requirements, it is suggested that CWs need 7 times less energy than activated sludge systems

Approach and Methodology

All materials for the construction will be purchased locally, to ensure sustainability.

The domestic vegetation was chosen based on: conservation of the regional ecosystems, resistance against extreme environmental conditions, remediation abilities and potential further socioeconomic exploitation.



Constructed wetlands

- Many wastewater treatment plants of small and medium communities are out of operation worldwide due to management problems and high operation and maintenance costs. On the other hand, constructed wetlands (CWs) proved to be a very reliable technology for wastewater treatment.

- **The advantages of CWs:**

combine simple,

low cost,

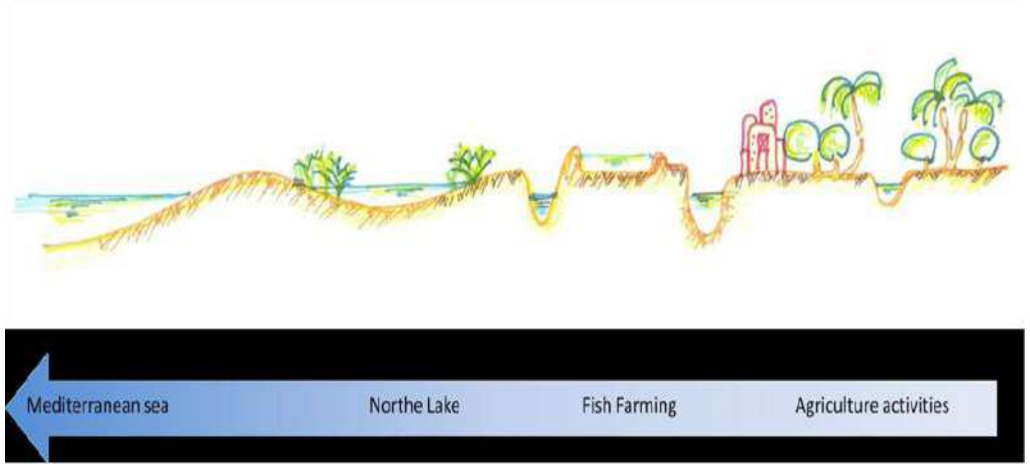
low-maintenance,

low energy,

reliable operation,

sustainable technology

high removal efficiency.



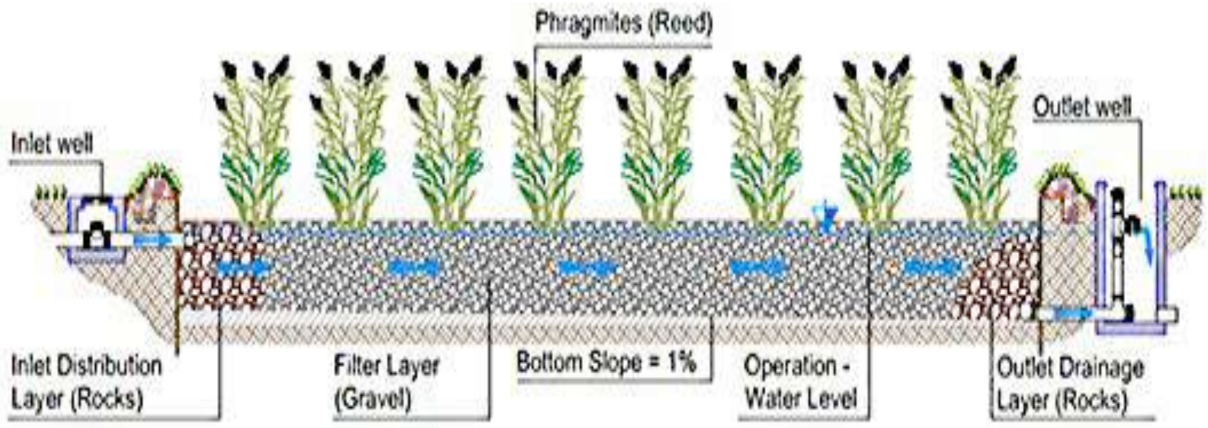
❑SEKEM farm

The system is field constructed for the treatment of sewage water and reuse for irrigation purpose. The area of the study is located in the East of Sharquiya Governorate. Thirty years ago, this area was a desert without any agriculture activity. It is now a well known farm which depends on groundwater and rains for irrigating the production of purely organic and pharmaceutical plants.

- One of the farm sewerage systems collects wastewater of schools and boarding school, offices, laundry and a few houses. The objective of this study is wastewater management and reuse for irrigating timber plantations, protecting the groundwater as well as integrating the design and construction using local materials. In addition, the purpose is to save water, protect the environment as well as public health.

Item	Units	Guidelines Standards
Conductivity	dS/m	< 2
Heavy Metals		
Cadmium	mg/l	0.01
Copper	mg/l	1.0
Lead	mg/l	5.0
Zinc	mg/l	1.0
Iron	mg/l	5.0
Fecal Coliform	MPN/100 ml	≤ 1000

- The work is to design and implement integrated real systems of wastewater treatment and reuse for the peri-urban and deprived / remote regions. A three chambers septic tank of $56m^3$ was constructed, followed by a $200m^2$ CW with a depth of 1 m. The outlet characteristics are given below. The quality of the treated wastewater is within the permissible Egyptian standards. No problems with odour exist while biological ways to control insects in a buffer tank are tested. Better agricultural production is expected.

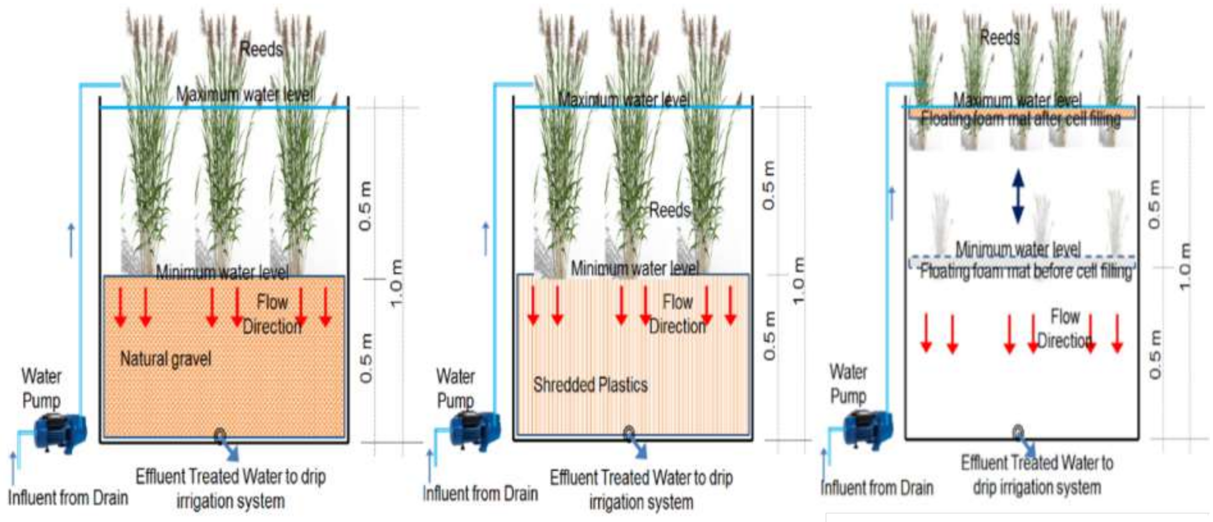


Low cost Drainage water polishing using microcosm constructed wetland units

- Three microcosm constructed wetland cells made from one m^3 recycled plastic tanks were investigated in its early stage operation to treat agriculture drainage water as a low cost unconventional irrigation water source.

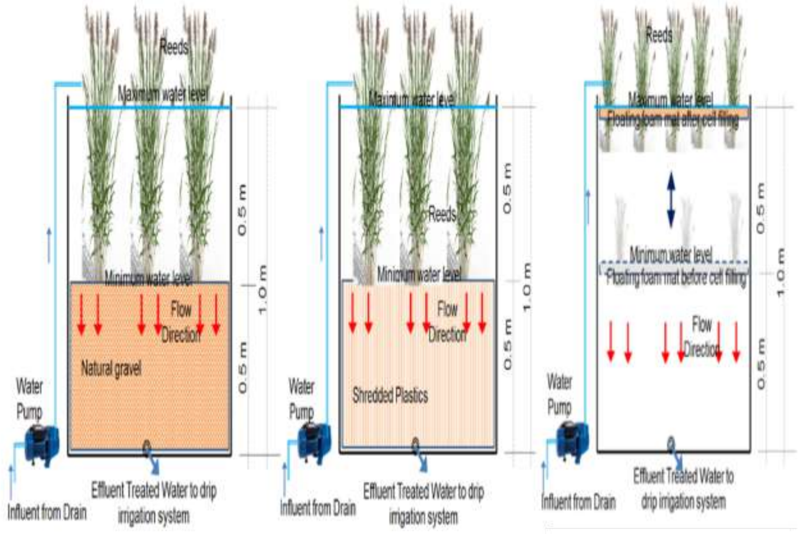
- Shredded Low-Density Polyethylene (LDPE) water bottles, natural gravel and foam floating reeds mats were used to produce 1 m^3 d^{-1} of treated water. The 3 cells managed to treat the drain water according to Egyptian standards of discharging drainage water at fresh water courses.

- The treatment efficiency of LDPE bed cell had the best removal performance followed by the gravel bed cell then the floating bed except for ammonia where floating beds acted better than the others.



- Microcosm CWs were introduced using recycled 1-m^3 HDPE tanks, filled with shredded LDPE water bottles or dynamic floating foam boards. Comparing with rooted gravel beds; these batch flow microcosms managed to treat the un-usable drainage water to the limit that it either could be mixed with the canals fresh water or directly used for crops production. Treatment performance of rooted LDPE bed microcosm was better than gravel bed followed by FTW microcosms. The elasticity and high porosity and surface area might be of the reasons of LDPE microcosm good treatment performance. Two investigated batch flow treatment cycles; 1-m^3d^{-1} and 0.5-m^3 d^{-1}managed to produce treated drainage water according to Egyptian standards.

Metal	(DRI, 1996-97) mg/l	Effluent mg/l	Removal Efficiency %
Copper (Cu)	0.019	0.0006	97
Nickel (Ni)	0.012	0.0007	94
Lead (Pb)	0.05	0.0072	87
Zinc (Zn)	0.085	0.0009	99
Chromium (Cr)	0.007	0.0002	97
Mercury (Hg)	0.003	0.0022	26
Cadmium (Cd)	0.012	0.0018	86

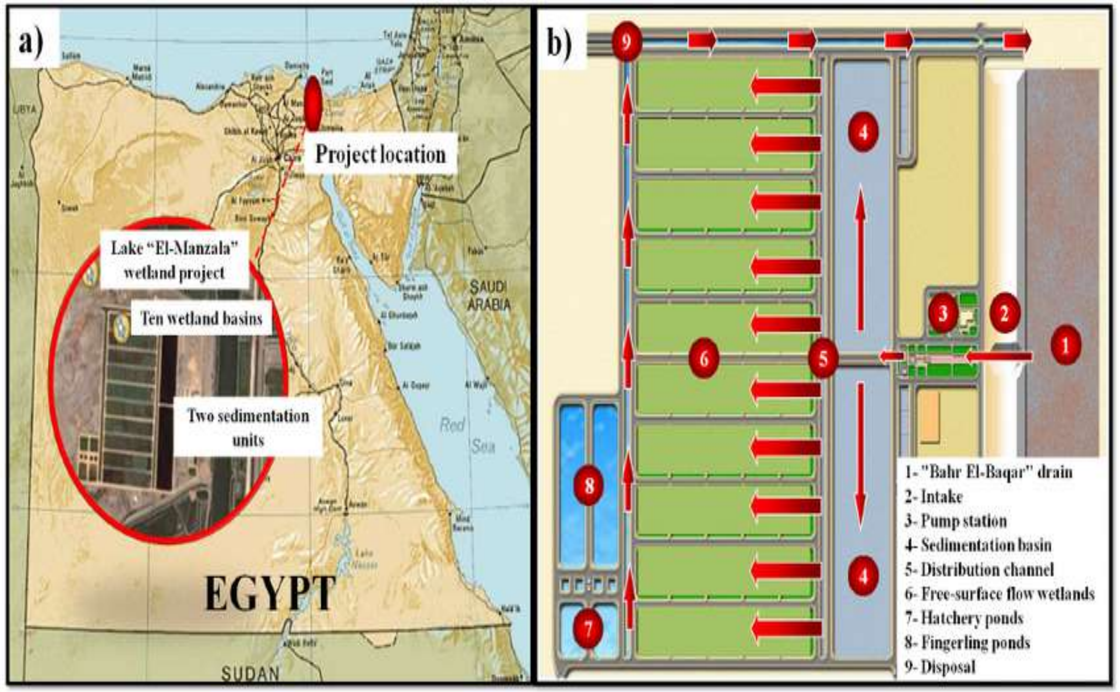


➢ El-Manzala wetland

Constructed wetlands are artificial transitional zones between terrestrial and aquatic system serving ecological functions such as fish, wildlife, waterfowl and aquatic plants. They also trap sediments and pollutants, cycle nutrients, and reuse treated water in agriculture.

- In Egypt, several drains are severely polluted by domestic, industrial, and agriculture sources. Bahr El-Baqar drain is one of those polluted drains that discharge to Lake Manzala. The Egyptian Environment Affairs Agency (EEAA) has initiated the design and construction of a 20 hectares engineered wetland, which will be operated by the year 2001.

The Global Environmental Facility/United National Development Program (GEF/UNDP) funds the project, with a main objective of treating 25,000 m^3 per day of the polluted drainage water as a demonstration for low cost technique for wastewater treatment to protect the ecology of Lake Manzala and Mediterranean Sea.



The constructed wetland system produces a diversity of treatment options to allow primary, secondary, and tertiary treatments. Expected effluent water quality is compared to irrigation water quality that reflected the suitability of reclaimed water via constructed wetlands for irrigation.

Stage	Channel	Type of Plant	Length (m)	Width (m)	Depth (mm)	Type Of Media (4-6 mm)
1	1	*Phragmites australis*	100	2.5	600	Flint
	2	*Napier grass*	100	2.5	600	Basalt
	3	*Phragmites australis*	100	2.5	600	Limestone
	4	*Phragmites australis*	100	2.5	300	Flint
	5	*Napier grass*	50	2.5	300	Basalt
	6	Papyrus	50	2.5	300	Limestone
2	1	seasonal crops	50	2.5	300	Flint
	2	seasonal crops	40	2.5	300	Basalt
	3	seasonal crops	40	2.5	300	Limestone
	4	seasonal crops	40	2.5	300	Flint
	5	seasonal crops	40	2.5	300	Basalt
	6	seasonal crops	40	2.5	300	Limestone

Conventional tree types that used in Egypt for effluent water of the constructed wetland

Phyx trees

Camphor trees

Caserina trees

Solution 1: **Afforestation using Treated Waste Water**

- **Paulownia *Aust* 003**

It adapts to a wide variety of climate, with temperatures ranging from a minimum of -10° C to an absolute maximum of 60° C. It grows in any kind of soil, even slightly clayey, Poor and degraded but deep. It has low water requirements: approx. 1.000 m^3 per year (Max. 40 liter per week in the hottest months, Min. 20 liter per week)

From studies conducted in the laboratory and the field, Zagazig, Egypt, through varietal selections, The ***Aust*** , Cod No. 003, has been obtained with characteristics that make it suitable for both the wood industry and biomass for energy purposes.

Rapid growth of the plant is just 4 years, with a minimum diameter of 35 cm and a height of about 10-15 meter.

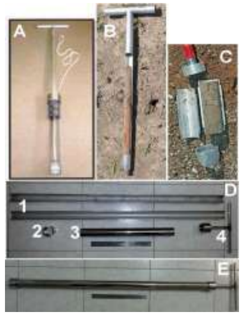
Rapid reboot capacity, after cutting, from the root system for a total of 6 production cycles in 25 years.

The plant can also grow in conjunction with other crops, especially low Plantations, better if leguminous. For example it can be planted at 5-6 m (inter rows), and easily allow the passage of large harvesting vehicles.

The WELL FORESTRY WORLDWIDE CARBON EMISSION has recognized the Paulownia clone ***Aust* 003** as a tree for the future of humanity, since it has high efficiency for carbon dioxide absorbent, and returning oxygen to the atmosphere.

Small scale field experiment

- ➢ **The obtained results of SOCP 445.65 Gg C compared to the surrounded regions of 320.5 Gg C with increase efficiency of 35 %**



sediment core samplers

The main message:

- Select the economy attractive plant type that motivate the local citizen/farmers and the policy makers to apply it

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Thank you for your attention