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Cause and Combat of Agriculture Land Desertification in Egypt Related to River Processes

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Abstract: Desertification is the extreme deterioration of land in arid, semi arid and dry sub humid areas due to loss of vegetation and soil moisture. The Nile water and the fertile soil along its banks created the perfect setting for the evolution of consecutive generations that existed along the Nile valley. About eight million acres of high productive lands were cultivated within the Nile Valley. This area presents 4 % of the total area of Egypt however, about 99 percent of Egypt population lives very close to the river itself, where most of these agriculture lands take place. Therefore agriculture land conservation is representing high priority to most of the country. A variety of natural and human factors are contributing to agriculture land desertification in Egypt. In Upper Egypt, agriculture land adjacent to the Nile River is under the threat of bank erosion. In nature lithology and its variation along the river length, channel slope, discharge and sediment, outside constrains and human intervention, force the river to grab a path that is sometimes not the one that the unhampered river would have taken. This process is resulted in the change of channel border position that leads to land degradation. Sand encroachment from the eastern and western desert is resulted in the alteration of river characteristics which accelerate the sedimentation activities near the agriculture land. This paper investigates natural and human factors that may have a bearing on the cause of desertification problem or represent a constraint to its solution. Field measurements and compilation of historical data are used to assess the possible causes and combat of each factor. On ground examples and some of the implemented mitigation measures are presented in this paper. Special type of trees is recommended to work as a barricade for sand encroachment. Bank protection of dumped stone and filter layer is used as a successful protection measure. The results of this study emphasize that thorough understanding of physical characteristics inside and outside the river system represent the main element in controlling the desertification processes.

Key words: River Nile • Desertification • Bank erosion • Sand encroachment • Protection measures

INTRODUCTION

The Nile Valley in Egypt is the main source of livelihood. This narrow strip around the river constitutes the most fertile lands. These lands as non renewable resources encounter many threats. They are ailing with increasing population growth and density, rapid urbanization and deteriorating of natural environmental resources. They are bordered by deserts on both eastern and western sides (see Figure 1 for locations). In addition many natural and human factors are contributing to the reduction of land productivity which is defined as land desertification. Soil erosion caused by water and/or wind is a major factor. This implies loss or removal of fertile soil through the action of moving water and wind. Salinity triggered by excessive irrigation practice decrease soil fertility and lowers consequently land productivity. The interaction between river hydrodynamics and human intervention has influenced the quality of the agriculture lands around the river. For examples, heterogeneities, vegetation and bank protection works for cities and towns can force the river border to alter its position. The negative impact of this alteration is land erosion of agriculture land adjacent to the river. The positive impact is to gain more land in the other side of the river by the help of people (intervention) but the quality of the lost land and the gained land is totally different and contributing to land desertification.

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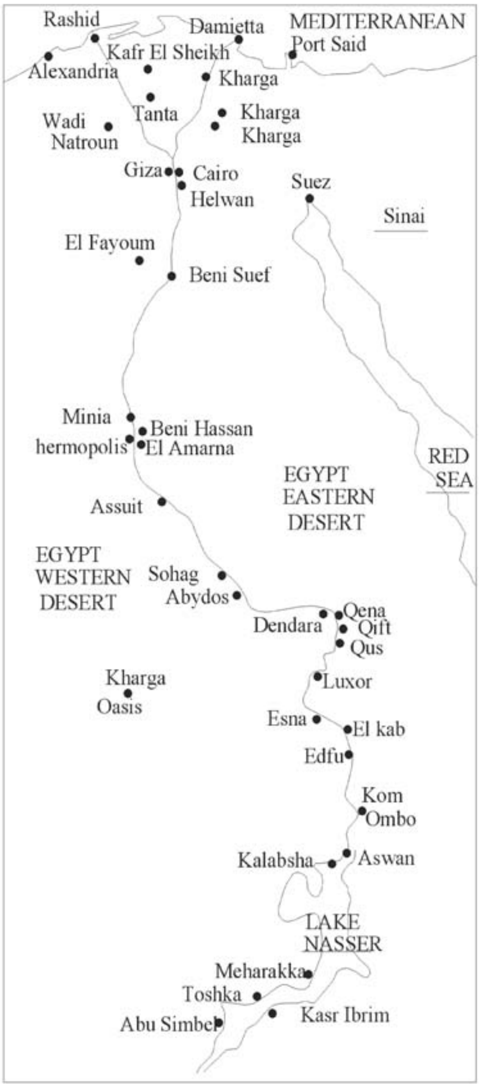

Fig. 1: location map

Dredged materials from river bed to satisfy navigation requirements are reused in agriculture purposes. The dredged materials may contain great potential of contaminants. Aeolian sand encroachment on the Nile was known for decades. However, the problem is aggravated due to the climate vulnerability and increased human activities. The aforementioned factors are investigated in this paper. Other factors are spotlighted from the literature point of view. The main objective is to evaluate the most common factors contributing to agriculture land desertification. Combating measures are used to mitigate some of these factors. New measures are also recommended. Different sets of data are used to achieve the study objectives.

Review Of Literature: The international community recognized desertification as major economic, social and environmental threat for many countries. Numerous internationally sponsored research addressed desertification. Irshad et al., [1] concluded that deterioration of soil and plant cover has adversely affected nearly 50 percent of land areas as the result of human mismanagement of cultivated and range lands. Also, about 4 billion hectares or 1/3 of the earth's land surface is threatened by desertification, over 250 million people are directly affected and one billion people over 100 countries are at risk. The united nation convention to combat desertification indicated that twenty four billion tons of fertile soils disappear every year (www.unccd.int). About 23 and 37% of the world cultivated lands are saline and sodic, respectively [2]. According to Kovda and Szabolec [3] nearly 10% of the total land surface is covered with different types of salt-affected soils. In Egypt, Shalaby and Tateishi [4] investigated the change in the land cover for the Northwestern Coastal Zone of Egypt. Remote sensing, GIS and field measurements are used in their study. They concluded that severe land cover change had taken place as a result of agricultural and tourist development projects. These changes in land cover led to vegetation and water logging in part of their study area.

The prevailed surface irrigation techniques combined with the overuse of irrigation water exert pressures on the drainage system. This problem when combined with the dominant heavy textured alluvial soils and seepage from the conveyance canals lead to water logging in many areas of the old Nile Valley which in turn lead to increase in soil salinity and in certain areas soil sodocity was developed [5]. El Gabaly- Desert Research Center, (DRC) as cited in [5] reported that salt affected soils represent between 35-43 % of the total areas in the old valley. This indicates adverse impacts on soil productivity between 30-35%. To overcome the salinity problems, integrated solutions are required, such as construction of drainage facilities, improved maintenance of irrigation infrastructures, on farm watercourse improvements, precision land leveling and incentives for land reclamation. Rapid growth of urban and residential encroachment to agriculture land around Nile Valley is creating complex challenges for farmers and neighboring communities. Scraping the soil top surface layer of 1-2 meter for the manufacturing of bricks is contributing to desertification process [5]. Researchers also addressed sand encroachment in Egypt Sahara, Hereher, 2010 studied wind action in the western desert of Egypt.

Maximum sand drift potential was observed at the southern edge was 40 m^3/m/year. These hazards extended to road and railways connecting oases to the Old Nile Valley. He indicated that sand encroachment hazards also threatened the course of the Nile River at Menia and Assuit in the Upper Egypt as well as Lake Nasser upstream Aswan High Dam (AHD). These hazards limit the productivity of the cultivated and reclaimed areas in the western fringes of the Nile Valley in Upper Egypt. Zahran and Willis, [7] reported efforts to combat shifting sand along El-Sheikh Zayed irrigation canal which convey fresh water from Lake Nasser to the newly reclaimed lands in Toshka project in the South Valley of Egypt. Four plants were cultivated Acacia saligna, Prosopis juliflora, Tamarix aphylla and Casuarina equesitifolia. These plants were irrigated by brackish groundwater using drip irrigation. It was concluded after two years that shelterbelt plants with native plants is efficient to control sand shifting in the Egyptian deserts. These phytobelts which enhance the deposition of the Aeolian sand at a reasonable distance from the target areas like irrigation canals or rivers were recommended for large scale applications. Soil surveys carried by the Ministry of Agriculture showed that there is a great need for land improvement and soil conservation to combat a reported decrease in the productivity of the land in the Nile Delta and Valley (old and old new lands). In 1971, the Ministry of Agriculture was vested with overall responsibility of carrying deteriorated land improvement techniques in Egypt resulted in an increase in the agricultural production exceeding 30%. In order to combat desertification, actions were proposed and enforced. For example, legislations were passed in the year 1983 and again in 1985 imposing serious penalties for scrapping of the top soil material for manufacturing red brick. This caused virtual halting of such practices. Urban encroachment on fertile lands prohibited and city limits were marked. However, urban encroachment still continues (at a much lower rate).

Causes Of Desertification

Soil Erosion By River Flow: In the Nile valley the cultivated area constitutes narrow strips of lands with an average width of 10 km surrounded by deserts on both eastern and western sides. The operation of AHD since 1968 has resulted in preventing yearly sediment supply to agriculture land along the river sides. This threatened the fragile balance previously achieved by yearly flooding and sedimentation processes. As a fluvial system, river must move sediment, so it looks for a new source to erode which is the soil of river banks and beds. Figure 2 was surveyed at Ekhsas (60 kilometer south to Cairo) indicates major changes between 1962 and 2003. The width of the cross section had increased which indicated bank erosion; Meanwhile, aggradation took place. Erosion or removal of soil material occurs when the soil displacing forces exceeding the resisting forces. This erosion may occur by the removal of individual particles of soil or by the removal of large mass for large scale failure. Field reconnaissances were conducted, 1981, 1989 and 2005 [8-10] to define the most common causes of land erosion along the Nile valley.

The main forces that erode soil material were hydraulic forces (see photo 1 and Figure 3), geotechnical instabilities and a combination of both. The flow adjacent to the agriculture land exerts a stress that exceeds the critical shear stress for soil erosion and therefore the movement of the particles is initiated. Fluctuation of river water resulted in pore water pressure increase in the soil mass during the falling time and this increases

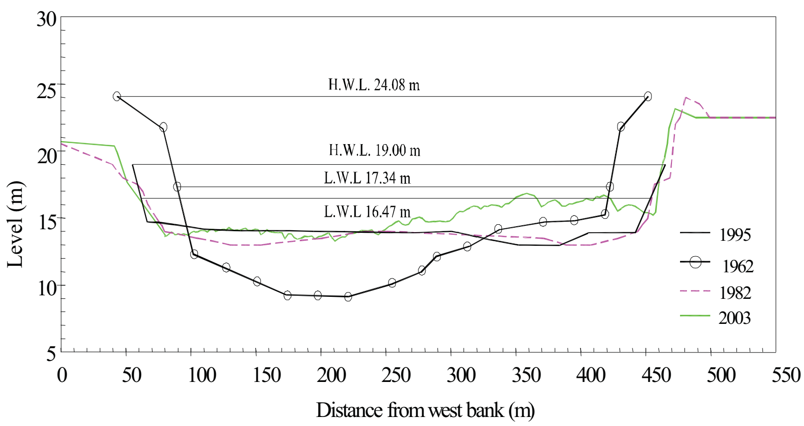

Fig. 2: land erosion as a result of river processes after the construction of AHD at Ekhsas location

Photo 1: Composite land failure as a result of toe material removes (hydraulic factors)

Photo 2: land erosion due to seepage effect

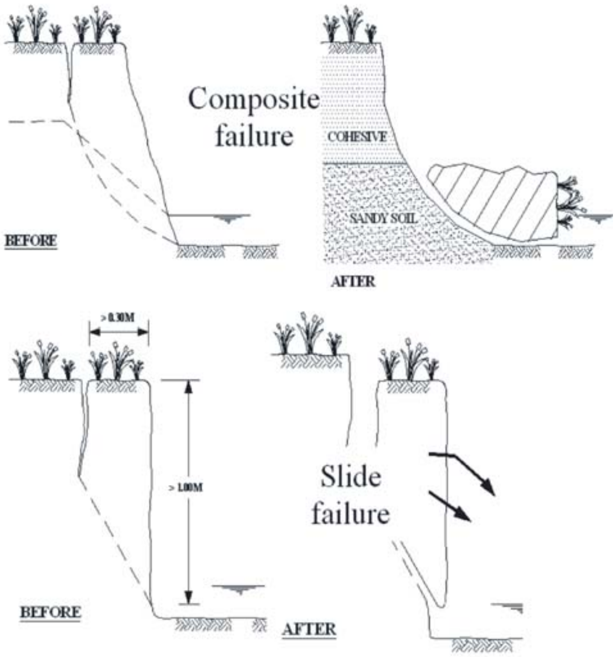

Fig. 3: Land erosion mode of failures

the potentiality for piping and for slide-type failures (see Figure 3). Stability of the river bank is dependent on the soil properties of the bank material. Failure occurs when the shear strength of the soil is insufficient to resist the seepage and gravitational forces causing downward displacement of the soil mass. (see photo 2). Moreover, change of water level has in turn direct impact on groundwater table. During the river low flow period, the ground water starts to seep to the river. During the high period however, the water recharges the soil. This process changes the soil properties and depending on the soil type the failure occurs. Movement of water through cohesive soils (Silt or clay) decreases the cohesion between the particles and reduces their strength. Cycles of wetting and drying of the soil are also extremely critical as they lead to block slumps, especially if the soil contains cracks or holes dug by animals or birds. The other type of erosion was associated with a soil composed of loose material (non-cohesive). This type of soil undergoes steady progressive erosion (see photo 3). The geotechnical aspects involve soil characteristics, river side height and slope adjacent to agriculture land. Increase of soil height results in an increase of shear stress at the sliding plane until it exceeds the maximum allowable shear. This will lead to a wedge or block slide and soil failure.

Photo 3: Steady progressive soil erosion reveals the root of palms

Photo 4: Low land heightened by dredged material in Damietta branch

Reuse Of Dredged Material For Agriculture: Rehabilitation work was undertaken in river Nile by the River Transport Authority (RTA) since 1999 to enhance river transportation. This involved the dredging of bed materials to satisfy water depth of 2.3 m from places where deepening is required. The dredged materials are reused by farmers to heighten their agriculture land to avoid inundation during high stage of the river. The farmers are unaware that these materials may have great potential of contaminants. Their concern is only concentrated that these materials will enable them to cultivate their land the entire year. Samples of dredged material (photo 4) are collected from 10 locations along Damietta branch, March 2008 to assess the extent of heavy metals in the soil due to dredged materials. The analysis indicates that soil type is sand which means light texture with high permeability. The PH values for the row dredged materials vary from 7.53 and 8.58 which indicate that the soil is neutral with the tendency of alkaline in one location. This problem can be combated by using organic fertilizer to produce CO_2 to decrease the PH value to the range 7-8.2. This will avoid occurrence of alkalinity problems which will lead to decrease the soil permeability. It will also prevent or decrease the solubility of heavy metals and subsequently avoid their risk. The use of O.M is important to increase the soil fertility which is negatively affected due to the continuous cultivation. The electrical conductivity (EC) values are coinciding with the value of the non-saline soils which are ranged between 0-2 ds/m except for one location.

Table 1 indicates the content of heavy metal in the collected samples. The average of the samples is compared to permissible values of agriculture land use, 2002 (see Figure 4). The figure indicates that the samples are suffering from heavy metal contamination however; the analysis indicates total content of heavy metal which includes soluble and precipitated forms. As the PH values of the soil are neutral to alkaline, which indicate that all the heavy metals are in insoluble forms. The problems of those metals may be appeared in case of decreasing PH value to the acidity range. As a factor of safety those soils can be cultivated by wood trees, palm dates, fruits without any environmental impact. Vegetables eaten fresh may not be cultivated in such soils.

Table 1: heavy metal extent (mg/kg) in dredged material in Damietta Branch (March 2008)

No.	Aluminium Al	Arsenic As	Barium Ba	Cobalt Co	Chromium Cr	Copper Cu	Zinc Zn	Iron Fe	Manganese Mn	Nickel Ni	Lead Pb	Strantium Sr	Vanadium V
1	20844	N.D	156.0	42.8	25.6	110.8	45.6	10408	275.2	57.20	N.D	44.40	34.8
2	20656	N.D	324.8	80.8	41.2	127.2	36.8	8364	216.8	80.80	N.D	80.40	21.2
3	25408	N.D	164.0	69.6	99.6	129.2	52.4	11576	332.8	80.40	N.D	137.20	56.4
4	49760	N.D	204.0	66.0	103.6	253.6	75.2	23080	539.6	90.40	N.D	112.80	246.4
5	28496	N.D	220.4	94.0	40.0	226.8	80.4	12900	297.2	70.00	N.D	120.00	77.2
6	50120	N.D	173.6	94.8	92.0	211.2	99.6	29856	607.2	88.84	N.D	105.60	261.6
7	49200	N.D	215.2	70.8	84.8	197.2	86.4	23984	539.2	69.20	N.D	131.60	265.6
8	54400	N.D	173.6	78.0	58.4	140.8	98.0	35416	788.4	91.20	N.D	102.00	326.4
9	34252	N.D	165.6	65.6	42.4	123.6	77.6	24752	539.2	84.40	N.D	155.20	152.0
10	51240	N.D	436.0	67.6	52.0	165.2	81.6	25352	614.8	86.40	N.D	98.40	283.2
avr.	38438		223.32	73	63.96	168.56	73.36	20569	475.04	79.88		108.76	172.48

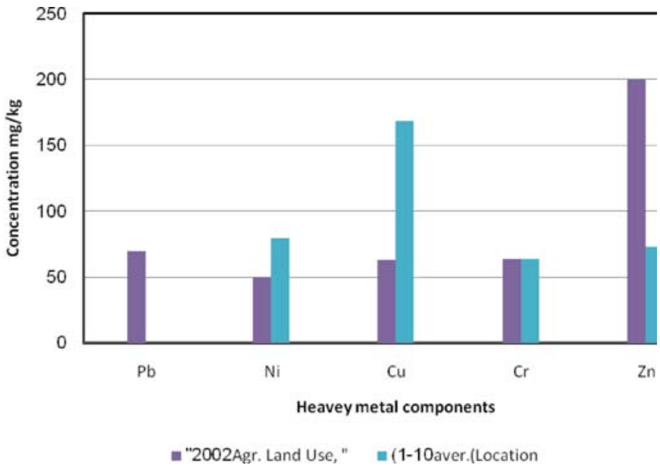

Fig. 4: Comparison of heavy metal content in bed material in Damietta branch to Canadian Agr. Land Use standard, 2002

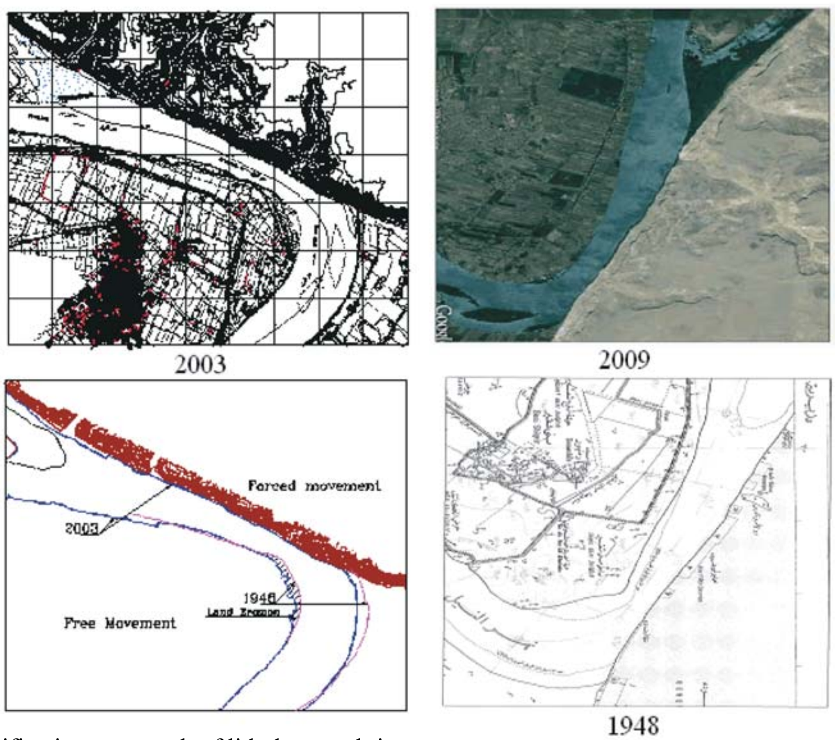

Fig. 5: Soil desertification as a result of lithology and river processes

River Processes And Lithology: The boundary of a river (plan form) is controlled by, slope, bankfull discharge and sediment characteristics. External factors that control river plan form are, type of bank protection, vegetation cover and urbanization along river banks. The confinement of lateral shifting by external controls may force the thalweg line to switches from one side of the river to the other. This process may result in altering the location of erosion and deposition throughout the cross section. This process is highly activated near the bends. Three degrees of confinement are defined [11] according to the status outside the border of the river. The first degree is the free outside movement, which is usually associated with broad flood plains consisting of relatively erodible material. In this type, the river bends follow the curves of the valley, so that, each river bend includes a promontory of the parent plateau.

The second type is the limited bend. In this type, the bend cut into solid rock or hard strata in deep gorges and exhibit meandering pattern similar to that of rivers in flood plains. In this type of bends, the banks of the channel are composed of consolidated parent material that limits the lateral erosion. The third type of bends is the forced bend. In this type the channel is highly restricted from external movements. Figure 5 illustrates bank line restriction only on the right border by the existence of mountain force the river border to follow its shape, however, the other border experience free movement resulted in land erosion.

Therefore, it can be concluded that the internal and external controls represent major factors contributing to land desertification. However, the rates of lateral shifting along the Nile River are highly variables and depend on many factors such as the magnitude and frequency of flow, the type of border material (loose or consolidated), the location in the bend at which the shift is measured and outside constrains (lithology and valley plateau). It should be mentioned that the seriousness of these factors dwell in the high interaction between them in addition to highly motivation exerts by human interventions for river development. However, this process can be managed or limited through complete understanding of river processes and morphology and the application of suitable regulation work.

Sand Encroachment: It was cited in Yehia, [12] that "The source of sand is located further north and that the predominant wind is oriented north-south to northwest-southeast and it deposits its load near Lake Nasser or into it. The sites of deposition are controlled by the variations in local relief (rocky hills and ridges) that deviates the predominate wind and/or break it into multi-oriented components and reduces their velocity, enhancing thus deposition of sand. The area is being permeated by moving aeolian sand. Its source is located further north related to Abu Muharik dune field and the narrow dune belts that parallel the western side of the Nile Valley intermittently between Beni-Suef and Aswan. Sand drift represented by sand sheets was not recognized in substantial areas of the region". O'Brien and Rindlaub, [13] derived the following relationship between sand discharge and wind velocity based on filed data

$$g_s = 0.036u^3 \qquad (1)$$

Where,

g_s = Sand discharge in pounds per foot of width per day.

u = The wind velocity in feet per second at a height of 5 ft above the surface.

This relationship is valid for a sand of 0.2 mm

Bagnold [14,15] conducted measurements in the Egyptian Western Desert and wind tunnel. For sand with a mean diameter of 0.25 mm, the sand discharge in metric ton per meter width per hour was:

$$g_s = 5.2 \text{ X } 10 \bullet^{4} (u-u_1)^3 \qquad (2)$$

Where,

u is the wind velocity in centimeters per second at 1 m height,

u_1 is the threshold velocity at 1 meter height which was found equal to 400 cm/sec

In wind tunnel, the rate of sediment transport for sand grains from 0.1 mm – 1.0 mm in diameter can be expressed by

$$g_s = b\left(\frac{d_s}{d_{so}}\right)^{\frac{1}{2}} \frac{p}{g}\left(\frac{t_o}{?}\right)^{\frac{s}{2}} \qquad (3)$$

Where,

g_s is the weight of the sand moving along a lane of unit width per unit time

d_s/d_{50} is the ratio of mean size d_s of a given sand to the mean size d_{50} of a standard sand taken as 0.25

The coefficient b is 1.5 for uniform sand, 1.8 for naturally graded sand, 2.8 for sand with a very wide range of grain sizes.

Despite the limitation of equation 2 to 0.25 mm sand, equation 2 is the most suitable equation since it was derived based on real data in the western desert of Egypt. The equation indicates that only wind speed greater than 4 m/sec will lead to the movement of sand. Table 2 shows the quantity of sediment discharge corresponding to different wind speeds.

Western Bank of the Nile River in the Governorate of Aswan is largely exposed to the wind-blown sand of the western desert. It is estimated that 39 kilometer of western bank of the Nile River within the governorate of Aswan has no vegetation covers or not more than 100 meters of vegetation covers. That is, river west bank is in direct contact with desert sand. The wind atlas provides essential information which can be utilized to investigate the potential of desert sand that may be dumped annually in the Nile River (see Figure 6 for wind speed map).

The atlas which is based on monitoring stations throughout the country indicates that the gulf of suez has the highest wind speed followed by the governorate of Qena, then, El Minia. Although, the wind speed in the domain of Aswan Governorate is not the highest as indicated in the map since it ranges between 4 and 5 m/sec (14.4 km/hr- 18 km/hr), the west bank of the Nile River in the governorate lacks enough vegetation cover and

Table 2: sand discharges related to different wind speed

Wind Speed (m/s)	Sand Discharge (t/m/hr)	Wind Speed (m/s)	Sand Discharge (t/m/hr)
4.17	2.407407	6.39	7089.102
4.44	45.65158	6.67	9860.741
4.72	195.8916	6.94	13274.36
5.00	520	7.22	17396.82
5.28	1084.849	7.5	22295
5.56	1957.311	7.78	28035.78
5.83	3204.259	8.06	34686.02
6.11	4892.565	8.33	42312.59

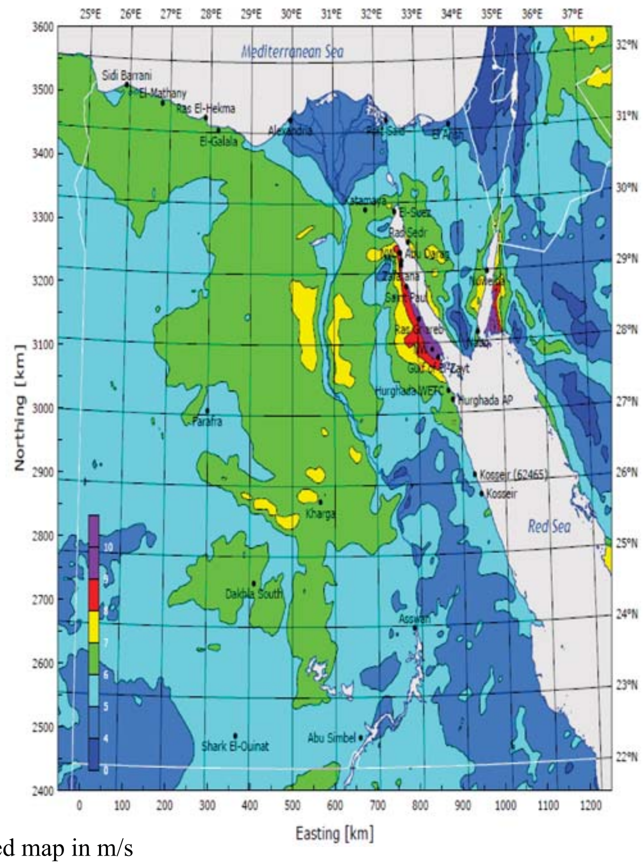

Fig. 6: Egypt wind speed map in m/s

the right bank is in direct contact with desert sand as indicated previously. Comparing wind speed obtained from the wind atlas of Egypt with values of sand discharge in Table 2, it can be concluded that during a wind speed of 5m/s (18 km/hr) up to 520 t/m/hr of sand may be dumped on the agriculture land near Aswan. The final figure may be determined depending on the wind duration and vegetation cover. It is highly recommended to establish monitoring stations near Aswan in order to come up with precise number for sand discharge into the River Nile. This monitoring might include measurements of bed load, wind speed and direction, effect of vegetation cover on wind speed and sand trapping.

Combat Of Desertification: To effectively control land desertification, it is essential to understand cause of desertification in order to select the appropriate solution, otherwise, large investments of time and money may potentially be wasted in projects that fail or require frequent maintenance. To combat soil erosion as a result of hydraulic and geotechnical factors, stone slope protection with a filter layer is used for land stabilization [16]. Stone slope revetments are structures running parallel to the channel. They are mostly combined with embankment for flood control and fixation of the low water channel. It should be noted that the long life and sustainability of the protection work is mainly depend on

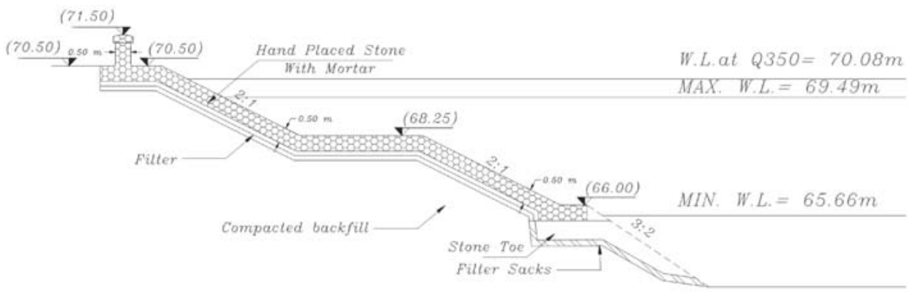

Fig. 7: Typical design for soil protection

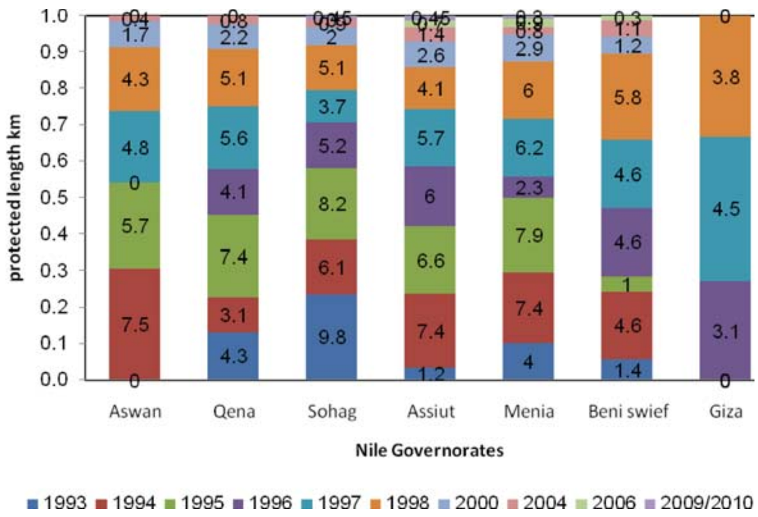

Fig. 8: Protection lengths distributed to Nile directorates

the follow up and maintenance process after construction. The typical shape of stone slope revetment is shown in Figure 7. Stone is dumped to form a toe following a smooth bank alignment and a minimum of irregularities in order to avoid flow disturbances that can lead to local scour and subsequent undermining. Stone is then hand placed on the slope with uniform thickness to an elevation one meter above the high water level. A side slope not steeper than 2 horizontal to 1 vertical will normally be stable. A thickness comprising at least two layers of overtopping stone should be used on the revetment slope. For area of high banks, high groundwater levels and complex soil profiles, mathematical models should be applied to guarantee the overall safety factor of the protection design through stability analysis. Many levels for the protection according to the purpose are applied to cover the entire stages through a year including min., max. and future discharge regimes.

A number of projects for soil protection works were implemented during the period between 1993 and 2010. Figure 8 indicates a protected length of about 208 km distributed to different Nile directorates.

Special type of trees can be cultivated (Acacia saligna, Prosopis juliflora, Tamarix aphylla and Casuarina equesitifolia) to work as a barricade for wind blown sand to agriculture land. To minimize land desertification related to lithology and river channel processes, a thorough understanding of the physical characteristics of the river system and the surrounding environment should be known. Field investigations, measurements and surveys, laboratory tests and mathematical modeling are tools can be used to control and minimize the land desertification processes.

Conclusion And Recommendation: This paper investigates the main causes of agriculture land desertification. The investigation focused on the causes related to Nile River and the agriculture land of the Nile valley. The study concluded that the major causes are hydraulic and geotechnical factors related to river flowing water. The main combat is soil protection by dumping stone with filter layer. About 208 km of protection work is implemented between 1993 and 2010. The interaction between river processes, lithology and human intervention force the river boundary to follow certain direction contributing to soil desertification. Careful studies should be conducted using different tools (field investigation, models and river regulation work) to minimize the adverse impact of lithology on land desertification. Sand encroachment is amounted to 520 t/m/hr near Aswan. Special type of trees can be cultivated (Acacia saligna, Prosopis juliflora, Tamarix aphylla and Casuarina equesitifolia) to work as a barricade for sand encroachment to agriculture land. The study recommended that wind blown sand monitoring station should be implemented near Aswan The analysis of ten samples of the reused bed material in the agriculture lands along Damietta branch indicates that soil type is sand which means light texture with high permeability. The PH values vary from 7.53 and 8.58 which indicate that the soil is neutral with the tendency of alkaline in one location. This problem can be combated by using organic fertilizer to produce CO_2 to decrease the PH value. The entire samples confirm the content of heavy metal contamination. The analysis indicates total content of heavy metal which includes soluble and precipitated forms. As the PH values of the soil are neutral to alkaline, which indicate that all the heavy metals are in insoluble forms. The problems of those metals may be appeared in case of decreasing PH value to the acidity range. As a factor of safety those soils can be cultivated by wood trees, palm dates, fruits without any environmental impact. Vegetables eaten fresh should not be cultivated in such soils. Compiling different conclusions, the study can recommend that workable solutions are needed to overcome desertification problems. These induced technical, system level and policy level interventions. Incentives should be activated for people education to adjust agriculture practices and also for new land reclamations.

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