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RESEARCH ARTICLE OPEN ACCESS

AGRONOMIC MEASURES FOR TAMING SAND AND DUST STORMS IN KUWAIT AND SOUTH OF IRAQ

A.M. Bahman[1*], Azza Al Jassim[2], Manar M. Mansour[3], Mohamed Nassar[4] and Mohammed Sadeqi[5]

[1]Senior Agricultural Advisor, Kuwait Fund; [2]Project Manager, UN-Habitat, Kuwait office; [3]First Specialist Engineer, Kuwait Fund; [4]Project Manager, UN-Habitat, Iraq; [5]Senior Engineering Advisor, Kuwait Fund

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****Corresponding author: Bahman. A.M.***

ABSTRACT

Desertification can be effectively mitigated by implementing many measures to reduce the formation of sand and dust storms. This article focuses on agricultural activities for restoration and rehabilitation of areas most prone to wind erosion in Southern Iraq, based on a scientific approach within the "improved resilience to transboundary sand and dust storms in Kuwait and Iraq Project", financed by Kuwait Fund. Implementing entities of the on-going project are the United Nations Human Settlements Programme of Kuwait and Iraq, with Kuwait institute for scientific research as the main scientific arm. In addition to other partners in Iraq, i.e. ministry of agriculture, ministry of water resources, universities of Thi-Qar and Al-Muthanna. The project emphasizes on infrastructure works and monitoring, consultancy services and capacity building, planning and management. Shelter belts considered as the most effective nature-based technique for mitigating soil stabilization within the project area, provided the availability and supply of required water through construction of suitable engineering designed irrigation systems, for the movement of water from the East Euphrates drainage system to the priority area. The scientific essence of this project enriched the knowledge and understanding of the nature of sand and dust storms that originate in this part of the world, and lead to recommendations and mitigation measures, with subsequent intervention plans by using suitable approaches to reduce sand and dust storms formation.

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INTRODUCTION

Kuwait Fund for Arab Economic Development (KFAED) has provided a grant to the office of the United Nations Human Settlements programme in the State of Kuwait (UN-habitat), for the participation in financing the *"improved resilience to transboundary sand and dust storms in Kuwait and Iraq* project". The Grant is administered by UN-Habitat in accordance with UN rules and regulations.

The description of the project is summarized as follows:

The project aims to improve the resilience of cities and communities in Kuwait and Southern Iraq to transboundary sand and dust storms, through improved knowledge and understanding of the conditions that originate sand and dust storms and the impact that results from them, restoring the ecosystem in the origin areas of sand and dust storms in southern Iraq, and enhancing the capacity of authorities and communities in southern Iraq to adapt to the impact of desertification and mitigate the causes of sandstorms resulted from climate change.(1)

The project includes the following main Components:

- **Infrastructure Works and Monitoring Equipment:** supply, construction and field Implementation of the interventions used to mitigate the impacts associated with sand and dust storms, the restoration of the natural ecosystems, and the supply and installation of monitoring equipment.
- **Consultancy Services and Capacity Building:** recruitment of professional experts and entities through delivery-based contracts to aid in the identification, study and analysis of the hotspot areas, using science and nature-based approach to develop the interventions necessary to implement the project components, and capacity building for local partners.
- **Project Planning and Management:** management and operation of the project to ensure the implementation of the project and the fulfillment of its activities.

The project is expected to be completed by the end of 2026. This article focuses on a specific project activity related to rehabilitation of agricultural infrastructure such as irrigation systems, cultivating and planting trees and shrubs in designated areas. The main information and data used in this article have been obtained and derived from many sources, i.e. the grant agreement (1), progress reports and action plans provided by UN-Habitat (2), in cooperation and coordination with the UN-habitat's Barsa office and other entities in Iraq. In addition to Kuwait Institute for Scientific Research (KISR)(3) reports,

as the implementing partner and the scientific arm to the project, and others.

Background: Hotspot areas are locations where sand and dust storms originate from or near surroundings. Great proportion of the storms in Kuwait are due to transboundary trajectories from hotspots area in Southern Iraq located at 250 Km from the Northern borders of Kuwait [(3)]. The operational works of the project began in January 2023, administered by UN-habitat's Kuwait office, covering some specific activities, such as conduct consultation meetings with relevant local authorities to share the recommendations derived and develop storms prevention plan for the targeted or priority areas, which cover about 132 Km^2. Priority area is the area most prone to wind erosion and most relevant for formation of sand and dust storms. The project area can be described, in general, as characterized by conditions conducive to wind erosion, flat topography lacking wind barriers, predominant soil textures of very fine particles, very low level of annual precipitation, high temperature, and spare or absence of natural vegetation. KISR's studies of remote sensing satellite monitoring (Multispectral Satellite Images) provided a large amount of useful information related to agricultural and geological studies in areas of interest, with precise details of vegetation cover and water bodies, in addition to soil contents and biophysical parameters of the study area. Essential baseline data were collected, such as soil maps, meteorological information, vegetation cover, wildlife, hydrology, and sand movement behavior. The agronomical component of this project is considered a major mitigation measure for the restoration of ecosystem in the area, where sand and dust storms (SDS) are mainly formed. The main direct beneficiaries of the project are both population of Kuwait and those of Southern Iraq, while indirect beneficiaries are the population living in the Gulf region, and this project is an example of cross-border cooperation.

Agricultural Activities: Meetings were held between the stakeholders with the local community representatives, to discuss many issues related to water delivery to the priority area through existing and the new main irrigation water ways. Discussion also covered efforts for small scale irrigation channel rehabilitation, in addition to plans for grain crop cultivation. Other meetings were conducted between KISR and the Iraqi Universities (Al-Muthana and Thi-Qar) focused on soil analysis comparison details, and the outcomes were the adoption of appropriate soil sampling systems and analysis methods. A map was developed to illustrate the priority area, along with locations for operations, such as land rehabilitation activities including dune fixation and the installation of proposed biological and solid windbreaks and the selection of the sites within the hotspot area. Topographical survey was conducted to acquire an elevation model to facilitate the detailed layout and engineering design of the irrigation supply system. This system is stretched from the Eastern Euphrates's channel to the priority area and encompasses the routing of primary, secondary, and tertiary canals, in addition to the placement of pumping stations and flood gates. The detailed layout and engineering design of the irrigation system were initiated based on the findings of the final survey report. Secured commitments for water transportation and land rehabilitation were reached with local authorities, i.e. Muthana governorate and ministry of water resources. This includes facilitating the transfer of drainage water to the priority area for agricultural purposes. The positioning of pumping stations ensures that irrigation water can flow to the shelter belts. The slope of the new canal is almost zero, the water flow is mostly dependent on 4 water pumps of $1m^{3/S}$ and the flood gates to regulate the movement as needed.

Topographical Survey: Results of topographical studies indicated a higher elevation in the Northern region of the priority area, facilitating the flow of irrigation channels from North to South. The topographical works included detailed survey, i.e. soil mapping and elevation for irrigation water system, technical design for the main phases of the project and tendering, procurement and awarding contracts. Pre-construction and construction phases I and II were completed, with a combined length of about 1719 Km of irrigation water ways, including new irrigation canal, in addition to supply, installation and commissioning of electrical water pumps, with all required accessories. Also, the works include rehabilitation and extension of existing irrigation channels towards the hotspot areas. The irrigation waterways comprise 16 Km, 263 Km and 1440 Km of primary, secondary and tertiary canals, respectively. A comprehensive digital map of the area has been established, ensuring a high-resolution representation of surface elevation and features. Solid windbreaks of about 420 Km of which 262.5 Km for Phases I and II, were constructed alongside the irrigation system, as a mitigation measure against soil deposition and stabilization, thereby reducing near surface wind speed and erosion. This aims to minimize the potential for soil material to be carried away by the wind, to reduce the occurrence of sand and dust storms. Such windbreaks are being constructed as earth works where soil material is being used to create parallel rows with a triangular or trapezoidal profile.

Soil Description: Soil of the project area is generally characterized as degraded desert sand-clay mixture, considered low in water-holding capacity, lacking in organic matter and low in essential nutrients. The dominant soil texture classes range from clay to silty-clay, with clay – loam being less prevalent, primarily originates from alluvial deposits of the Euphrates river in a flood plain. In general, the soil of the area is heavily affected by salt accumulation to varying degrees. Table (1) shows the ranges of the physical and chemical properties of soil samples from the different areas of the project. Soil Physical and chemical analysis of the project area concluded that the collected samples showed, in general, sand with very coarse and coarse sand. Also, the soil is alkaline nature with low organic matter. One of the main tasks of this project involves actual rehabilitation of the selected areas to maintain and safeguard the ecosystem, therefore, effective applied research is important in the field of soil improvement for revegetation and biodiversity conservation. This research includes land stabilization, planting deep-rooted trees species as wind barriers, planting mixed crops with trees, shrubs and grass species, for the establishment of cover vegetation and restoration of degraded lands. Some solutions have been considered for the rehabilitation task and summarized as follows:

Table 1. Properties of soil samples

pH	Organic Matter (%)	Grain Size (%) **					$Caco_3$ equivalent (%)	EC ($ds.M^{-1}$)
		V.C.S	C.S	M.S	F. S	V.F.S		
8.12 – 8.6	0.140 - 1.30	2.9 -18.4	3.1-24.3	3.7-20.6	4.3-13.1	6.0-14.9	21.75- 48.9	2.4-18.3

*From KISR and university of AL-Muthanna Labs [(4)]

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V.C.S = Very Coarse Sand
C.S = Coarse Sand
M.S = Medium Sand
F.S = Fine Sand
V.F.S = Very Fine Sand

- **Mechanical Method:** By using suitable heavy machineries such as bulldozers, excavators and shafts to stop sand movement and provide opportunities for the growth of natural plants that can withstand drought and salinity, in the form of green belts.
- **Sand Barriers:** By Constructing earth mounds (sand barriers) with trenches that work as obstacles of sand encroachment, to reduce the chance of wind erosion.

- **Biological Method:** By restoration the vegetation cover of shrubs and trees accompanied by natural plant that can tolerate high drought and salinity. This is one of the strategies to protect the surrounding environment, as apart of afforestation.

Water Access: Access to water in the project area is available as near surface ground water, which is too saline for agricultural purposes and plant cultivation, except halophytes or salt – tolerant plant species. This water is utilized for the shelter belts within the design of the project. Also, it is used for irrigation to cultivate species of barely that can be grown in saline water, which will be introduced by the farming communities around the project area, as grazing animal feed. The main source of water available for irrigation purposes in the project area is the low to moderately saline drainage water from the East Euphrates channel, for the needs of the halophyte species of trees and shrubs, that make the shelter belts. Hence, access to irrigation water suitable for biological windbreaks needs is the most important component within the plan of action of this project. Once these trees have matured, they will get water demands through their root system. Regular water quality is monitored for all irrigation works related to the project. The key milestones involved for the irrigation system are outlined below:

- Installation of 4 pumping stations, each with a capacity of $1m^3$/sec.
- Rehabilitation and maintenance of existing irrigation system of about 24 Km in the pre-construction area. All other canals are newly constructed in phase I and II, over 1426 km in length.
- Construction of new irrigation canals of about 263 Km in length

deposition and stabilization in the project area is setting up hedge-rows or shelter belts, that was commenced with the construction of irrigation systems. Shelter belts flanked the tertiary irrigation canals on one side, and require water for only a few years until tree seedlings reach suitable sizes, the trees are expected to grow up to 15 meters in height, and below the tree canopy shrubs and bushes will thrive. Required water will be supplied via tertiary canals, with seedling planted alternating on both sides. The total length of the shelter belts, along the irrigation canal is about 1440 Km. The estimated total number of seedlings required for the total length ranges between 0.5-1.0 million seedlings for a single line belt, with distance of 50-75 meters between each belt shelter. Currently, the project is planning for 150,000 seedlings of Conocarpus and Tamarix. The seedlings are provided by the national plant nursery of the ministry of agriculture in Iraq. However, the full effectiveness of the system will only be realized after few years of planting. Shelterbelts consist of combinations of plant species of different heights and nature, including trees (15-20 meters in height), shrubs (1-5 meters), and ground-covering grasses. The following plant species have been identified for the shelter belts designed for project area, they are highly tolerant to salinity and drought: -

Tree Species: The project selected a combination of 3 tree species in equal proportion (1:1:1) for the shelter belts.

- **Prosopis Cineraria, or P.Juliflora:** Also known as Ghaf tree, P. spicigera or P.Spicata : This tree is considered one of the backbones of shelterbelts selection in the region, and provide ample shade. It improves soil fertility by fixing atmospheric nitrogen.
- **Tamarix Articulata (Salt cedar) or T.aphylla:** it can occupy habitats that are unsuitable for other species. It is a potential source of medicinal benefits.

Table 2. Water quality of AL-Gharraf drainage canal

pH	EC (ds/m)	mg/L								
		TDS	CL	So_4	HCo_3	No_3	Na	Ca	Mg	K
7-8.3	1.2-1.9	760-1232	187-288	147-210	102-327	2.2-7.2	84-150	80-125	23-43	34-77

Source: (5)

The main possible sources of water for irrigation purposes during the first year of planting are the following:

The Eastern Euphrates canal: It is the main drain canal runs between the Tigris and Euphrates Rivers, that was completed its construction in 1990 for various irrigation purposes. It collects water from the drain networks to prevent mixing with the water of the two rivers and ensure its transport to the Shatt Al Arab, formed at the confluence of the Euphrates and Tigris rivers, and then to the Arabian Gulf. It is located at a distance of 20 Km from the hot spot areas to irrigate several locations by pumping to the needed sites according to land topography at the eastern side of main highway. The total length of this canal is about 565 KM from North of Baghdad to Barsa, at a flow rate of 80 – 110 m^3/sec.

North Al - Gharraf Mebzel (Drainage Water): It is water canal dug into the ground for the purpose of collecting excess drain water, to be provided to the areas of the western side of the main highway, and delivering water through pumping to agricultural lands. The total length of this drain is about 157 km and connected with the previous canal at 217 km with water discharge rate of $46m^3$/s. It is one of the important branches of the Tigris river. Table (2) shows the quality of Al-Gharraf Canal water in the project area which is within the ranges of water quality for irrigation [7].

Mitigation Measures: The aim of mitigation measures is to reduce wind speeds near ground surface. Shelterbelts (tree lines) are a nature-based technique solution with the purpose of breaking near surface winds, and stabilizing the soil. They are useful for protecting cultivated areas against wind erosion, and limit soil particles uptake, thus aiding moisture conservation as a benefit for crop farming. Shelter belts often host various wildlife such as reptiles, insects, birds and small mammals. The most effective technique for mitigating soil

Acacia Nilotica (Arabic Gum Tree): The wide shape of its canopy provides ample shading against sunlight in the area below. It is most suitable and native to the region. Can be used for ecological benefits, fodder, fuel and timber.

Shrubs Species: The main shrubs selected to be populated under the area beneath the tree's canopies (under Storey) are the following:

- Conocarpus erectus and/or lancifolius (Green button wood): This species has remarkable resilience in similar environments of the project. The leaves of these plants are used as fodder for livestocks, and can be used as an ornamental plant.
- Atriplex halmius (Salt bush): is suitable for arid regions, its leaves are palatable as fodder for domestic grazing animals.
- Suaeda fruiticosa and/or S.vermiculata : It is native to the region, and aids in soil stabilization. It is an edible medicinal halophyte and helpful for many remedial purposes
- Zagophyllum simplex (Tetraena simplex): Small shrub ground covering, it is a succulent plant that co-habitats with other grass species.

Grass Species:

- Panicum Turgidum (bunchgrass): used as fodder with high leaf and for erosion control and seed production.
- Stipagrostis plumose: Native to the region, adapted to desert dunes. It is an evergreen and can be used as a forage to livestock.
- Cenchrus Ciliaris (Foxtail buffalo grass): Widely used as a forage grass, grows mainly in sandy soils for erosion control.

The above-mentioned species have been cultivated previouslywith encouraging results, and form green belts and windbreakers to reduce sand movement, as part of afforestation of the project area. Such species can tolerate a range of between 12000 – 15000 ppm of total dissolved solids (TDS) in the irrigation water [(12)], and the taproots of the trees can reach the water table and extract water down to 20 meters. The water requirements for trees and shrubs can vary greatly depending on many factors such as age of plants, species, soil characteristics, climate conditions and others. In general, watering desert plants, as in the project area, need a range of between 3-25 liters per day per tree or shrub during the first few months, and 20-115 liter per week and per month, once the plants are established for the first few years. A general rule of thumb regarding watering depth is to ensure the water gets into the soil at least 12 inches deep for ground cover or small shrubs, 12-18 inches deep for medium to large shrubs, and 24-36 inches deep for trees [(13)]. Currently the project is trying to use multiple methods to reduce water consumption including Zeolite, polymers and biotech (nano-technology) to increase soil water retention. "Deep watering" is a term of watering to a sufficient depth to reach a plant's deepest roots. In general, all desert adapted young trees need to be watered regularly for two years until they are established [(14)].

Operation and Maintenance: Both the Iraqi ministry of water resources and ministry of agriculture, in collaboration with the local communities, are responsible for implementing the operation and maintenance measures of the irrigation system and installed equipment, after UN-Habitat exit the project to ensure sustainability. This includes servicing and checking of pump stations, nurturing and maintaining shelter belts and solid windbreaks, as well as monitoring and stabilizing active sand dunes. Furthermore, the local communities will benefit from cultivating certain crops to contribute to their benefits. It is well documented that the use of water in the hotspot area will not negatively influence water access for human consumption, or agricultural activities within the vicinity of the project area. The implementation of the project is in accordance with relevant Iraqi environmental Law and the National adaptation plan.

Challenges

The project encountered some obstacles and challenges at the beginning, such as:

- Some delay due to security conditions which affected access to the selected areas of studies.
- Difficult negotiations prior to the implementation, with some local communities and farmers raised their concerns and disagreement regarding the necessary field works.
- Lengthy procurement process of budgeting and purchasing procedures for field monitoring equipment within some partners, due to bureaucratic routine.
- Delay in the delineation of the priority area before initiating field works.
- Some difficulties in regard to transfer of equipment and soil samples cross border between Kuwait and Iraq.
- Delay and rescheduling of training sessions to enhance capacities of local communities and authorities.
- Delay in coordination and agreement among different entities involved, such as research institutions and universities.

Sand and Dust Storms damages: Many damages with negative impacts, are caused by sand and dust storms events to Kuwait and South Iraq, as outlined below:

- Estimated annual dust fallout rate into Kuwait of over 60 Tons per Km^2, and sand removal of about 350,000 m^3.
- Wind erosion causes changes in surface soil texture, loss of fertility, loss of organic matter, and reduced water holding capacity.
- Causing desertification by declining and loss of agricultural and cultivable lands, through the disturbances of the soil cover [(8)].
- Annual economic disruptions of over US$ 200 Million in Kuwait, include key urban infrastructures, airport, sea terminals, industrial and oil production and export losses. Also, air travel delays and cancellation, school shut downs and public works, commercial disruption, local transportation, sand encroachments and annual removal, and non-productive lost working hours. In addition to severe health impacts on population causing allergies, respiratory diseases like asthma, and other dust-health associated problems, and their effects on hospital admissions and possible mortalities [(9,10)].
- Data collected from climate monitoring statistic of meteorological administration of Kuwait, for years 2000-2021[(11)], showed that an average of 137 days of dust in a year. Also, showed results in health and environmental problems with economic loss estimated at around US$ 614 million per year.

Conclusion and Lessons Learned

To reduce the events of sand and dust storms in Kuwait, it is a must to mitigate formation of such storms in Southern Iraq, where up to 40% of sand and dust carried to Kuwait originate in this area. The main factors causing the storms in this region are high speed winds, soil type, aridity and poor vegetation cover. The on-going project "improved resilience to transboundary sand and dust storms in Kuwait and Iraq" is considered as a success story before it's completion, in spite of the obstacles and challenges faced the journey of implementation and operation throughout different stages and phases of progress. The main outcomes of this project are ameliorate knowledge and understanding of the behavior and formation of the storms, and implementing mitigation measures for restorations of ecosystem in the areas where the events are mainly formed, in addition to enhance capacity building of all partners involved. Revitalization of agriculture land is considered one of main goals of the project through creation of biological shelter belts, as eco-friendly solution.

Many lessons derived and learned from this promising project and are summarized as follows:

- Well designed scientific research and planning lead to develop recommendations for successful intervention and approaches that result in reduction of the formation of sand and dust storms, due to pivotal role and invaluable contribution of partner scientific and academic institutions in executing the action plan.
- Communication, discussion, negotiation and dialogue with local communities are necessary to achieve project's goals.
- Operational transparency with partnership cooperation and coordination among the stakeholders play vital roles to address obstacles and find solutions for effective success, through sharing of information for reaching mutual agreement.
- Learning experiences gained through the rich knowledge and understanding collected from the project, i.e. impacts on human, environment, preventive mitigation measures for restoration of ecosystem in the region. Measures should also be taken in cities, towns, and villages to minimize the impact of sand and dust storms.
- Participation in International conferences and workshops is important to share with others the outcomes of the project implementation, built on strong scientific and evidence-based approach [(6)]. The conducted training workshops aimed at enhancing the capacities of the involved authorities and academics in the scientific tools and analysis used to identify, mitigate, and assess sand dust storms. The training sessions and workshops provided solid recommendations for field implementation.
- The Project could be considered as a pilot or initial phase of implementing mitigation measures to tame sand and dust storms across the Gulf region.
- More detailed field research works needed for future assessment in the same domain of sand and dust storm impacts. Further dialogue with other Gulf States should be communicated to scale up the project in the region, as the project's

implementation is considered a proof of concept for mitigation measures.

- Shelterbelts, along with other ecosystem services, are considered the most effective approach for mitigating soil deposition and stabilization in the priority area.
- Irrigation is a key to fight desertification, and successful adoption of such practice leads to more production for food security, through applying suitable engineering design to promote sustainability of irrigation networks.
- The project is aligned with UN agenda for Sustainable Development Goals (SDGs), including promote sustainable agriculture, ensure healthy lives, water use efficiency, build resilient infrastructure, combat climate changes, protect ecosystem, and global partnership.

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