primary road system of the neighborhood consists of relatively wide "wonerfs" (roads for the combined use of vehicles and pedestrians) stretching from east to west, to allow solar exposure of the houses on their northern side. The secondary system is of narrow alleys in a north-south orientation, that will be used by pedestrians only, and which will be shaded during most of the summer days (fig.15). Most of the houses are grouped into clusters of four, and are forced to the outer set-back lines of the lots. The clusters are surrounded by relatively tall solid built fences. This was done to achieve relatively large *private* open spaces between the houses, and to increase the density close to the alleys and the public roads in order to get them shaded by the building masses.

With its very small size and rapid population growth, Israel can not afford looking at the desert as a wasteland. The Negev is the country's only land reserve and developing appropriate architecture and building technology is essential for its development. It is a pity that the country is investing so little in preparing its future.

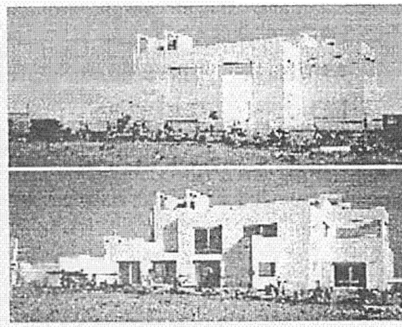

*Fig. 12,13 - Sede-Boker - The Etzion residence, south and east elevations. Summer mode (top). and winter mode (bottom) Notice the large blind protected openings.*

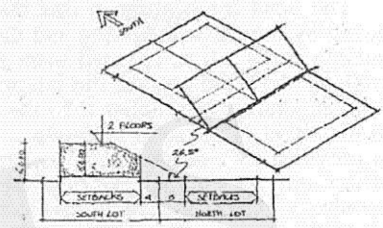

*Fig. 14 - Sede-Boker - The solar neighborhood. Volumetric constraints used for the design of the houses, to assure solar and ventilation rights.*

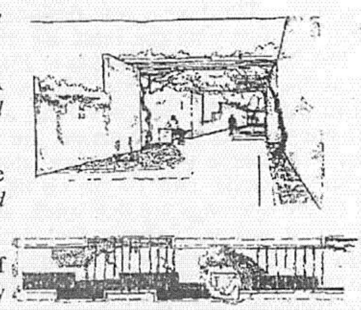

*Fig. 15 - Sede-Boker - A view of a pedestrian alley. Notice the high fences and the shading which provide a protected environment.*

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沙漠研究 5S, 85-88(1995)
Journal of Arid Land Studies

# Urban and Regional Development Strategies in a Desert Environment: Three Case-Studies in Israel's Negev Desert

Yehuda GRADUS* and Eliahu STERN**

Abstract - The present study examines three man-built settlement projects in Israel's Negev desert - the entire Negev settlement system, the internal structure of towns and neighborhoods, and Bedouin urban settlements - in the light of the urban and regional concepts applied in their planning and development. Preconceived urban models cannot simply be transplanted to arid zones; the planning process and its implementation must be responsive to the unique human and physical environments involved.

Key words: regional development, urban planning, indigenous nomads, Negev

## 1. Introduction

Desert areas make up a third of the world's lands. In an era of increasing population growth, with possible shortages of food, arid zones will be the frontiers of future development, and the proper strategies for planning man-built environments in desert areas may shortly become a major world concern. Israel's experience - both successes and failures - has much to contribute to the future development of other desert environments throughout the world.

The present paper focuses on the interaction between the human-built environment and the desert. Various traditional desert cultures have formed their settlements and homes in ways appropriate to their arid environment, adaptations that have evolved over generations and articulate or reflect the natural environment's constraints. What happens when the modern man-built environment interacts with the desert can be studied in Israel, which was established in 1948 on a territory that was two-thirds desert, and had urgently to settle large numbers of new immigrants in the desert.

This paper examines three settlement projects in Israel's Negev desert, in light of the urban and regional concepts applied in their planning and development. It becomes clear that preconceived urban models cannot simply be 'transplanted' to arid zones; cultural and environmental considerations are essential for the implementation of such projects. A change in attitude is necessary in the planning process in desert areas: moving from the preconceived to the responsive.

The first case-study deals with the regional planning strategy of the entire settlement system in the Negev. The preconceived concepts derived from Zionist ideology are examined, and the impact of the arid environment on the system's evolution and the ensuing readjustment of concepts are explored.

The second example deals with the urban planning concept of the internal structure of towns and neighborhoods in the desert, and how this concept changed, due mainly to responsive environmental considerations.

The third case is that of planning for the indigenous Negev Bedouin - how planners perceived future urban environments for this population, and how the original models were readjusted in light of environmental and socio-cultural considerations.

## 2. Ideology and Planning in Arid Environments

Spatial planning in Israel cannot be separated from ideology, which influences development at all levels. Population dispersion, one of Israel's major national planning goals, is seen as the basis for claiming sovereignty over the land, and also reinforces the major goal of the Zionist movement, the "return to the old homeland". The conquest and cultivation of the desert were also major objectives of Zionism. Ben-Gurion, one of the founding fathers and Israel's first Prime Minister, expressed this clearly: "If the State does not put an end to the desert, the desert is likely to put an end to the State....Science and pioneering will enable us to perform this miracle [of transforming the facts of nature and making the desert bloom]...." (Ben-Gurion 1956).

Zionism also regarded agriculture as the foremost instrument for Israel's development, a means of social rejuvenation; the city has traditionally been viewed by it as a necessary evil. However, successful absorption of the masses of new immigrants required that they be placed in urban centers rather than rural settlements, which suffered from a lack of employment opportunities and a shortage of water and fertile soil. Therefore, small urban settlements with a rural atmosphere and linked to rural settlements were considered a second-best plan - a compromise between ideology and reality.

Israel's early planners were influenced not only by ideology but by their own backgrounds and training. Most of them were architects influenced by the English and German schools and the professional styles prevalent during the British Mandate period. The most influential concepts were that of the garden-

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city model and the idea of a balanced national and regional hierarchy confining strongly-interlinked rural and urban settlements to one system. Both of these anti-urban concepts nicely complemented the rural bias of the dominant socialist Zionist ideology.

## 3. A Settlement System in an Arid Environment

Selecting a strategy of optimal spatial distribution of settlement in an unpopulated frontier desert environment is still a theoretical issue in most countries, but for Israeli regional planners, it was an issue of real and immediate policy. Their preconceived concepts, derived from a ruralistic ideology, have had a significant impact on the evolution of the man-made urban system in the Negev. Their plan was to create balanced and integrated regions, each with a central urban core as a service center. These urban centers were to constitute a hierarchy of central places (Cristaller 1933), ranging from small urban centers to metropolitan areas. The policy objective was population dispersal and spatial equality rather than concentration - one of the few cases where development of an urban system was based on a theory of spatial organization. However, in the application of this plan, the physical desert environment was almost neglected. In certain cases, where planners realized it would be difficult to establish towns in the arid environment solely as service centers to a rural hinterland, they proposed establishing towns to provide housing for workers in the mining and other regional industries.

During the early 1950s, ten new towns were established in the Negev based on this preconceived concept of the dispersed hierarchical central place. By the early 1960s, it was evident that the economic development of the towns could not be based on service-provision to surrounding rural areas, and there was no significant interaction with the small agricultural settlements that had developed northwest of Beer Sheva. The latter, which had their own marketing and purchasing organizations and were part of national movements, bypassed the towns, which offered only a low level of health, educational and cultural services and inadequate physical urban planning, and suffered from high unemployment and widespread poverty.

It became obvious that a change of development strategy to one more appropriate to the desert environment was crucial. The government launched a massive industrialization program in the 1960s, to create new job opportunities; by the early 1970s, the towns became typical company towns, vulnerable and dependent on outside decisions. The industrialization of the Negev towns, the expansion of the industrial complexes, and the spread of private and government investment in the region, created a demand for a more efficient pattern of service provision. Beer Sheva emerged as the natural center for the entire Negev, with the regions' large employers locating their headquarters there. It became obvious that a polarized growth center strategy was more economically efficient than a dispersed strategy. The government recognized the need to develop the city as a major regional center and made three significant decisions: (1) Beer Sheva was declared the capital of the Southern District, and regional government offices were located there, providing thousands of service jobs; (2) a new central medical hospital serving the entire Negev was established in 1962; (3) the Ben-Gurion University of the Negev was founded in 1965 as a scientific base and training center for professional workers for regional industry, education and health services, attracting many higher socio-economic status workers to the city.

The Negev urban system now functions as an integrated unit, as one metropolis. Instead of a continuity of built up areas, there are 'islands' of small and medium-sized urban communities and industrial complexes, separated by arid vacant land but connected by a network of roads. Analysis of commuting patterns indicates a clear radial pattern focusing on Beer Sheva. The pattern suggests that we are dealing with a mobile interconnected system of shared interests, which acts as both a single labor market area and a single service unit. Any significant change in the economic activities, employment or population of one part of this integrated set of cities, towns, villages and industrial complexes, isolated in space but interdependent and linked to a central city, will affect all the other parts (Gradus and Stern 1980).

The Central Place theory adopted by Zionist planners as a strategy for regional development suffered from the following weaknesses: it was developed in an agricultural environment but applied in an arid zone with little agriculture; it emphasized dispersal, regional balance, hierarchical systems, and the service sector, primarily consumer-oriented activities, which were ineffective and inappropriate where economic activity is conditioned mainly by the location of raw materials. It is evident that this strategy prevented the Negev's urban settlements from becoming self-sustaining communities.

If a country's goal is planned, permanent settlement in remote deserts, rather than temporary places for residents to earn money while exploring for natural resources, it must provide basics such as good health care, education, cultural and commercial services capable of competing with those in the national core. Regional development must aim to create a compact, functionally inter-related system with a major dominant growth center capable of providing those necessities.

## 4. Garden-Cities in an Arid Environment

The potential problems in applying a preconceived Western model of urban planning to non-Western populations in an arid environment are demonstrated in the designing of the internal structure of the city of Beer Sheva (Gradus 1978). The school of thought prevalent among Israeli planners of the new towns was that of garden-cities (Howard 1965) divided into neighborhood units. The idea of creating a rural atmosphere in an urban environment while keeping contact with the land, one of the major concepts behind the garden-city movement, greatly appealed to leaders and planners of the Zionist socialist movement, and to the local leadership and founders of Beer Sheva, who were veteran members of the socialist agricultural sector.

European garden-cities were planned for low density housing arranged in homogeneous, semi-self-sufficient neighborhood units, each with its own schools, shops, libraries, community centers and the like. Internal winding streets would be built, unrelated to the transportation system of the other neighborhoods and the city as a whole, and each neighborhood would be surrounded by a 'green belt'. These principles were applied in Beer Sheva as well as other Negev new towns. What was created however was a dispersed city composed of quarters remote and detached from one another, with no physical or social links between them. Instead of homogeneous communities, conclaves of ethnic and occupational structure formed. There was a lack of architectural diversity, of urban consolidation. The dispersion of services and the winding roads necessitated large municipal expenditures, created problems of communication and orientation, and required residents to walk long distances in the desert heat. The undeveloped vacant areas designated 'green belts' between neighborhoods created internal deserts within the city, lessening the urban feeling.

By the early 1960s, it had become evident that the garden-city concept was inapplicable to Beer Sheva's desert environment and its socio-cultural reality. The new readjustment policies placed the emphasis on consolidating the city, condensing it, and thus transforming it into an organic unit functioning as a single economic and social entity. In a desert environment, an integrated planning approach is preferable to the autonomous dispersed-neighborhood units approach. Multi-storied housing was built, primary and secondary arteries were constructed within and between neighborhoods to facilitate traffic, and all roads were aimed at one axis channeling the city's transportation.

Twelve years after the implementation of the garden-city concept in Beer Sheva, the town of Arad was founded 40 km to the east. This time the desert environment was studied carefully and the entire planning was done on location, adopting a more practical and realistic approach.

## 5. Bedouin Towns in an Arid Environment

The last case study is that of the urban settlements planned for the Negev's indigenous nomadic Bedouin population, now numbering some 90,000.

The Negev Bedouin belong to twenty-five tribes scattered over an area of 1000 sqkm, mainly in the north and central parts of the region. Most of them came to this area after 1949. Their spatial spread is also due to a process of spontaneous sedentarization, which has been taking place over the last 20 years, but has only recently become a planning problem (Musham 1970). The Bedouin's scattered pattern of permanent and semi-permanent spontaneous settlements has conflicted with development programs for the Negev, partly because of inefficient use of space, and hampered - and rendered more costly - the supply of regional services. The Israeli government has therefore been attempting to resettle the Bedouin in planned urban settlements forming an integral part of a regional development program.

Forming man-built environments for indigenous nomads can be potentially disruptive to their whole system of life (Rapoport 1978). Rapoport (1979) suggests several principles for reducing the incongruence between traditional lifestyles or settings and new ones, creating supportive environments based on 'natural groups': (1) the spatial organization of settlements, neighborhoods and dwellings should be related to social organization, space and time use, meanings, and control of communication and interaction; (2) settlements and dwellings must been seen in context and allow for preservation of important cultural elements; (3) affective and perceived density should be related to traditions.

Israel's first attempt to develop an urban settlement populated solely by former nomads - Tel Sheva, near the city of Beer Sheva - failed because it did not apply the above principles, but rather implemented preconceived planning concepts and misinterpreted the effect of local environmental conditions on the Bedouin and their socio-cultural needs and behavior. No consideration was given to spatio-social division or possible interaction patterns. The high density of the town, the small dwellings with few windows, the misconceptions about Bedouin shopping practices, all contributed to the failure. The planning process was accompanied by continuous conflict between official policies and the independent Bedouin.

The lessons were however learned; a responsive planning process was successfully tried out in a second planned settlement, Rahat, located 16 km north of Beer Sheva, relating urban structure to Bedouin socio-cultural traditions. In Rahat, each social element is spatially identified with an urban element. Each neighborhood serves as an independent social framework, allowing for tribal territoriality, while its internal structure accommodates the hierarchical structure of traditional Bedouin society, each street being identified with an extended family within the tribe.

A second element in Rahat's success involved the channeling process: residents were offered large plots of land per family and encouraged to build their homes according to their own budgetary limits, needs and pace, while the physical and social infrastructure was pre-planned. In addition, the town's master plan also provided for growth and development, especially the strips of open public space between the neighborhoods, and for the Bedouin's changing occupational profile, moving toward industry rather than husbandry or agriculture.

Tel-Sheva's master plan has been revised according to Rahat's responsive planning concepts and standards, and three more Bedouin towns in the vicinity have been so developed, implementing what has proven to be successful planned sedentarization of nomads (Stern and Gradus 1979).

6. Summary and Lessons for the Future

The three case-studies examined above demonstrate the real and potential problems arising due to the application of transplanted urban and regional development concepts - the Central Place and Garden City models - originating in different cultural and environmental conditions to a fragile arid human ecosystem. The transplanted models reflected the Zionist ideology of 'back to the land' without considering what 'land' means in the desert, where Western spatial, physical and social standards proved unrealistic and inappropriate.

Analysis of Israel's experience in formulating and implementing development policies in its Negev desert can contribute to future development projects in arid zones, and shows how desert planning must be sensitive to local needs and conditions and facilitate a framework for continuous response and interaction between the various elements of the arid system.

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沙漠研究 5S, 89-94(1995)
Journal of Arid Land Studies

# Trans-Saharan Wind Flows Observed on Meteosat 4 Satellite Image

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Abstract - Thanks to the use of Meteosat imagery the relationships between the dry ecosystems of Sahara-Sahel and Sudan along one unique Global Wind Action System and the rain forest are detected.

Key words : Remote sensing, Meteosat, Aeolian actions, Rain forest

The Meteosat 4 Infra-red satellite image of January 3th 1992 (METEO FRANCE CMS LANNION), thanks to its scale of 1 : 26 000 000, shows a dust and sand storm over the Central and Eastern parts of the Sahara and the Sahel (27-30°N) until the tropical margin of the Guinean zone (5 to 10°N), along a distance of 3 000 km (Fig 1).

Our first objective, similar to the studies carried during the late 1970's (Mainguet, Cossus et Chapelle, 1980), consists of a synthesis of the figures of aeolian activity visible on satellite imagery, and of a determination of the *mega-venturis* and their effects on aeolian circulation. The second part shows how the wind currents are organised around the Saharan and Sahelian mega-obstacles (Mainguet, Chemin et Borde, 1985). In third part analyses the eastern Saharan wind and sand flow and finally tries to show that the limit of savannah-forest is dependent on aeolian dynamics.

## 1. Diagnosis of Aeolian Dynamics and Definition of the Notion of Global Wind Action System (GWAS) (Fig 2).

We have called GWAS (Mainguet 1992) an aeolian dynamical system where particles are deflated or winnowed, transported by suspension, saltation, reptation and creeping and finally accumulated in loess sheets, sand veneers, dunes, dune fields, and sand seas. How the Sahara, the Sahel and even the Sudan ecosystems are located in one unique Global Wind Action System at a synoptic scale in which are embodied secondary smaller local to regional wind action systems, will be seen. On the satellite image in the area of wind activity different features can be observed :

1.1. Areas where narrow strips with high reflectance alternate with strips of low reflectance as observed between the Ahaggar mountain and the Tibesti mountain. They were understood in the previous analysis as areas of dominant transport associated with wind activity, essentially consisting of corrasion of stony plateaux (mainly sandstone), giving a landscape of *yardangs* and *kaluts* (aerodynamically carved rocks) (Mainguet, Chemin 1990).

1.2. Areas of high reflectance characteristic of active sand seas with unprecise boundaries on the satellite images because of escaping sand plumes precisely at the moment of the registration of the image in the erg of Fachi Bilma and Haoussa.

1.3. Topographic obstacles responsible for specific aeolian patterns as :
- divergences upwards of the relief : the best example is located upwards of the set of Ennedi/Jebel Marra;
-Areas of average reflectance immediately leewards of a major obstacle which are shelter areas, the most spectacular being leewards of Aïr with a length of 500 km.
-Figures of convergence, for example leewards the Jebel Marra.

1.4. The mega-venturies. A venturi is defined as a constriction in a channel conducting fluids, which locally produces a pressure decrease and therefore an acceleration of the fluid, which leads to a greater kinetic energy and therefore to a great erosion and transport potential (Mainguet, Borde, Chemin 1985). When two topographical reliefs are not too distant : 300-400 km as for the Tibesti and the Ennedi; in the corridor between them appears a neck where the pressure is low and the speed higher according to the Bernoulli law. In this furrow the wind has carved the most prestigious system of kaluts of the planet in the paleozoïc sandstones of Borku.

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The description of these main aeolian figures leads to an analysis of the behaviour of wind in the Central Sahara (Mainguet 1976).

## 2. Observation of a Wind Current as Organised Around the Ahaggar, Major Obstacle.

The comprehensive central Saharan aeolian dynamics is ordered by one mega-obstacle, the unity Ahaggar-Tassili with a surface of 203 350 km$^2$, more than 3000 m high (average 1800 m) and to the south the Aïr massif of 66 150 km$^2$ with a maximum altitude of 1500 m (Mainguet, Canon 1977).

**2.1.** In 1979 (Mainguet, Cossus et Chapelle, 1980) the Meteosat Images, through aeolian figures have shown a wind flow beginning south of 29°N (Edeyen de Marada), curved around the easternside of the plateau dominated by the Jebel El Aswad, crossing the eastern half of Murzuk sand sea, and the Djado plateau before being oriented ENE-WSW in direction of Aïr and divided in two branches, the southern one rejoining the Tenere.

**2.2.** On Meteosat 4 Image of 1992 the wind current is a sand and dust current. The load in aerosols is not dense enough to hide totally the soil surface which stays visible. The material which flows in transit in direction of the unit Tassili-Ahaggar, carried by the harmattan wind, starts as those of the 1970's in the sand seas of Marrada and Kalansho and continues towards the Rebiana sand sea which seems to have lost a part of its surface since the observation of 1979. There, the diachronic analysis of the images of 1979 and of 1992 allows us to propose a new hypothesis of a slight loss of surface of the deposits of the Central Saharan sand seas simultaneous to drought.

The plateau of Djado 500 km in the N-S direction shows an intense wind activity mainly of corrasion giving a *kalut* landscape. More leewards, the Aïr massif produces a subdivision of harmattan wind in two branches. The most southern one flows south of Aïr in the direction of the major sahelian E-W aeolian system, prolonging the Tibesti-Ennedi *venturi system* until 7°E. There is presently a quasi continuity of the aeolian transport between 16°E (Erg Bilma) until 0°, located at 800 km leeward of the Aïr (Mainguet 1972). On the 1979 image such a continuity at this latitude was not visible.

## 3. The Major Aeolian Flow of Sahara : the Eastern Flow (Fig 2).

In 1979 the major Saharan aeolian eastern flow started in the Qattara depression, then widened, running in the Great Sand Sea of Egypt to the boundary of Libya from the Nile Valley until the eastern face of Tibesti through the Gilf Kebir. After turning around the eastern face of Tibesti, at the latitude of the Tropic of Cancer, the current curved before crossing the Erg of Bilma and Tenere acquiring then an E-W direction until lake Debo south of the curve of the river Niger. Meteosat 4 of 1992 confirms these patterns. North of Jebel Oueinat 23°N, the air is full of dust but the soil surface is visible. South of this latitude the density is too high to show the whole surface. On the image of 1992, the wind currents have three main sets of characteristics.

**3.1.** The continuity of the currents from 30°N to the southern Sahel (Mainguet et Guy 1975) : the convergence of the two aeolian flows, which have the same origin north of Egypt at the latitude of the Qattara depression, is located at the north of the Central African Republic, south of Chad and Sudan. The track on the soil surface of this aeolian current is linked by areas of reflectance which are deflation areas, others where *kaluts* are dominant and which are areas of corrasion.

**3.2.** In 1979 the aeolian sand transport was visible only on the western bank of the Nile; in 1992 it is visible on the two banks, and it seems, that the aeolian flow is able to transport its load of particles across the valley. Between 10 and 15°N. a larger part of the Nile is hidden by the migrating particles. This transport affects the whole curve of the Nile which is at a right angle to the aeolian current, confirming how much the valley and the agricultural activities are threatened by encroaching sand.

**3.3.** The effects of the mega-obstacles : Tibesti-Ennedi-Jebel Marra (Fig 2). Leeward of the *Tibesti-Ennedi venturi*, at the latitude of Chad lake, the most oriental flow from the GWAS Sahara-Sahel is divided in two branches, one with a N-S direction drawing a wide circle (Fig 3). The other branch, north of Chad lake, has an east-west direction which can be followed on Meteosat 4 until Mali where the river Niger draws its curve at the latitude of Gao (16°N, 0°). There, the aeolian flow reaches the Niger valley before crossing it and feeding the sand sea east of Aoukar.

The Niger valley, almost at right angles to the sand flow, acts as a sand trap which traps high volumes of sand which cannot be neglected when undertaking hydraulic management of the river. The building of a dam could have catastrophic effects on sand accumulation, because, with the regulation of the river flows and the suppression of the floods, the aeolian material is trapped and not evacuated during the dry season.

## 4. The Southernmore Dynamic Extension of the GWAS Sahara-Sahel (Fig 4).

In 1979, the analysis of Meteosat of 28 February has allowed description of the aeolian flows on the soil surface in the Sahara and its Sahelian boundaries (Mainguet, Cossus et Chapelle, 1980) and to follow the most meridional extension of these currents.

On Meteosat 4 in East Africa the harmattan has its longest trajectory of 7 000 km, from 27°N (North of Egypt) until 12°N Jebel Marra. The first mega-topographic obstacle met by this flow is the unit Ennedi (1400 m)-jebel Marra(3088 m). Upward of these two massifs the current is divided in two branches. The divergence reaches a maximum width of 780 km and a length of also 780 km with the convergence at 9°N. The western branch has a NE-SW direction until Chad lake (13°N, 13°E) where it curves towards the south. This curve was not visible on the 1979 documents.

It is in Uganda (3°N) that the aeolian flow has its longest meridional extension. Therefore the hypothesis can be proposed of a progression of aeolian dynamics towards the equatorial zone : the farthest extension being visible in NE Cameroon, the Central African Republic, Sudan, north Zaïre, and Uganda between 3 and 5° N.

## 5. The Location of the Limit of Savannah-Forest, a Consequence of Aeolian Dynamics ?

This limit is visible on Meteosat 4 through the difference in reflectance, the savannah having a lower reflectance than the forest. West of the African continent the limit appears in Guinea (12°N), then, towards the east, it slides at 10°N in northern Ivory Coast (10°N, 7°W) then further east it approaches irregularly the equator until 5°N. In south Sudan (5°N) aeolian activities can be detected at the limit of savannah-forest by the existence of periodical strikes.

The northern limit of evergreen forest has its most southern location precisely at the confluence of the two peri-Jebel Marra branches, SE of the massif. At 15°E, in the Central African Republic, the northern limit of the evergreen forest is at 5°N. In SE Sudan, the limit is further north (Juba forest) near 10°N and 22°E. Further east the limit is in Uganda; the northern limit is located on the equator. It is also there that the GWAS has the largest extension towards the south.

<u>Conclusion</u> - The hypothesis of the previous publications (Mainguet 1977), proposing that the central Saharan sand seas, with a negative sediment balance, were losing their material to the benefit of the meridional sand seas, is confirmed in 1992.

In the Sahel, where the NE-SW aeolian flows are becoming E-W, after a curve at the latitude of the Tropic of Cancer, exists a vast area of reattachment where areas of deposition, with a positive sediment balance, have been developed. Since the beginning of the second half of the twenty century, in the fifties, according to observation of aerial photographies (FAO 1956-57 Tichit NE 29-XV n° 081-82-83), areas of positive sediment balance are becoming areas of negative sediment balance caused by land degradation and aeolian erosion.

The continuity on several thousand kilometers of the aeolian current should be related with the succession of topographical mega-obstacles which create *venturi systems* where the speed of the aeolian flows is increased, inducing sequences of systems leading to its self maintenance.

We have seen that aeolian export of desert dust is reaching the rain forest and so enrich the fertility of the soil. For example, the soils of the tropical rain forest along the Gulf of Guinea and along the Nile

Valley owe their fertility largely to wind deposit and not just to silt deposition by the Nile River.

This study demonstrates the interdependance of all the ecozones north of the equator, and requires from the managers interested in combating wind erosion a special attention to the whole GWAS and not only a local one.

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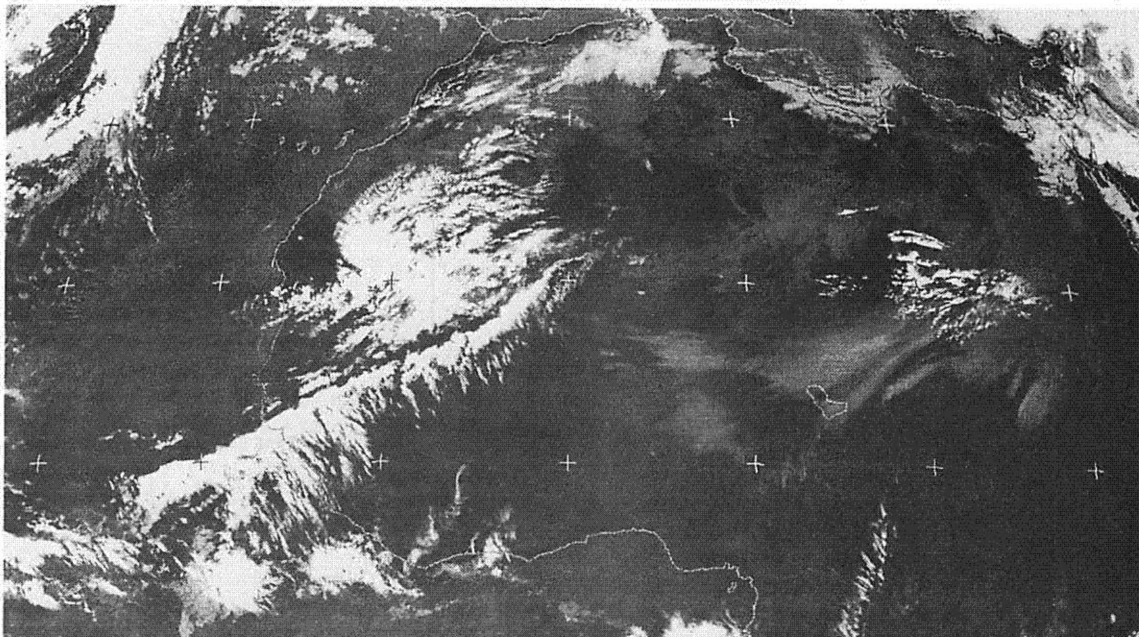

Fig 1 : The Meteosat 4 Infra-red satellite image of January 3th 1992 (Meteo France CMS Lannion) thanks to its 1:26 000 000 scale shows a dust and sand storm over the Central and Eastern parts of Sahara and the Sahel (27-30°N) until the tropical margin of the Guinean zone (between 5 and 10°N) along a distance of 3 000 km.

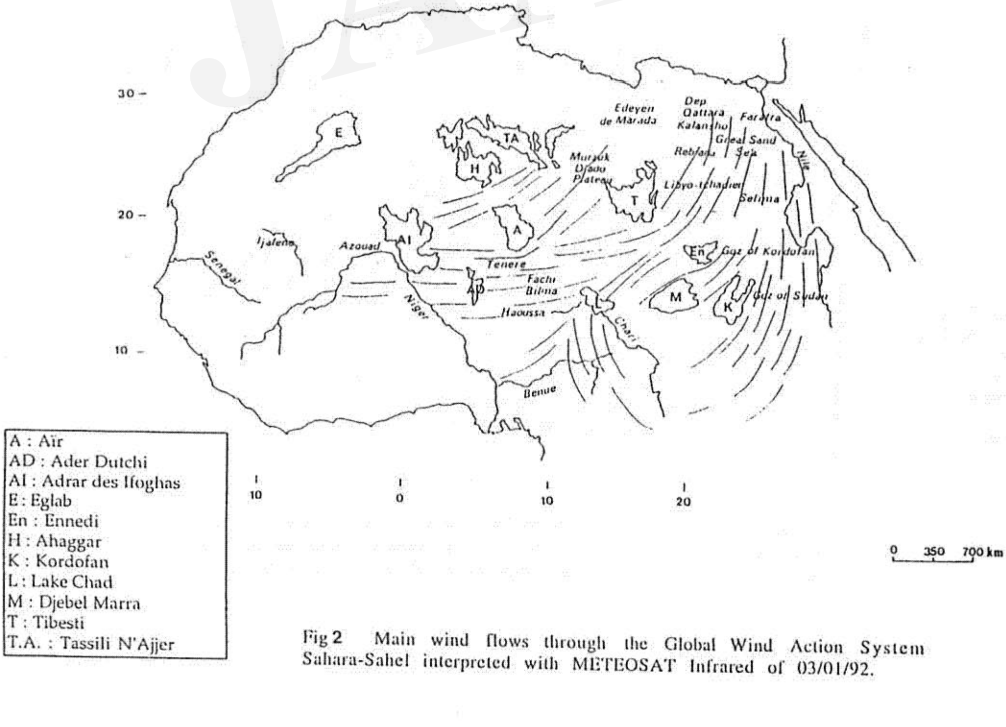


Fig 2 Main wind flows through the Global Wind Action System Sahara-Sahel interpreted with METEOSAT Infrared of 03/01/92.

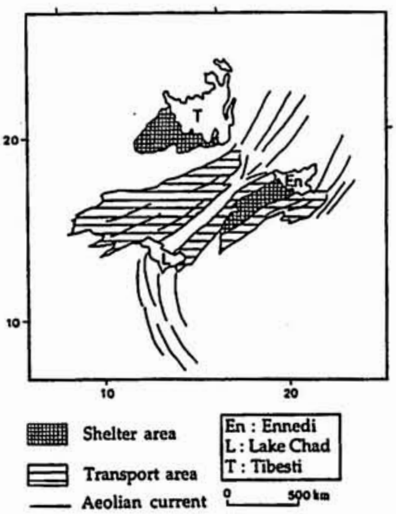


Fig3 The Ventury System between Tibesti-Ennedi and Lake Chad

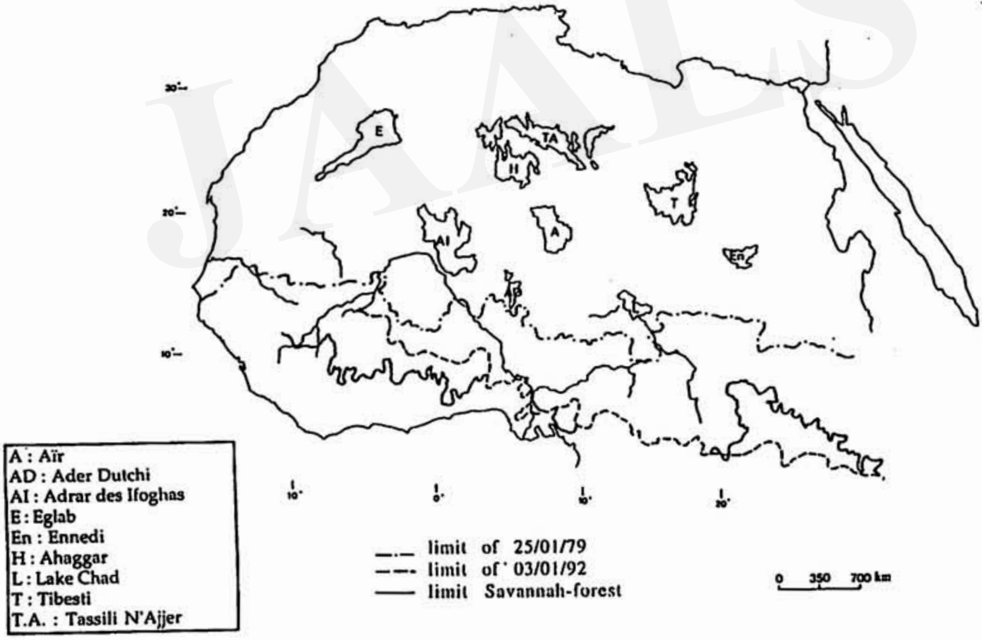


Fig4 Fluctuations between 25/01/79 and 03/01/92 of the southern limit of influence of the trans-saharan and trans-sahelian wind flows and relationship of the south limit savannah-forest of Global Wind Action System.

沙漠研究 5S, 95-97(1995)
Journal of Arid Land Studies

# Control of the Aeolian Sand Disaster along Tarim Desert Highway

Chen Guangting*

Abstract - In this note the rules of aeolian sand movement, its basic control measures and some new sand-stabilizing materials are presented with respect to the oil-transporting highway of Taklimakan Desert.

Key words: Oil-transporting highway Sand movement rules Control measures

The study of aeolian sand control techniques is one of the key programmes in the construction engineering of the Tarim oil-transporting desert highway.

Taklimakan Desert is the second largest shifting dunefield in the world. With more than 85% of its area covered by shifting dunes, it is the most mobile dunefield in the world. The desert highway, starting from Xiaotang, 40. 8km south of Tarim River, passes shifting dunefield which will prevent the highway from effective use without sand control measures. Therefore, the control of sand movement together with construction of the highway on dry sandy base is considered as the key problem to be studied.

Researchers from six institutions, including Tarim Headquarter of Oil Exploration and Development, Lanzhou Institute of Desert Research(CAS), Xinjiang Institute of Biology, Pedology and Desert Research (CAS), Lanzhou Institute of Chemical Physics Research (CAS), Xinjiang Institute of Transportation Research and the Northwestern Branch of Railway Research Academy, are responsible for the research work into sand disaster control.

The research programme is managed by means of a contract regulating the research target, which is to establish a comprehensive shelter system and technological regulations guaranteeing the year-round use of the highway on the basis of field investigation, observation and laboratory experiment. The desert highway reached TZ4 oil well by the end of July, 1994, with a total length of 219km protected by a shelter system. Subsequently, the aeolian sand control engineering of 17km of main branches, and 12km of branches to different oil-wells was also completed. The completed shelter system of 248km doubled the original plan, in addition to those around oil wells and airports, making the total protected area amount to 20,000,000m², and sand-preventing fences to 300,000m. The whole project falls into 3 subprojects: ①the counter-measures to different types of sand disaster and the establishment of an optimum protection system; ② the development of understanding the basic rules of aeolian sand movement; ③application and test of new sand control materials.

## 1. The rules of aeolian sand movement along the highway are clarified, and form the theoretical basis for the design and construction of shelter system on one hand, and compensates for the blanks in the related scientific knowledge of Taklimakan Desert on the other hand

Two meterological observatories were set up in Xiaotang and Mancan in 1992 to collect the basic climatic information of the inner part of Taklimakan Desert. In the following 2 years, various

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field observations were conducted along the northern section of the highway. These included measurement of sand flux distribution and transport rate on different sites of dunes and different ground surfaces, the air flow pattern of different roadbed sections, and the effects of sand control fences. As a result tens of thousand of data sets were collected. The simulation expeximent on the turbulence of sand laden wind was conducted in a wind tunnel. To measure the movement rate of different types of sand dunes observation pins were installed in Xiaotang. Morphological changes and movement were monitored in 2 patches of sample fields to estimate aeolian sand intensity. The aeolian sands of Taklimakan Desert are mainly fine or very fine, with mean diameter of 0. 087mm ($\phi = 3.52$). Therefore sand movement is relatively easily initiated by wind. The annual total duration of wind speeds over the initiation threshold ranges from 28140min—39330min, with 70 sandy days. Sand movement mainly occurs in spring and summer, having the temporal distribution characteristics of wind and heat coincidence. As far as its spatial pattern is concerned, sand activity gradually intensifies to the inner part. The RDD (resultant drift direction) is mainly NNE along the northern section and ENE along the southern section. Small sand dunes of 1. 0—1. 5m high move 3—10m in Xiaotang, 6— 15m in Mancan, and an estimated 20m in TZ. The estimated annual sand flux across the highway is 2692t/km in Xiaotang and 4322t/km in Mancan. Sands mainly concentrate in the lower part, those of 0—20cm accounting for 98%, and 0—10cm 80—95%.

Aeolian sand disasters fall into 2 categories, wind erosion and deposition, which are the instant behavior of air flow and dependent on the saturation condition of the sand drift. When the air flows are saturated with sand, deposition occurs, below saturation erosion occurs. The saturation condition is determined by wind velocity and sand supply. The rate of sand drift fluctuate frequently, as does the process of aeolian landform formation and evolution, and the rate of wind erosion and sand deposition along the desert highway. The above mentioned instant behavior of sand drift was first postulated through our work. However, sand drift is also influenced by many other factors, such as moisture content of sands, grain size, and vegetation coverage. The general theory of sand movement must be explained by multi-variate mathematical models. Based on this theory the aeolian dynamic zones on different geomorphological unit can be discerned along the highway.

2. Many trials and selections are needed to develop the optimum sand control system, which mainly consists of mechanical stabilization, combined withretardation, transportation and deviation

As soon as the project began, researchers decided to test technigues which had proved successful in the eastern part of our country. A shelter system with Chinese characteristics was recommended. Mechanical measures are used to guarantee the highway's operation, biological measures are used to establish new ecological systems and chemical measures supplement the other two. After 2 km of scientific, and 30km of industrial experiment, the basic principles were identified on the basis of aeolian sand activity along the highway. A set of techniques consisting of "prevention, retardation, stabilization, transportation and deviation" was introduced. According to their basic principles, the mechanical sand-stabilization belt of straw checkboard can be divided into 3 types: (1) totally closed; (2) partly closed; (3) totally exposed. The optimum width of the protection system is under investigation. It is dependent on its structure, type, expected duration and the materials used. Considering the situation at Taklimakan, researchers revised the previous formula to estimate the optimum width of the shelter system. Consequently the maximum width is estimated to be 100m which can be reduced or increased on the basis of sand disaster intensity and direction. Meanwhile design standards have also been regulated.

3. The economic target regulated by the contract was met by introducing seven new sand stabilization material. These included

Stabilization of the dune ridges by sand-laden bags to prevent dunes from movement, straw checkboard using crushed reeds, stabilization of shifting sand using annual herbaceous plants, L—P chemnical fixer, poly compound chemical fixer and nylon network fences. Crushed reeds and nylon network fences are widely used along the highway. Other techniques are under further test.

Rainfall in Taklimakan Desert generally is rare but very concentrated. For example, there occured 29. 6mm of precipitation on May 30, 1992, accounting for 56% of the annual total. Making full use of the rainfall characteristics, researchers have sown annual herbaceous plant seeds within straw checkboards, resulting in a coverage over 15% of the land surface. In some areas vegetation coverage amounted to 20— 30%. Vegetation residues can also bring sand stabilization even when the plant is withered. Sand drifting is a world-wide problem, requiring selection trongh this kind of engineering construction.

The shelter system along the Tarim Desert Highway plays a very important role in transportation, and the related research work is highly praised. However there do exist many weak points in need of furthur research.

沙漠研究 5S, 99-101(1995)
Journal of Arid Land Studies

# Effect and Countermeasure of the Energy Resources Exploitation to the Ecologiacl Environment

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Abstract—This paper discussed the effect of the Shenfu coal field exploitation on the environment and the control countermeasure which won an initial ecological result.

Key Words: Energy sources, Environment, Countermeasure

## 1. Present Status of Exploitation

The Shenfu coal field, which is praised as the cross-century energy resource base of China, has come to a new stage of rapid development through 8 years of construction. The coal field is 2,509 $km^2$ and has a 1,595,000 million tons of deposit, which are 14 percent of the deposit surveyed and 30 percent of the total reserves of power-aimed coal in China. 7 pairs of pits which have a designed scale of 15 million tons annually have been put into operation. Multiple mining facilities that are able to produce 3 million tons of raw coal annually has been put into operation in the Daliuta coal pit, the largest modern mining pit in China which has a designed sacle of 6 million tons each year. Using a complete set of advanced imported equipment and a modern management model, the construction of Huojitu coal pit and a power station have been completed. The 169 km-long railway line between Baotou and Shenfu, which couples with the coal exploitation area, has been open to traffic, as is the main trunk line and the production line, which are 267 km long altogether. Another line linking Shenfu and Pingshuo which is 274.1 km long with 65 km in the mining area is in the track laying stage and is expected to open in the near future. An upsurge in promoting the development of traffic and economy by means of coal exploitation is now in the making.

## 2. New Worries

The construction of energy resource base has caused new worries. The exploitation area is the main source of sediment to the Yellow River. In the first stage of the Exploitation Project of energy resources (1987-1992), 34.442 million tons of abandoned earth, stone and cinder were disposed. The amount will be 288.667 million tons in the second stage (1993-2000). During

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the whole Project, a sum of 323 million tons of abandoned materials will be disposed, of which 60 percent enter river channels directly. It added new soil losses to the base which had had high wind and soil erosion. According to the data from the runoff stations in Shenmu, Gaoshiya and Wangdaoheng, before the exploitationthe mining area transported as much as 23.17 million tons of sediment to the Yellow River annually. On average 31.038 million tons of sediment entered the Yellow River each year in the first stage of Exploitation Project and the increased sediment was 7.868 million tons which accounted for 34 percent of the amount of original sediment. In a water rich year(P=20%), it was as much as 42.218 million tons, a 19.048 million tons increase which accounted for 82.21 percent of the amount of original sediment. If the trend continues, transportation to the Yellow River in the second stage will be 35.492 million tons and the increased sediment will be 12.322 million tons which will account for 53.28 percent of the amount of original sediment. In a water rich year the amount will be 48.258 million tons, which will account for 108.3 percent of the annual average amount of original sediment. On account of the abandoned materials of exploitation and sediment produced by erosion, the riverbed of Wulanmulun river, which is the branch of the Yellow River passing through the Exploitation region, has been heightened 4 metres above the former river course. The torrential rain on 21st July, 1989 made 17 pits and 9 open-pits along the channel break down, and the railways destroyed by floods resulted in an over one month breakoff of transportation. In another flood that took place in August, 1992, 13 thousand ha. farmland and grassland as well as dams were destroyed. The flood level in the streets and schools of the mining area was over one metre deep. The direct loss caused by these two floods only was 27 million RMB yuan.

3. The Countermeasure

During the long period of combat with the sand, people living in the Yulin prefecture have learned the laws of sand flow and invented a set of combating technologies that give first place to biological control which combines technical measures. When they combat with the sand, they have followed the principle of taking measures and setting precautions in the light of local conditions and disasters. Biological control is the planting of tree and grass according to the above mentioned principle. Unified planning about farmland, rivers, forests and roads should be used to coordinate with belt, network and sheet forests in a premise of "right tree on right site" and forming a combating system of multiple species and forest types. Technical measures include construction of anti-wind hedges of different forms, such as line, network and grass rope by using firewood, crop straw, branches and earth. The sand dunes are evened up by the force of waterflow in those areas where there are water sources. The concrete method is as follows: this area is in the major project of "the Three-North Shelterbelt Project" and "the Desertification Combating Project", which both are among the list of China's six biggest ecological projects. The overall arrangement of the Projects are : to construct the first large scale row of backbone shelter belts along the border of Shaanxi and Inner Mongolia to lessen wind and cut sand flow in order to prevent the drift sand from entering Shaanxi; to construct the second such shelterbelt along the southern edge of the desert to give a head－on interception to its southern invasion. These two belts add to 850km with a remaining afforestation of 95 thousand ha.. The region of exploitation is at the east starting point of the two belts which form a converging attact from north and south to the desert. As for the different dunes between the belts, different kinds of anti－wind hedges are built. Sand－fixing seedlings are planted in between and net－shaped hedges are used to completely close the sand land. The linehedges, vertical to the major wind direction, should be built in the lower part facing the wind, one third from the bottom of dune. The forest between hedges can be used to level the place two thirds from the top by the force of wind. The dune can be evened up, by and large, in 4 to 5 years. While the slope facing the wind become gentler, the forest site goes gradually up. All the sand dunes will be covered with trees on the whole by 3 or 4 repeating processes. Evening up of dunes by water force is the major method employed in combating sand. Rivers, lakes and reservoirs are used as water sources and the water is drawn into the sand land by gravity or machinery. After the dunes are evened up , smooth land will come into being through the levelling by man power or machine. Through soil improvement, the desert will be changed into fertile farmland, orchard and vegetable base or factory, school and residential regions. As for the wetland widely scattered in the mining area, in which high humidity affects the growth of plant, the harmony between desert combating, soil improvement, drainage and irrigation should be created to form a series of technical measures developing and utilizing the sandy land.

4. The Ecological Benefit

The comprehensive management on the desert in mining area has achieved remarkable benefit and the desert landscape has greatly improved. Generally the height of sand dunes were 3－5 metres lower and slopes 5－7 degrees gentler. The sediment transported to rivers began to decrease. In the protective scope of the farmland shelterbelt network, the wind speed was decreasd by 28.8 percent and relative humidity increased from 5.2 to 16.0 percent compared with those in the open area. In the sand－fixing forest land, the soil texture has been changed. Compared with the non－forest land, the proportion of fine particles increased 9 to 14 times and the proportion of organic matter 4.5 to 11.5 times. The dead litter in the sand－fixing forest land weighed 1.5－2.7 tons per ha.. The increment of fine particles and organic matter in the soil increased.

沙漠研究 5S, 103-106(1995)
Journal of Arid Land Studies

# Water Resources Development Problems and Features in the Aral Sea Basin

Hikaru TSUTSUI [1] and Nobumasa HATCHO[1]

Abstract - Problems associated with water resources in the Aral Sea basin have been Analyzed. Demand based calculation of water needs can be a first step to find viable and feasible solution to the water resources and associated environmental problems in the Aral Sea Basin area. In addition, new initiative to conserve environment by creating shallow water bodies in the dried sea bottom of the Aral Sea has been described and its implication was discussed.

Key Words: Irrigation Needs, Reference Evapotranspiration, Artificial Reservoirs, Water Balance

## 1. Introduction

The Aral Sea used to be the world's fourth largest inland lake and is located in the arid region of Central Asia. Its area covered approximately 68,000km$^2$ and the maximum depth was 67m. The water runs into the lake through two major rivers, Amudarya and Syrdarya of which the water sources are the Tien Shan and the Pamir. Until the 1950s the water level was comparatively stable due to the total quantity of water inflow from the Amudarya and Sirdarya rivers (about 110 km$^3$/year), precipitation and ground water were nearly equivalent to evaporation loss from the lake surface. The level of water, however, has drastically dropped over the last 30 years due to water and land resources development that started after World War II.

.Reclamation of 7.6 million hectares of irrigated farm land caused environmental degradation in and around the Aral Basin . While the Aral Sea has recessed by about 60 percent from its size in the 1950s and its salinity has risen from 1 percent to 3-3.7 percent, the yield of fishery that used to be over 40,000 tons/year has gone down to zero. The Aral's recession has also destroyed river and sea transport and the ship building industry. The drop in the level of the Aral Sea has caused other diversified and complicated environmental problems. As the level of ground water reduced, many large and small wetlands and lakes around the Aral Sea have dried up or have been salinized. Salts accumulated on the surface of the lake bottom are now blown about with sand and dust and damage human health and farm lands in the surrounding towns such as Aralsk and Muynak.

Among many studies carried out so far, the most important is the one on water resources which has the direct impacts on the Aral Sea itself, agricultural development, and environments. Previous studies have mainly focused on water availability and supply of Amudarya and Sirdarya rivers without paying much attention to how the water is used locally. It would be important now to shift the focus from the supply side to the demand side when Colhozes and Sohozes which played important roles in managing water locally are being disintegrated. Without establishing local specific measures of managing water effectively, any proposals for saving water to avoid further deterioration of water supply conditions and environments will not be feasible.

As a first step, water demands of lower Amudarya delta are simulated. The model is a robust one with many unknown parameters and assumptions, however, it can be a start for initiating the analyses on water demands. In addition, by establishing this kind of water model, the variations in parameters can easily be reflected in the calculation of water demands which contributes to establishing better balance between water demands and supply as well as initiating better water management practices. In addition, newly proposed project for conserving environment by constructing dike systems in the Amudarya delta area is briefly described and discussed for its possible future implications.

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## 2. Agriculture and Irrigation Requirements

**2.1 Land Use/ Cropping Patterns** Any viable solution must address the water use for cotton production, since this one crop consumes nearly 50 percent of total irrigation needs in the region. Irrigation application for cotton in the region varies from 7,500 to 10,100 $m^3$/ha per crop season averaging 8,700 $m^3$/ha. A transition away from cotton requires the emergence of alternative economic activity, for example, by generating employment in a greatly expanded cotton textile industry as a substitute for primary cotton production.

Low-productivity saline soils, on which low yields now are obtained despite enormous water use, must be removed from irrigation. Even if only 5% of the lands which are least suited for irrigation, that is 0.5 million hectares, are removed from irrigation (given a current existing water consumption on these lands of 15,000 $m^3$/year), water saving would amount to some 7 $km^3$/year. It is possible that because of environmental and economic concerns it will be desirable to remove an even larger area from irrigation because 15% of the irrigated lands in the Aral basin are in an extremely unsatisfactory condition, with the saving of about 15-20 $km^3$/year or more.

A study also must be made of the possibility of reducing the area under rice cultivation. Rice is the crop requiring the most water and under the conditions prevailing in the region its irrigation consumes 25,000-55,000$m^3$ of water per hectare per year. A reduction of the areas planted in rice in the region by at least 100,000 hectares would make it possible to liberate at least 3 $km^3$ of water annually. It must be noted that most part of such large amount of water is used to leach salts that accumulated in the soil during non-rice crop cultivation period. Leaching function of rice cultivation should be taken into account in considering the reduction of rice irrigated area.

It is entirely evident that the intensive expansion of irrigated land must be replaced by the more intensive use of existing irrigated lands through improved irrigation water management and efficiency, crop rotation system and crop mix as well as improved and appropriate technologies.

**2.2 Calculation of ETo and Net Irrigation Needs** Reference evapotranspiration(ETo) of the lower Amudarya delta is calculated by Penman-Montieth method with the climatic data of Chimbay. Wind data at Chimbay was not available and values of Mazari-Sharif in Afghanistan was used. The calculated results from April to October (vegetation period) are shown in **Table 1**.

Major crops grown in lower Amudarya delta area(KKAR:Kara-kalpakstan Autonomous Region) are cotton, rice, fodder and maize. FAO standard crop coefficients in dry region and growing period for different growth stages are utilized to calculate crop water requirements for different planting periods. Net irrigation needs ($m^3$/ha) of each major crops are calculated on a decade basis and is shown in **Figure 1**. Calculated values and those by Dr. Zhu and other sources are shown in **Table 2**.

**Table 1 ETo in the lower Amudarya Delta (Chimbay station)**

| | April | May | June | July | Aug. | Sept. | Oct. |
|---|---|---|---|---|---|---|---|
| Rainfall(mm/month) | 14.1 | 11.4 | 3.5 | 1.2 | 2.9 | 4.3 | 8.7 |
| ETo(mm/day) | 2.8 | 4.5 | 5.9 | 6.2 | 5.1 | 3.2 | 1.8 |

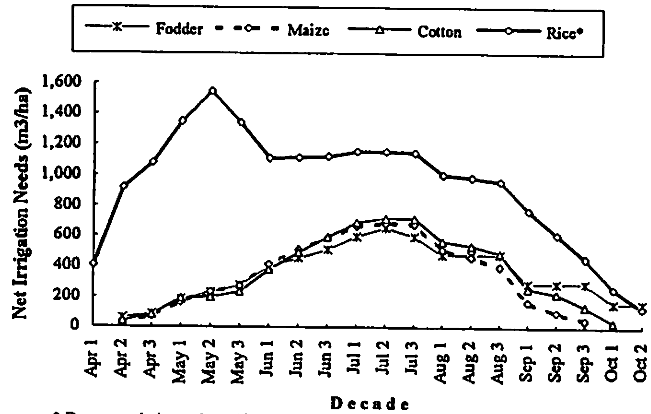
**Table 2 Comparison of Net Irrigation Needs ($m^3$/ha)**

| | Calculated[1)] | Dr.Zhu (1991) | Field Survey[2)] | Institute [4)] | Hydro Model[5)] |
|---|---|---|---|---|---|
| Cotton | 7,341 | 7,500 | 3,500[3)] | 7,200 | n.a. |
| Rice | 20,733 | 28,000 | 24,000 | n.a. | 24,300 |
| Fodder | 7,436 | 9,500 | 8,000 | n.a. | 7,600 |
| Maize | 6,700 | 7,600 | 6,500 | 6,500 | 5,250 |

1) Field Application Efficiency of 90 % assumed. 2) JSIDRE/JIID Joint mission in September 1994

3) 40 percent of the need is supplied from ground water 4) Institute of Sredazgiprovodkhoz Moscow 1990)

5) Standard irrigation rate based on Hydro-model in Kazakhstan



* Deep percolation = 5 mm/day, Land Preparaton Water=380mm

**Figure 1 Calculated Net Irrigation Needs ($m^3$/ha) in the Lower Amudarya Delta**

The calculated results show similar values to other information sources except for rice which is calculated relatively low. The reason could be attributed to relatively small deep percolation rate assumed or crop coefficient used for rice. In addition to climate and crop data, such factors as the water supply from underground, the difference in irrigation method, and leaching requirements which affect irrigation needs would require further field studies for establishing better water management model based on crop water demands.

## 3. Simulation of Water Demands in KKAR

To test the viability of demand based approach mentioned as above, water demands in KKAR with an irrigated area of 558,600 ha was simulated using the cropping pattern of 1987. Planting starts from the second decade of April and harvest is done in October. The peak demands period came in July with the peak of 1,090 $m^3$/sec in the second decade (case I). When the areas of cotton and rice are reduced as much as 30 percent and the area of maize increased to 33 percent (case II), the peak demands is reduced to 1,018 $m^3$/sec and 1.6 $km^3$ of seasonal water demands could be saved. Similar saving and peak cut can be done by improving the irrigation efficiency from original 50 percent to 60 percent (case III) with the saving of 1.8 $km^3$ of total demands and peak cut to 908 $m^3$/sec in July.

By establishing simple simulation model, it is easy to change parameters of irrigation and check the impact on water demands. The model can be applied to identify in which area efforts should be directed to save water and to better match between water demands with supply .

## 4. Environmental conservation by creating artificial water bodies

An initiative to create artificial reservoirs (water bodies) in the dried bottom of the Aral Sea has started in 1987 to conserve environments and to rehabilitate local production bases such as fishing, mink culture, and irrigated agriculture*. Artificial reservoirs are created by constructing dikes along the contour lines with an average water depth of 0.9-2.5m.(see **Figure 2**) The dimensions of artificial reservoirs are listed in the **Table 3** below.

In addition, lakes Sudochie (area 61,500 ha with 922 mil. $m^3$) and Makpalkul (15,300 ha with 230 mil. $m^3$) are rehabilitated to allow water level control for fish breeding. Natural lakes and ponds are supplied with river/drainage discharge.

Creation of these reservoirs and water bodies has swiftly brought about benefits to the region. Fish catch which once had been more than 20,000 ton in the southern part of Aral Sea in the early 1960s and become zero in the early 1980s has recovered to 4,670 ton in 1993. Mink production reached back to 10,000 in 1994 and new irrigated area of 31,000 ha has been developed. With the return of agriculture/fish production, the population of Muynak, which was 20,000 in 1960 and

* In the vicinity of Aralsk town, Saryshynganak reservoir was constructed by a dike crosing the north-eastern edge of the Aral sea and by diverting water from the Syrdarya River by Kazakhstan Government.

declined to less than 10,000 in 1987 has recovered to about 13,000 in 1994. In addition, it is reported that the incidence of dust storms has been declined.

**Table 3 Dimensions of Artificial Reservoirs**

| Reservoir | Capacity | Area | Water duty | Dike |
|---|---|---|---|---|
| | mil. $m^3$ | 1,000ha | mil.$m^3$/year | L(km)/H(m) |
| Mezhdu. | 850 | 38 | 200 | 1.3/11 |
| Muynak | 210 | 14 | 298 | 21.5/4 |
| Rybak | 165 | 11 | 232 | 6/5 |
| Jiltyrbas | 210 | 14 | 736 | 38/4 |
| Adjibay | 290 | 29 | 821 | 25/4 |
| Total | 1,725 | 106 | 2,287 | |

Future plan includes total development of 267,000 ha of water bodies. Several problems have to be solved to realize full developments of these water bodies. First is the stable supply of water from Amudarya. Total expected discharge required for compensating evaporation and water uses are expected to be 4.5 $km^3$.

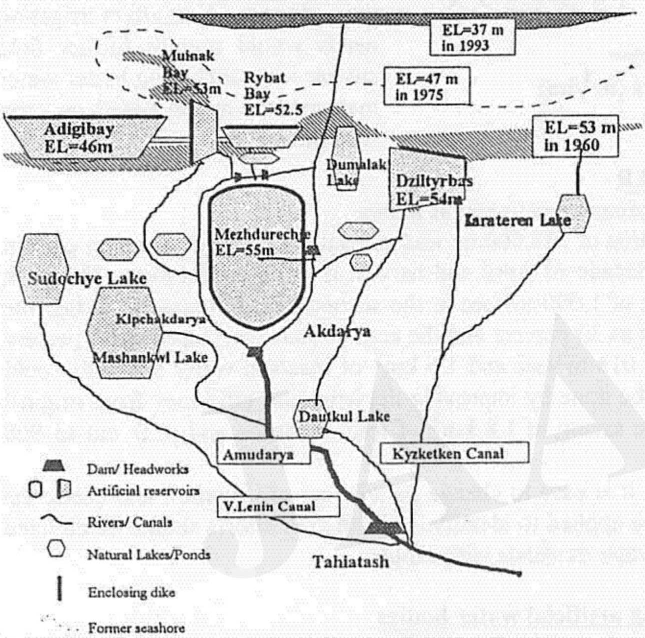



**Figure 2 Layout of Artificial Reservoirs**

First is the stable supply of water from Amudarya by improving water use efficiency and other measures mentioned above. Total discharge required for compensating evaporation and water uses is about 4.5 $km^3$. To prevent the drying-up of these water bodies, careful attention should be paid to the secured supply of water. Second is the problem of sedimentation. Measures should also be adopted to prevent the sedimentation of created water bodies by high silt load of Amudarya river which amounts to 40 million tons/year.

Impacts of creating these water bodies, especially on the water balance( inflow and evaporation rate) and sedimentation, need further investigation before implementing full development plans

## 5. Conclusion

Problems associated with water resources in the Aral Sea basin have been discussed. Demand based calculation of water needs can be an important initiative to find viable and feasible solution to the water resources and associated environmental problems in the Aral Sea Basin area. In addition, new approach of conserving environment by creating shallow water bodies in the dried sea bottom could become viable option if careful attention is paid to available supply and sedimentation problems.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沙漠研究 5S, 107-110(1995)
Journal of Arid Land Studies

# Effects of Forest and Net Windbreaks on Climatic Improvement and Protection of Sand Movement in Arid Lands of Northwest China

**Taichi MAKI*, Borong PAN**, Mingyuan DU*** and Ryoji SAMESHIMA*****

Abstract – Prevention of desertification and greening a desert might be obtained by techniques of climatic improvement or alleviation brought about by forest windbreaks and net windbreaks. Micro-meteorological observation related to the climatic conditions in arid lands were carried out at the Turpan Desert Research Station in Northwest China. It is suggested that forest and net windbreaks could be very effective for the alleviation of adverse climatic conditions in arid lands, and could be effective for the prevention of sand erosion or sand movement around farmlands in oases or agricultural areas and roads in sand dune areas.

Key Words: Climatic improvement, Desert, Marginal land, Meteorological alleviation, Forest and net windbreaks

## 1. Introduction

Arid and semi-arid lands occupies one third of the total surface area of the world. The process of desertification has been accelerated recently by over-development, cultivation, deforestation, grazing and consumption of water resources based on mainly artificial reasons. Although a desert has long been developing in China, particularly in Northwest China, the desertification has been recently increasing. Meteorological observation was carried out at Turpan, Xinjiang Institute of Biology, Pedology and Desert Research, Chinese Academy of Sciences from 1990 to 1994.

It was demonstrated that the meteorological elements, i.e., wind speed, air temperature, surface soil temperature and relative humidity could be improved and sand movement or sand erosion also could be prevented by the uses of the multiple row forest windbreaks made of several kinds of mixed trees and by the polyethylene Russell net windbreaks under very dry conditions in all seasons, in particular at the high temperature season.

## 2. Observation Methods

Meteorological elements of wind speed (U) at 1.5 m, air temperature (Ta) and relative humidity (RH) at 1.0 m, and surface soil temperature (Ts) at 0 m were measured, and the height and lint number by hill for cotton crop were observed for two rows of mixed trees made of *Ulmus pumila* L., *Elaeagnus angustifolia* L. and *Populus euphratica* Oliv.

Relative wind speed (Ur) is the standard value 100% at −20 H. This numeral H is the multiple distance of windbreak height (negative sign: windward, positive sign: leeward).

## 3. Observation Results

### 3.1 Observation with two rows of tamarisk windbreaks

Schematic diagram of two rows of tamarisk forest windbreak is shown in Fig. 4. The porosity of windbreak was 50% at higher layer of it and 0% at lower layer. The heights of windbreaks were 10.0 m and 5.5 m, and the heights of tamarisk trees were 2.5 m and 4.0 m for the first and second windbreaks, respectively in April and July, 1992.

(a) 15:30 April 25 (Fig. 1A): U was decreased significantly by the first windbreak, recovered largely and decreased again by the second. Ts was low inside the windbreak due to shade, but high at the top of the windbreak. RH increased inside to leeward side of the windbreak. Ta was high by the windbreak.

(b) 18:30 April 25 (Fig. 1B): U decreased drastically by the first windbreak except at the top of the windbreak, recovered a little, decreased again after passing through the

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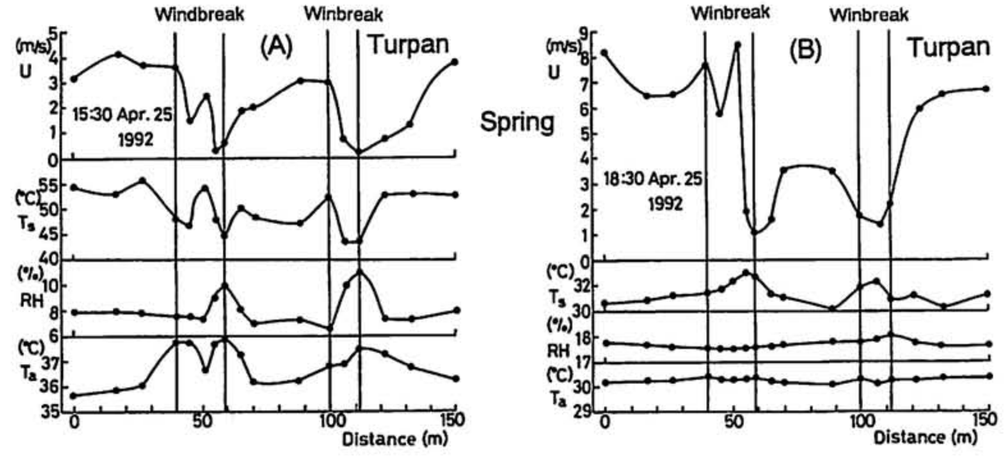


Fig. 1. Meteorological improvement caused by two rows of tamarisk windbreak.

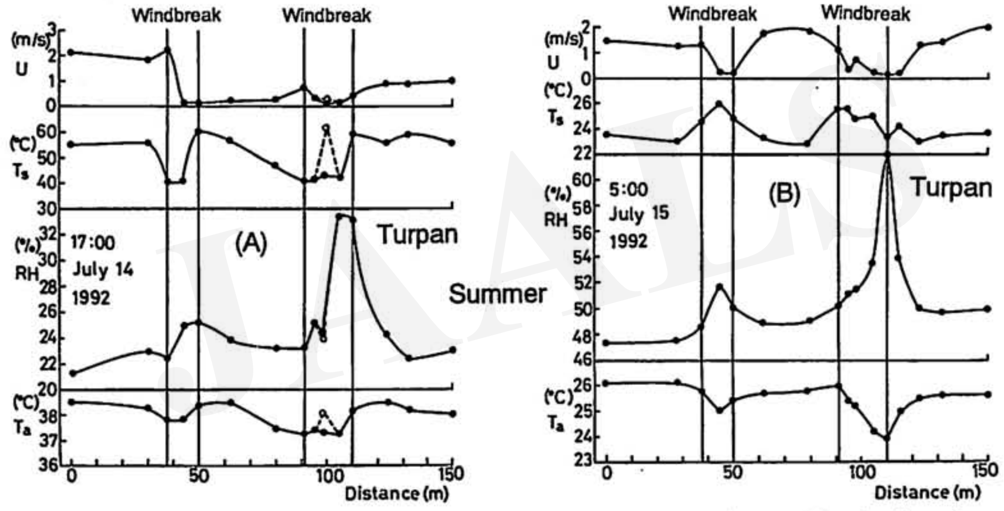


Fig. 2. Meteorological improvement caused by two rows of tamarisk windbreak.

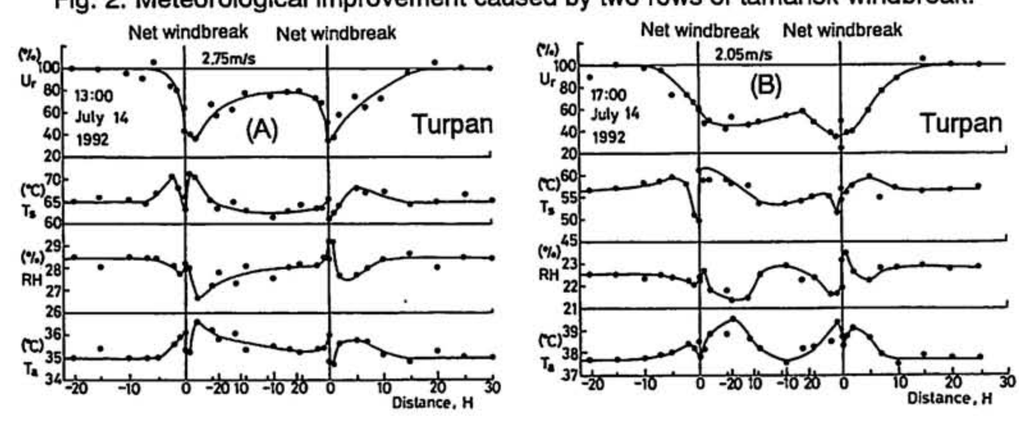


Fig. 3. Meteorological improvement caused by two rows of net windbreak.

second and recovered fast. Ts was slightly high inside the forest windbreak. RH and Ta were not changed because of strong wind.

(c) 17:00 July 14 (Fig. 2A): U was decreased significantly by both windbreaks. Ts was low inside the windbreak, but high at the top of the windbreak. RH increased inside to leeward side of the windbreak and maximum relative humidity increased with windbreaks. Ta was low due to decreased soil temperature.

(d) 5:00 July 15 (Fig. 2B): U was decreased by two rows of windbreaks. Ts was high inside the windbreaks. RH increased from the first to second windbreaks and maximum relative humidity increased with windbreaks. Ta was low inside the windbreak because of the humidity increase.

3.2 Observation with two rows of net windbreaks

The net windbreak consisted of polyethylene Russell net 1.85 m in height and 30 m in length with the net density of the value (100% – porosity) of 40%. The interval between two rows of net windbreaks was 50 m. Observations of two rows of same net windbreak were carried out in July, 1992.

(a) 13:00 July 14 (Fig. 3A): Ur decreased significantly by the first net, recovered fairly and decreased again by the second. Ts and Ta increased near the net in both windward and leeward sides, however, the change of RH showed the reverse change of Ta.

(b) 17:00 July 14 (Fig. 3B): Ur decreased significantly near the first and was small at the area between two nets, but the protected area of Ur was not wide in the leeward side of the second. Ts and Ta increased until 10 H in the leeward side. RH decreased by the first, but recovered or increased a little after 10 H of both nets. Changing pattern of Ta was reverse of that of RH.

3.3 Protection of drifting sand with two row forest windbreaks

The sand accumulation is shown in section view in Fig. 4. The heights of sand accumulation by the first windbreak were 8.0 m and 7.5 m for high and middle places, respectively, however, the height by the second was 1.5 m.

3.4 Protection of drifting sand with net windbreak

(a) The heights of sand accumulation by net windbreaks were observed in May, 1991 (Fig. 5A). Sand accumulated at the region from –5 H to 12 H. The sand accumulation of 40 cm for the B net of 45% density was higher than that of 30 cm for the A net of 40% at 3 H leeward side for 6 month terms, and sand did not accumulate just under the nets by strong wind.

(b) The sand accumulation for the B net of 45% in August, 1991 is shown in Fig. 5B. The heights of sand accumulation were highest 60 cm and 45 cm around 3 H to 4 H under the conditions of no sand and sand accumulation, respectively, because of difference of sand supply. The lower part of the net was buried by sand of 35 cm depth for some areas.

3.5 Effect on crops by mixed forest windbreaks

(a) The effects on the crop height of cotton caused by windbreaks of Elaeagnus and Ulmus (elm) are shown in Fig. 6A. The crop height was greatest at 3 H and smallest at 13 H for the first windbreak or –2 to –3 H for the second. The second windbreak of Elaeagnus and Populus (poplar) had the great height at around 14 H or –1.5 H. The height of cotton was 15 cm in the control field without forest windbreaks.

(b) The crop height was greatest at 4 H to 5 H and smallest at 12 H to 13 H (Fig. 6B). The second windbreak had the greatest height at around 16 H or –2H. The control height was 50 to 80 cm.

(c) The change pattern of cotton lint number by hill (Fig. 6C) related to cotton production was more significant than that of the crop height of cotton. The protected area was rather wide in spite of the severe environment under the dry and hot condition.

4. Concluding Remarks

(1) Windbreaks have characteristics that severe climate over a wide region is alleviated; water consumption decreases, crop production increases and crop quality improves. Consequently, windbreaks are very effective at the marginal land in arid lands.

(2) The effects of windbreaks in summer in the dry lands indicate a decreased wind speed, increased humidity and decreased temperature at night, but there is no similar effect on the daytime temperature. However, the final total effect must be evaluated

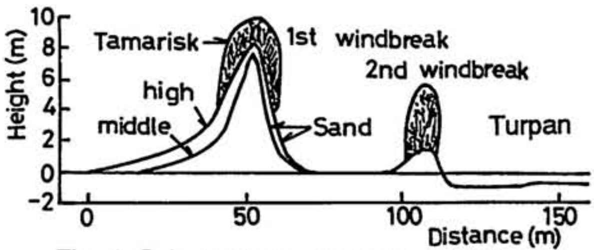


Fig. 4. Schematic diagram of two rows of tamarisk forest windbreak.

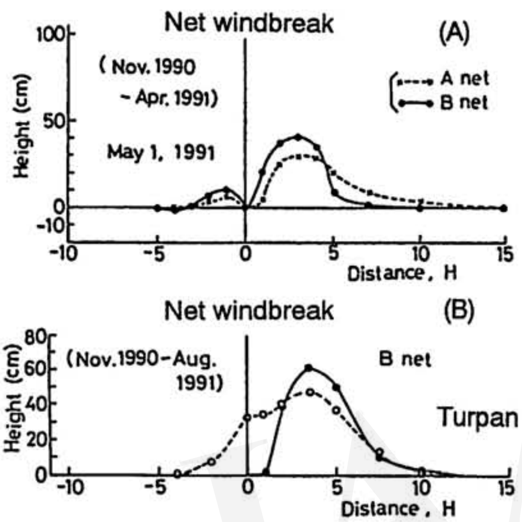


Fig. 5. Variations in sand accumulation produced by net windbreaks.

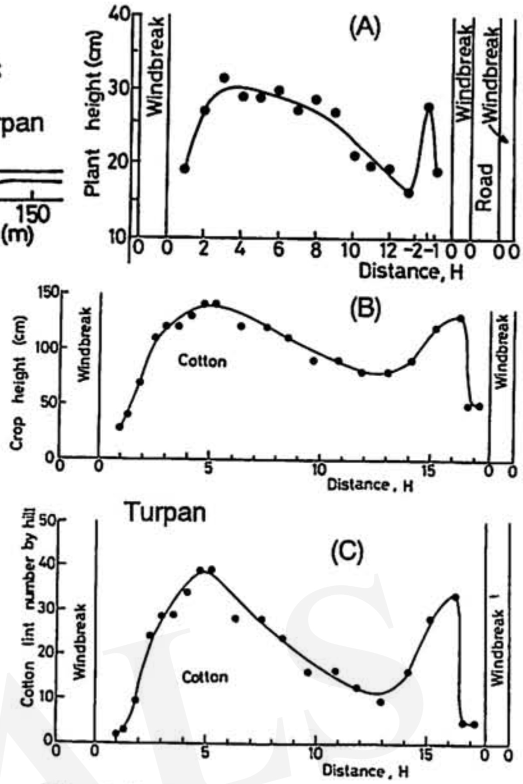


Fig. 6. Variations in (A, B) heights of cotton and (C) cotton lint number by hill by two rows of windbreak.

over a long time period.

(3) It is suitable for forest windbreaks in the frontier of marginal regions because tamarisk has great resistance to strong wind, dryness, heat, cold, sand and salinity.

(4) It is important to make multiple rows of windbreaks made of mixed trees, i.e., Ulmus, Elaeagnus, Populus, etc. It is possible to create oases and agricultural farming in arid lands.

(5) Protection from strong wind, wind erosion and drifting sand by decreasing wind with net windbreaks are evaluated as significant. It is effective to set the nets of 40 to 50% densities in arid lands for improving climatic condition, and for protecting wind erosion and sand accumulation.

(6) The growing of forest windbreaks takes many years, but net windbreaks can immediately function and also protect for growing forest windbreaks.

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沙漠研究 5S, 111-114(1995)
Journal of Arid Land Studies

# Integrated Control of Tailings Desertification in Jinchang,China

Cong Zili[1]*

Abstract - Jinchang city is a base producing Ni and Co in China. Tailings are emitted during refining ore, and tailings desertification results in severe environmental pollution. In this paper, the causes of tailings desertification, control measures, and social, environmental and economic benefits after controlling are discussed. In addition, the possibility of afforestation and farm recovery are proposed.

Key Words:Tailings,Desertification, Cover engineering

## 1.Introduction

Jinchang city is located in the east of Hexi Corridor of Gansu province and has a typical dry continental climate, dry and windy. It is the biggest Ni and Co base in China. Some nonmetallic products, such as sulfur, selenium and tellurium are also extracted.

The old tailings-reservoir of Jinchuan Company, north of Jinchang city, was about 3.15km$^2$, stores 38.77 million tons of sludge from 1964 to 1991. The tailings were of small-size(as shown in table 1.) Tailings sand moved with wind and endangered farmland and people's lives, so control was urgently needed.

Table 1. Grain size distribution of tailings

| grain size (mm) | >0.15 | 0.15-0.10 | 0.10-0.074 | 0.074-0.053 | 0.053-0.043 | 0.043-0.030 | 0.030-0.020 | 0.020-0.010 | <0.01 |
|---|---|---|---|---|---|---|---|---|---|
| percentage(%) | 4.01 | 4.64 | 13.49 | 13.18 | 9.23 | 16.87 | 17.92 | 12.65 | 8.01 |

## 2.Process of Tailings Desertification

The conditions of tailings desertification are: deposited area chequered with coarse and fine grain around the reservoir, dry atmosphere, and strong wind. There are 74 days with wind-speed more than 8m/s and, 17 days with wind-speed more than 24m/s every year, the instantaneous maximum wind-speed was 34.2 m/s(1993.5.5). Wind-speed on the top of the reservoir could be described as follows:

$$Kn=(1+0.06H)V, \quad (1)$$

where Kn is wind-speed on the top of the reservoir, H is the height of the reservoir and V is the wind-speed on the ground.

By evaporation and percolation, the water loses very fast in deposited sludge. Thus, the surface of reservoir is dry and loose, the tailings moisture is only 0.96%. Tailings sands were blown out of the reservoir and formed, tailings sands formed round, drift, crescent dunes and a dune chain on northeast and north of the reservoir with an expanding of dry area and deflation. In the condition of nonpile movement, the rate of transferring sand followed equation:

$$Q=(V_1-V_0)^{1.38} \quad (2)$$

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where Q is the rate of transporting sand; $V_1$ is wind-speed at two meter height; $V_0$ is threshold wind-speed of tailings sand at two meter height, here $V_0$ is 7m/s; R=0.91.

The tailings sand extended SE with winds from NNW, NW, WNW. The trail of sedimental tailings sand can be found as far as 8km away, and the polluted area was 5183ha. The contaminated area and deposited quantity of tailings are shown in table 2.

Table 2. Contaminated area and deposited quantity of tailings

| type of land | area(ha) | deposited quantity($m^3$) |
|---|---|---|
| edge of reserve bridge | 3.75 | 98760 |
| forest land | 74.00 | 148000 |
| urban district | 624.00 | 124800 |
| discarded farmland | 52.78 | 52776 |
| farmland | 287.22 | 84171 |
| gobi grassland | 4141.25 | 82900 |
| total | 5183 | 591407 |

Tailings sand outside the buried farmland, polluted air, and harmed production, life and the environment of Jinchuan County.

## 3. Controlling Tailings Desertification

From 1984, Jinchuan has tried to control deflation and extension of the tailings reservoir in several ways. In 1992, on the basis of these practical experiences, the Lanzhou Institute of Desert Research suggested an unified plan on controlling desertification of tailings by bioengineering. This plan could be described as " overlaying, impoundment, recovering vegetation and planting ". First, the tailings sand land was overlaid by gravel soil and irrigated using waste water. Then, the polluted land was vegetated and cropped by soil reclamation.

In order to accomplish this plan, a great deal of preparation was done. We observed and studied experiences about controlling desertification, collected a great deal of information about meteorological phenomena, water quality, depositing process of tailings, grain size distribution, bearing capacity etc.. According to the relationship of blown sands, wind-speed and particle size as shown in Table 3., we considered that particle size of more than 80% of gravel cover must be above 0.5mm, the maximum must be above 10mm for the surface cover.

Table 3. Threshold wind-speed of gravel

| diameter of gravel(mm) | 1-1.25 | 1.25-2.5 | 2.5-5.0 | 5-10 | 10-20 | 20-40 | 40-80 |
|---|---|---|---|---|---|---|---|
| wind-speed at 6m height(m/s) | 15.2 | 20.1 | 26.5 | 35.0 | 46.2 | 61.0 | 80.5 |
| wind-speed at 10m height(m/s) | 16.0 | 21.1 | 27.8 | 36.7 | 50.5 | 64.0 | 84.5 |

The control processes were: (1)repaired ways from quarries to reservoir; (2)leveled the desert surface of reservoir; (3)transported gravel and covered the surface of reservoir; (4)leveled gravel overlay. The covering engineering was begun on April 6,1993, and ended on September 17,1994.

## 4. Controlling Results

After controlling, sand pollution and its harmful effects disappeared. A better biotic environment and social-economic benefits were obtained. A black desert changed into even on which cars can move easily. Suspending dust disappeared . Sand transport rate is now only about 1/5133 of that before covering. Many kinds of plants, such as Suaeda glauca Bge, Halogeton arachnoideus C.A. Mey etc. inhabited the area naturally in the first rainy season after the tailings sand was covered. They occupied about 15-30% of the area. The surface of tailings reservoir was abundant in grasses, air was refreshed and life environment was improved.

Compared with other suggestion which would cost 25 million yuan and last for nearly 10 years, this engineering cost only 4.5 million yuan and last for 18 months. More than the investment in the engineering, a large amount of money and time will be saved, which would be spent on cleaning dust on equipment, streets and industrial rooms, etc. Better economic benefit will be earned also from stick breeding on the waste farmland.

## 5. Improving Biotic Environment Completely by Afforestation

Some researchers considered that Ni and Co would cause chlorosis (Wllohouse),and aeschynomenous phytogroup would disappear in nickeliferous soil (Editedly).

In this paper, the content of Ni, Co and Cu in tailings is 42.9, 8.1, and 17 times respectively as much as in soil, as shown in Table 4. And the content of all salt is 10.8 times as much as in soil. The pH of waste water used in irrigation is about 7.36. The content of salt in water is 2446mg/L, Cl, Ca and Mg is 930mg/L, 85.44mg/L and 114.05mg/L, respectively, and metal elements in waste water are much more than that of irrigating water, as shown in Table5..

Table 4. Content of Ni, Co, Cu in tailings and soil

| sample | Ni | Co | Cu |
|---|---|---|---|
| tailings | 0.206 | 0.0114 | 0.165 |
| soil | 0.005 | 0.0014 | 0.010 |

Table 5. Content of metal elements in industrial waste water(mg/L)

| elements | Ni | Fe | Zn | Cu | Co | Mn | Pb | Cr |
|---|---|---|---|---|---|---|---|---|
| waste water | 8.67 | 2.69 | 0.39 | 0.32 | 0.21 | 0.081 | 0.024 | 0.017 |
| irrigating water | 0.046 | ---- | ---- | 0.007 | ---- | 0.02 | ---- | 0.003 |

In spring of 1994, we planted 44 kinds of plants, such as arbor, shrub, grass, crops and fruit trees on about 1.6ha. Most of them grew up very well, but high content of salts and metal elements in tailings and waste water injured some trees. Rhus typhina L. and Populous gansuensis C Wang et H.L. Yang. appeared mosaic, but plants of the bean family did not show this symptom.

## 6. Recovering Cropping on Abandoned Field

Due to the pollution of nickelliferous tailings, about 53 ha of farmland was abandoned. In order to find ways of recovering farming, we did contrast tests with the same agritechnique, irrigating water, etc. on a tailings polluted field(test field) and a nonpolluted field (contrast field).

The test field was made up of 75% tailings sand and 25% natural soil, and the contrast field was natural soil. About 3kg/m$^2$ of sheep dung was used in each field. There were few differences between the two fields in size, salt and nutrient contents, but the differences of content of Ni, Co, Cu were notable (in Table 6). The content of Ni, Co and Cu in the test field was as 34.4, 6.4, 11.9 times higher than that in the contrast field respectively.

Red pepper, sword bean, cauliflower, potato, tomato, eggplant, wheat, barley broom corn millet and soybean grew up much better and had higher yield on the test field than on the contrast field. Because tailings are black-grey and sandy, the test field had better heat-absorbing ability and higher soil temperature. These provided a better conduction for thermopiles (e.g. red pepper) and resulted in higher output. Although the content of Ni, Co and Cu were much more on test field, agricultural products were in the same order on the two fields as shown in table 7..

Table 6. Content of nutrient and metal elements in test field

| sample | organic matter(%) | quick resulting nutrient(mg/100g) | | | metal elements(%) | | |
|---|---|---|---|---|---|---|---|
| | | hydrolytic N | $P_2O_5$ | $K_2O$ | Ni | Cu | Co |
| test field | 0.096 | 2.06 | 1.17 | 31.6 | 0.172 | 0.119 | 0.009 |
| contrast field | 0.614 | 2.90 | 1.24 | 14.6 | 0.005 | 0.010 | 0.0014 |

Table 7. Output and content of metal elements in agricultural products

| sample | output(t/ha) | | contents of metal elements(mg/kg) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | test field | contrast field | sample position | type of sample | test field | | | contrast field | | |
| | | | | | Ni | Co | Cu | Ni | Co | Cu |
| wheat | 3.08 | 2.14 | seeds | dried | 10.7 | 0.18 | 14.6 | 3.3 | 0.14 | 10.6 |
| barley | 2.21 | 2.00 | seeds | dried | 5.6 | 0.15 | 9.0 | 2.6 | 0.15 | 8.1 |
| broom corn millet | 1.53 | 1.34 | seeds | dried | 26.3 | 0.60 | 14.1 | 15.8 | 0.27 | 6.4 |
| soybean | 2.78 | 2.14 | seeds | dried | 55.8 | 0.96 | 51.5 | 33.5 | 0.72 | 55.3 |
| broad bean | 2.16 | 2.44 | seeds | dried | 28.2 | 0.34 | 74.8 | 10.0 | 0.15 | 60.6 |
| sword bean | 24.96 | 9.67 | fruits | fresh | 6.9 | 0.09 | 5.6 | 2.00 | 0.03 | 4.9 |
| potato | 33.36 | 26.68 | tuber | fresh | 0.5 | 0.12 | 41.7 | 0.3 | 0.05 | 2.0 |
| tomato | 65.16 | 62.81 | fruits | fresh | 0.9 | 0.06 | 5.2 | 0.5 | 0.08 | 5.8 |
| eggplant | 29.14 | 28.92 | fruits | fresh | 4.5 | 0.31 | 64.2 | 3.0 | 0.12 | 15.2 |
| red pepper | 26.08 | 6.752 | fruits | fresh | 6.4 | 0.10 | 4.4 | 1.4 | 0.28 | 27.8 |
| cauliflower | 37.74 | 31.40 | flower | fresh | 2.6 | 0.05 | 2.3 | 1.2 | 0.01 | 8.1 |
| winter white radish | 40.27 | 41.68 | root | fresh | 1.0 | 0.05 | 18.7 | 0.7 | 0.09 | 2.0 |
| water melon | 44.22 | 67.14 | fruits | fresh | 1.4 | 0.07 | 0.8 | 0.9 | 0.06 | 1.2 |
| bailan melon | 30.87 | 44.57 | fruits | fresh | 1.1 | 0.06 | 0.2 | 1.1 | 0.07 | 1.4 |
| hami melon | 20.51 | 24.86 | fruits | fresh | 0.8 | 0.05 | 0.1 | 0.4 | 0.05 | 1.0 |

All these show that: crops could absorb some metal elements selectively. By soil reclamation, polluted land could be cropped again.

## 7. Conclusion

Desertification of tailings always pollutes the environment seriously. By overlaying, irrigation, recovering vegetation and cropping, it only cost a very short time to control tailings. This test is very profitable to control pollution of tailings and industrial waste in an arid area.

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沙漠研究 5S, 115-118(1995)
Journal of Arid Land Studies

# The Effect of a Desert City on Aeolian Dust Deposition

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Abstract - The effect of a desert city on dust deposition was studied in the city of Beer- Sheva located in the northern Negev desert of Israel. Samples of dust were collected in five different locations in the city and its outlying suburbs, and were compared with two reference points located 13 km west and 27 km east of the city in an open, undisturbed tract. The average quantity of dust in the city and the average rate of deposition was more than 200% greater than the amount collected outside the city. The average diameter of the dust was 21 μm in the city and 14 μm outside the city. The mineralogical composition of all dust collected was identical, and similar to the local loessial soil.

Key words: Dust, Desert city, Urban climate

## 1. Introduction

Desert margins are known as areas where large quantities of dust were deposited. The city of Beer-Sheva is located in a valley in the Northern Negev Desert. Beer-Sheva, which has an annual average rainfall of 206 mm, is in a transitional zone between the semi-arid area in the north and the arid area to the south. There is no rain during the hot summer season between June and September. The modern city of Biblical Beer-Sheva was founded at the end of the 19th century. Its greatest period of development was after 1949, and today it has 140,000 inhabitants. A chain of errors and lack of understanding of the desert environmental conditions characterize the physical planning of Beer-Sheva after 1948. The planning of a garden-city of small urban units divided by open spaces designated for gardens created, instead, open spaces between the urban units which serve as dust bowls.

## 2. Urban modification of wind turbulence

The airflow changes over city buildings are most important for dust transport. Several wind tunnel models and actual measurements in cities have shown that flow is diverted and deflected around and on top of buildings, thus creating two important changes in the wind characteristics: first, there are many eddies in which the vertical component of the wind is very strong, which provides the means of lifting up coarse dust particles; second, the diversion of flow around the corners of buildings make these points particularly windy -- up to twice as windy as they would be if there were no buildings (Hanlon, 1972). These strong winds around buildings increase the rate of deflation of dust-sized particles in the city streets. The air above a city is usually warmer than that above the surrounding countryside (urban heat island). This effect is very salient during nights, with thermal inversion causing air circulation patterns that enfeeble the inversion and create a dust dome over the city.

## 3. Aim of study

The hypothesis behind the research is that the urban heat island, together with the increase in the airflow speed and vertical component over the city, and construction and infrastructure

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activities produce growth in the amount of dust deposited in the city. Since many studies on aeolian dust deposition have been based on traps that were put on tops of buildings (Jauregui, 1989; Pye, 1992; Lin et al., 1994), it is important to learn the proportion of dust deposition between the city and the open areas around it.

## 4. Methods

The investigation was based on sampling the potential settling dust on four structures in the city of Beer-Sheva: the City Hall, the Meteorological Station, a patio (courtyard) in a neighborhood on the western side of the city, and one of the university buildings. Settling dust was also collected in Omer, a garden suburb of Beer-Sheva. These results were compared with dust deposited in two areas outside the city: one 13 km westward, and the other 27 km eastward. The deposited dust was analyzed according to weight, grain size, and chemical and mineralogical composition.
Dust was collected in dry traps, which consisted of round plastic bowls with a depth of 5 cm and a flat bottom of a diameter of 22 cm covered by a layer of 16 mm diameter marbles, thus creating a rough surface that can trap dust particles.
The traps were placed on building roofs, window sills, etc., and on a one meter high stand. Outside Beer-Sheva, the traps were placed on a tower, at four heights: 1, 2.7, 4.4 and 6 meters. The dust collected from each trap was sieved by a 44 μm sieve. The Coulter Counter used was able to measure the grain size distribution in the range of 1.6-41.0 μm.
The chemical analysis was determined by energy-dispersive X-ray spectrometer in a scanning electron microscope (SEM). The mineralogical composition of the dust was determined by X-ray diffraction (XRD) analysis.

## 5. Results and discussion

Dust deposition was sampled during four separate sequences, at different times of the year. During the first sequence, Spring, dust traps were exposed between April 24 and May 28, 1991. Weather conditions during this period were characterized by light to moderate north westerly winds, and there were no dust storms. The second sequence, Fall, from August 31 to October 4, 1991, was also characterized by winds from the northwest. The third sequence retrieved samples from dust traps exposed during a major regional dust storm which occurred on November 3, 1991. Weather conditions during the fourth sequence, Summer, from July 22 to September 22, 1992, were also typical, with moderate northwesterly breezes in the afternoon, and no recorded dust storms.
The amount of dust collected in the traps at one meter above the surface can be seen in Table 1. Results show that the amount deposited in the city was 230% to 250% of that deposited in the open areas outside the city. The suburb Omer, which is densely vegetated, had less deposition of dust, although the amount deposited there was 170% of that in the open areas. In the city, there was considerable variance in the amount of dust deposited on the different buildings. The patio and the City Hall, which also encloses a courtyard, trapped the highest amount of dust. Spring is the season with the highest rate of dust deposition. During dust storms, the rate of deposition is 20 times greater than during calm days.
The amount of dust is known to decrease with height (Tsoar and Pye, 1987). A uniform trend of decrease was given by the two stations outside the city (Figure 1A). The City Hall Tower and the University building showed a considerable reduction at low heights of 5-10 meters and from there the rate of decline lessened. This was a distinctive characteristic of the City Hall Tower (Figure 1B).

Table 1. The amount of dust deposited during the four periods of sampling at the different locations in the city, the city suburb (Omer), and the two open areas west and east of the city. All samples were taken at an elevation of one meter except for the university, where they were taken at 3.5 meter. The 'Total' column gives the weight of dust deposited in the traps in grams. The 'p/day' column gives the rate of dust deposition in g $m^{-2}$ $day^{-1}$, and n/d=no data.

| Period | Spring '91 | | Fall '91 | | Dust storm | | Summer '92 | |
|---|---|---|---|---|---|---|---|---|
| Location | Total | p/day | Total | p/day | Total | p/day | Total | p/day |
| City Hall | 0.31 | 0.24 | 0.26 | 0.13 | 0.30 | 3.95 | 0.36 | 0.16 |
| Met. St. | 0.25 | 0.19 | 0.40 | 0.20 | 0.27 | 3.55 | 0.48 | 0.21 |
| Patio | 0.43 | 0.33 | n/d | n/d | 0.40 | 5.26 | 0.39 | 0.17 |
| Univ. | 0.41 | 0.32 | 0.30 | 0.15 | n/d | n/d | 0.72 | 0.31 |
| **Average for city** | **0.35** | **0.27** | **0.32** | **0.16** | **0.32** | **4.25** | **0.49** | **0.21** |
| Omer | 0.24 | 0.19 | 0.25 | 0.13 | 0.19 | 2.50 | 0.20 | 0.09 |
| 13 km-W | n/d | n/d | n/d | n/d | 0.11 | 1.45 | n/d | n/d |
| 27 km-E | 0.12 | 0.09 | 0.16 | 0.08 | 0.14 | 1.84 | 0.22 | 0.09 |
| **Average for open area** | **0.12** | **0.09** | **0.16** | **0.08** | **0.12** | **1.64** | **0.22** | **0.09** |

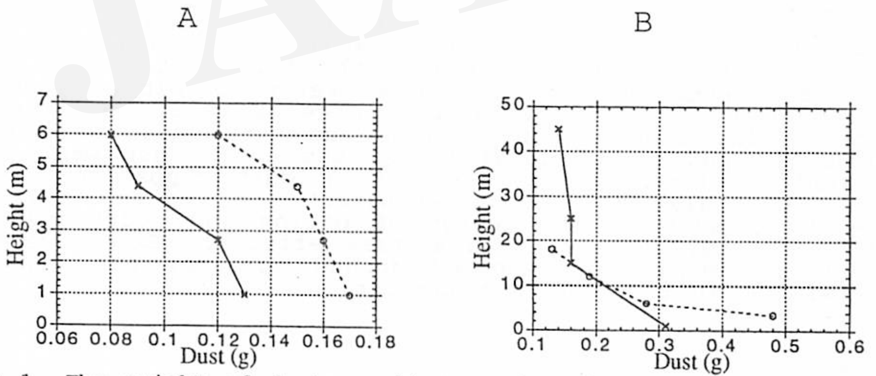


Figure 1. The weight of dust caught as a function of height. A - shows the results for the two towers outside the city (solid line=13 km westward and dashed line=27 km eastward). B - shows the results on two tall buildings in the city (solid line the City Hall Tower and dashed line the University building).

The grain size in the open area was smaller than that of the city (Figure 2). The open area dust was better sorted (SD=1.12) relative to the city (SD=1.22). The average grain size of all the dust-sized particles for the open area was between 13-16 μm (6.0-6.25 ϕ), and it was significantly different (at 1% level) than the city dust, which was, on average, between 19-23 μm (5.5-5.7 ϕ).

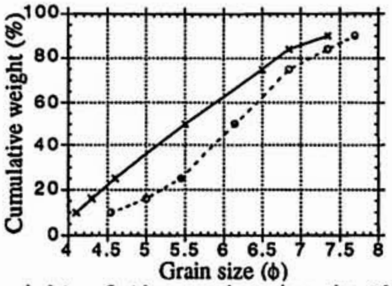


Figure 2. Cumulative weight of the grain size in the city (solid line) and the open areas (dashed line).

The chemical and mineralogical composition of the dust collected from all traps, in the city and outside it, was similar. The dust particles were composed mostly of quartz and calcite, with smaller amounts of dolomite, feldspar and clay (mainly kaolinite) minerals. The same proportion of these minerals exists in the local loessial soil, which indicates that the source of the dust is the local unvegetated soil surface. In the open areas, the composition during the dust storm was similar to that deposited during the calm periods. In the city, the relative abundance of calcium increased, while aluminum, found mostly in the clay particles, decreased. Hence, the proportion of clay minerals in the dust deposited during the dust storm may have been smaller in the city than the open area.

## 6. Conclusion

Dust sampled in urban locations may not represent the natural dustfall typical of the surrounding area. Dust deposition near buildings in a built-up urban area on the fringe of the desert was found to be greater than in undisturbed reference sites in the open areas, and was characterized by large spatial and temporal variations. The composition of urban and rural dust was similar, reflecting the make-up of local soils, but urban dust was coarser. While building elements had an effect on dust deposition, various strategies commonly employed by architects to reduce exposure to airborne dust, such as the design of patios and courtyards, were found to have negligible or even adverse effects. Extensive use of vegetation and minimizing exposed ground surfaces are apparently more successful in reducing dust deposition.

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## *Activities in the world*

A1: Chaired by H. Tsoar & J. Shrestha
A2: Chaired by B. Fergusson & M. Ozaki

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Invited Special Articles



Original Articles

沙漠研究 5S, 119-122(1995)
Journal of Arid Land Studies

# Strategies to Prevent and Combat Desertification in Mexico

Manuel Anaya Garduño[1]

Abstract.- Desertification is affecting, more than 90% of the National Territory at different levels. Strategies to prevent and combat desertification should consider the following: decision and political skill, legislation, internal and external market, education, participation of land holders, technology transfer, master plans at state and municipality levels and funding mechanisms.

Key words: Desertification, Land Degradation, Strategies.

## 1. Introduction

Arid and semi-arid conditions are present in more than 75% of the Mexican territory. Mexico has two major deserts: named Chihuahua and Sonora Deserts, their extension goes northward across international boundary into the United States of America.

Drought affects several states of Mexico; during the last 100 years, more than 12 severe events have been present in the following states: Baja California Norte, Baja California Sur, Sonora, Chihuahua, Coahuila, Nuevo Leon and Tamaulipas. Between 7 and 12 droughts have affected the states of: Sinaloa, Durango, Zacatecas, San Luis Potosi, Guanajuato, Queretaro, Hidalgo, Mexico, Guerrero, Oaxaca and Yucatan. Drought affects more than three million hectares under cultivation every year, in pasture lands the lack of fodder crops and water, kills different animal species.

Human population in Mexico shows some migration patterns due to adverse climatic conditions, misery and poverty, there is a challenge to consider population resettlements, and combating poverty, mainly in isolated areas. Land degradation in the arid and semi-arid zones of Mexico is becoming a serious problems, because it is already present in 22 states (Anaya, 1994 a)

Mexico has been, is and will be a country of contrasts; however, it has tech nology and social potential to find the way for sustainable development.

Desertification processes in Mexico are caused by the following aspects: deforestation, overgrazing, over-exploitation of aquifers, erosion, salinization, diminishing the organic matter content, reduction of soil depth, and contamination. These processes are related with population density, in this matter the central part of Mexico covering 20% of the national territory has 60% of the total population, this central part is related with the neovolcanic belt and with arid, semiarid and subhumid zones, and it is the most affected area of Mexico (Anaya, 1994 b)

Mexico currently farms 22 million hectares of its land, 75% under rainfed condition. This is a potentially dangerous situation since, given the projected population of 110 million by the year 2000 and an upper limit on farmable land of about 25 million hectares, the country will have an average of only 0.24 hectares per capita at its desposal. If adequate measures are not taken famine will surely result. (CONAZA, 1994).

It is estimated that overgrazing has damaged more than 60 million hectares of the National Territory and that these lands exhibit the worst deterioration. In second place, with regards to area covered and damage inflicted, are forests, which have suffered from badly-planned felling, uncontrolled cutting of firewood and fires. In third place is dryland agriculture, which occupies around 21 million hectares and where aeolian and hydric erosion are prevalent. Finally, irrigated agriculture occupies 5.8 million hectares and poses dangers of salinity, lack of drainage, marine

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intrusion, over-exploitation-of water resources and accelerated silt build- up in resorvoirs. As a result of these processes, the rate of advancement of desertification in Mexico, today is greater than the rate of recuperation of affected areas and represents a danger for the sustained production of food.

The above facts indicate the need for adequate integral planning for the use of water, soil, flora and fauna resources with the objetive of preventing desertification, reducing ecological deterioration, assuring sustained food production and a better social development. (Anaya, 1994 a,b,c.)

Recent studies conducted by Anaya (1995 a) show that more than 90% of Mexico is affected by physical, chemical and biological deterioration, as can be seen in Figure 1.

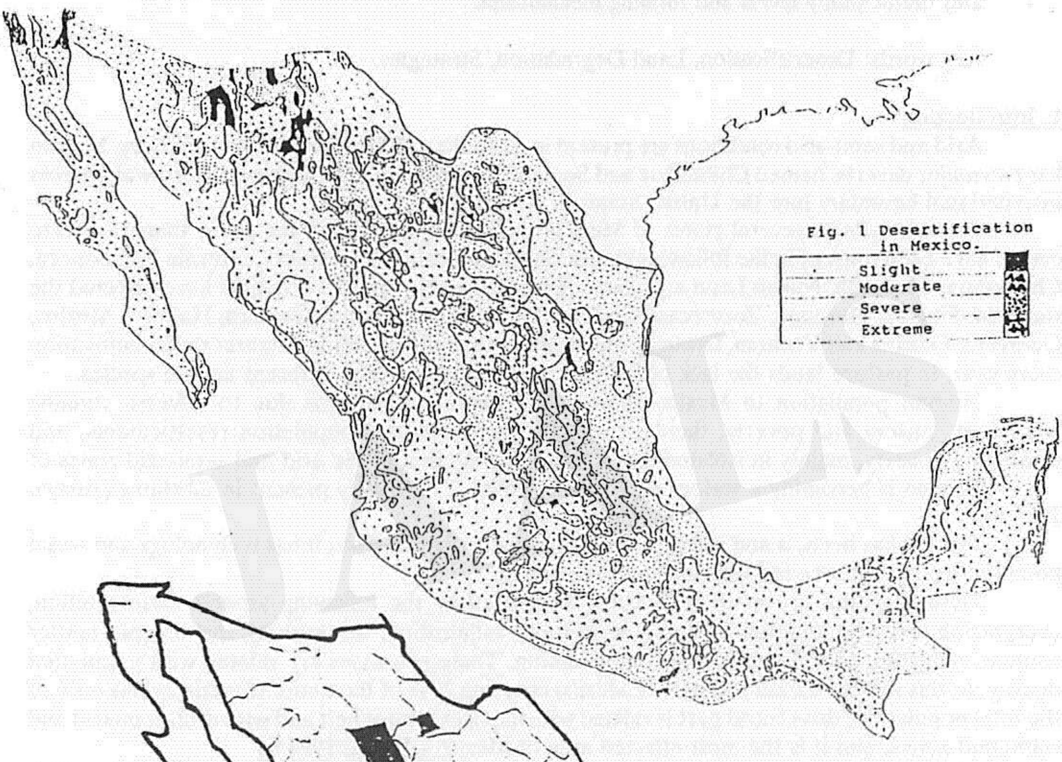

Fig. 1 Desertification in Mexico.

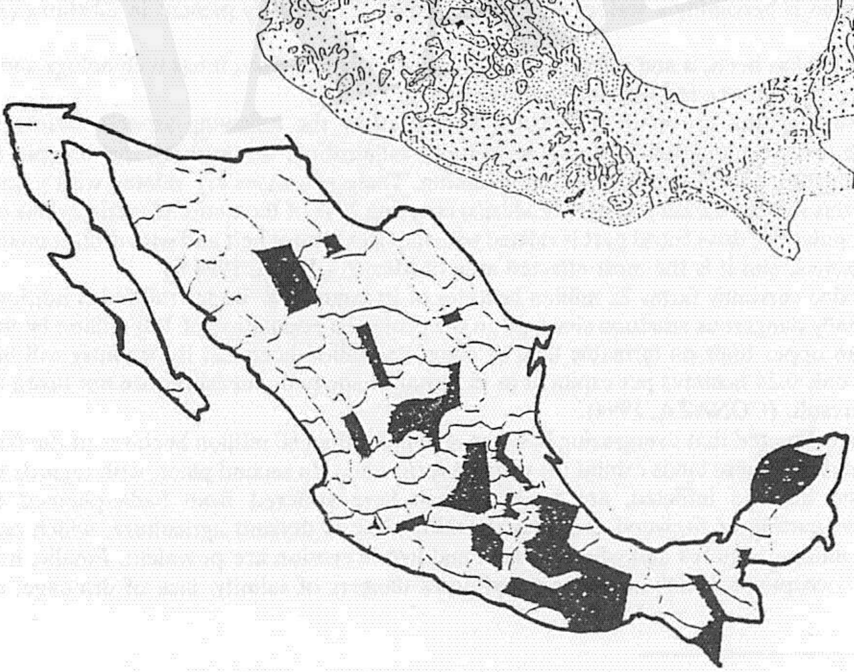
Fig. 2 Zones With Mayor Nutritional Problems

Besides desertification factors, it is very important to consider social and economical indicator such as: migration, poverty, educational level, health, protein consumption, carbohydrate consumption and children's mortality Figure 2, shows a map about nutritional levels in Mexico. Overlayed figure 2 on figure 1, indicates a high relationship between global desertification map with the one showing nutritional levels. This indicates the need to define priorities to prevent and combat desertification by considering desertification and the socioeconomic indicators. (Roldan, et. al., 1988)

## 2. Technology and Desertification

Desertification is a phenomenon promoted by man and caused by exceeding the potential limits of desertification which exist for the various land-uses. Any land-use by man signifies a potential danger for the system and selection of appropriate technology tends to minimize this danger and increase productivity.

Desertification is often caused by the need for man to subsist and many other times by the desire to over exploit the natural resources. Technology represents a link between the natural and social systems and may or may not result in the optimum management of the natural resources. There are many examples of the correct and incorrect application of technology -there are cases where the wrong application of technology has been responsible for many environmental problems of which desertification is only one.

Technology can be considered as simple, intermediate or advanced, depending on the established reference framework, although simple is not necessarily related to traditional or primitive technology. Appropriate technology can be, from the point of view of its complexity, simple, intermediate or advanced, and therefore a particular technology may be appropriate under certain specific conditions and inappropriate under others.

To date there exists in Mexico a great variety of technologies generated by empirical and scientific know-how; it could be said that in general there is no limit to technological solutions to the problems of desertification. In the majority of cases, the factors inhibiting efforts to combat desertification are social, economic and political.

The selection and application of technologies to fight against desertification in Mexico will be based upon the education and motivation of the local population, the availability of well-trained technical personnel and the levels of investment and time dedicated to the recuperation of specific areas under the process of deterioration.

## 3. Basic Considerations for a Plan of Action to Combat Desertification in Mexico (PACD-MEXICO)

* The National PACD should be incorporated to a National Plan for Development considering strategies planning framework for integrated projects and for sustainable development.
* To consider and to evaluate relationships between Desertification, Climatic Changes and Biodiversity in order to avoid duplicity.
* Establishment and reinforcement of a data bank with mechanisms to exchange information at different levels.
* The Plan should consider a long-term aproach (5-10 years at least), taking in account periodical evaluations; coordination, cooperation, efficiency are basic components for a succesful result.
* Reinforcement of relevent research and development projects based on the following: National Program of Solidarity, National Plan for Reforestation, National Program on Soil and Water Conservation, National Commission of Water, National Commission of Arid Lands, National Program for Animal Production, National Program of Education, National Commission of Population, Indigenous National Institute, National Institute of Information, Geography and Statistics, Mexican Institute of Social Security, Agrarian National Institute, Social Development Department, Agricultural and Hydraulic Resources Department, Prevention will be easier and more economical than reclamation measures to control desertification.

* Establishing long and short-term programs in forest zones, pasture lands, rainfed and irrigated farmlands and areas under nomadic cultivation. Other land use systems are roads, national parks, human settkements and mines.
* Employing the watershed as an ecological, hydrological production unir for concerted action by communities, technicians and institutions.
* Promoting a national, state and municipal technological information network to allow the effective exchange of experiences from diverse social, economical and ecological backgrounds.
* Promoting collaboration between scientists and technicians from all areas of study, as well as national and local planning to fight desertification, through a Scientific and Interdisciplinary Consultive Committee on Desertification Control.
* To reinforce capacity building through community participation linked to financial resources an mechanisms at different levels, local municipal, national, subregional, regional an international.

## 4. Conclusion

By the year 2000, there will be 110 million human beings in this nation, each and every one will require food and acceptable living conditons. So, real social and economic, development will be the only way to prevent and combat desertification.

However, if our natural resources continue to be squandered, the Mexican territory will soon be northing more than a lifeless desert incapable of providing for our basic needs.

The battle against nature and man himself is an uphill one; yet, all is not lost, hope of victory remains, through the joint efforts to save our children from a future of misery, poverty, famine and death.

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沙漠研究 5S, 123-126(1995)
Journal of Arid Land Studies

# Technology of Desert Development in the Commonwealth of Independent States (CIS)

Igor Zonn*

Abstract — Deserts and semideserts in the CIS occupy nearly 250 M. ha and possess high natural and resource potential. The technology of fixation of shifting sands, efficient use of pastures, irrigation agriculture management are considered. Independent republics of Central Asia remained with their «baggage» of technologies, the application aftereffects of which have caused grave ecological consequences.

Key Words: Desert development, Technology, Ecological problems

## 1. Introduction

Deserts and semideserts in the CIS countries occupy about 250 M. ha (Kazakhstan — 170, Turkmenistan — 40, Uzbekistan — 30, Tadzhikistan — 7, Kyrghyzstan — 3 million ha). They are distinguished by rather large resources of solar heat ($10^4$ M Joule/$m^2$/year), and extremely insignificant precipitation (80—400 mm/year). Surface runoff is mainly limited by the piedmont zone. Two great rivers are crossing the desert territories — the Amudarya and Syrdarya, inflowing the Aral Sea.

Desert areas possess high natural and resource potential. Cotton belt developed on the basis of wide-scale irrigation with growing of rice, fruits, vegetables, melons and grapes is within their boundaries. Substantial industry and infrastructure are established on the basis of oil-gas and mineral-salt belts. Sheep raising, karakul sheep breeding and camel breeding are developed at the area of 224,9 M ha, occupied here by the pastures.

Today, when the republics of Central Asia acquired their independence, it would appear quite reasonable that they tend to reconsider the interrepublic character of desert development, which under conditions of the Former Soviet Union were considered only for establishment of raw material appendage for the center (cotton, gas, gold, polymetals, ets.). For the time being the deserts of Central Asia proceed to remain the only one territorial and production complex with the old «baggage» of technological methods of development.

## 2. Desert Development Technologies

There remain the following basic technological trends of desert development:

2.1: Fixation of shifting sands;

2.2. Land reclamation and improvement of desert pasture output;

2.3. Efficient use and conservation of water resources, watersaving technologies with irrigation agriculture;

2.4. Use of solar and wind energy (Zonn et al., 1990).

2.1. Fixation of Shifting Sands. The fixation is implemented with the use of mechanical, phytoreclamative, physical and chemical technologies.

The traditional way of sand stabilization in the deserts of Central Asia is the establishment of different types of mechanical barriers of plant material. Standing row barriers, the barriers in chessboard pattern with height up to 0,3—0.7 m, half-hidden standing row barriers and the barriers in chessboard design with the height up to 20 cm, row matting (the width of the row is 60—70 cm), and longitudinal matting (the width of the row is 25—30 cm) and matting in parallel strips, are the most commonly used designs here.

Standing barriers and the barriers in chessboard design provide the general fixation of shifting sands. Mattings and longitudinal fixing barriers provide only fixation of sand surface. All kinds of fixing barriers establish favorable conditions for growing protective plants.

Sand binders are grown on these areas by planting seeds, seedlings or cuttings. The following standard rates for fixing the area of ha are used in practice: 6 rg of Halxylon persicum, 8 kg of Calligonum, 6 kg of Salsola Paletzkiana for seeds; 3000 pieces (things) of seedlings or cuttings.

Forest amelioration is carried out in the following directions:

— establishment of protective forest belts along the borders of oases, field edges, channels. These belts consist of native and exotic woody and shrubby species under irrigation. The forest barrier of Haloxylon aphyllum at the northern edge of Bukhara oasis, Uzbekistan. It is 110 km in length and 4 km in width;

— establishment of forests in the desert regions of stock-breeding for protection ageinst strong winds and for improvement of the fodder basis;

— regeneration of the areas where vegetation was destroyed due to construction of roads, pipelines and open wells;

— afforestation and fixing of chifting sands and sand drift control as well. The most important problems here are: development of methods for afforestation of oasis sands, oriented at protection of irrigated lands, canals settlements and roads against sand drifts.

Sand fixation works were mechenized only due to the use of chemical substances, covering the sands with

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antideflation coating. More than a hundred of different binding materials have already been tested. Among them are hydroxy acid+waste oils, bituminous emulsion pastes, wastes of phenol-formaldehyde production, wastes of carbon-graphite electrode production. The promissing chemical binders in the CIS countries are Nerosin, oil industry wastes, sulphate-alchohol barda, Gassipole resin, etc. Different methods of binder application to sand surface, the mechanization of labour-consuming processes, as well as accomlishing of sand fixing works, including afforestation, are being developed.

2.2. Land Reclamation and Improvement of Desert Pasture Output. The system of measures on rational pasture use includes: interfarm distribution of pastures according to the generall scheme of their complex reclamation and irrigation, fixing of optimal limits for sheer-breeding farms in reference to different natural regions, pasture turnover, working out of feed balance, improving of pastures use technology, creating emergency (extra) feeding stocks, improving of pastures by means of interseeding of valuable and palatable plants, creating a system of stable control and pasture management system.

At the intrafarm pasture distribution the attention is paid to: herbage character on different parts of the territory, pasture forage suitability in different seasons and availability of watering places. One of the main factors for uniform grazing is equal distribution of water sources in the pasture territory. It is done thanks to underground water use by means of well construction and collecting lf atmospheric precipitation by means of ground and underground storage lakes. Sometimes the water pipelines are constructed for pasture irrigation if is necessary. There are 154 pasture water pipelines built and operating in the republics of Central Asia, supplying water to 2418 watering places and watering 6,4 million ha or 6,9% of pastures.

Grazing schemes provide for better pasture control, which is reached by use of one and the same pasture territory at various seasons. Some pastures can have "a rest" if it is necessary. It gives the opportunity to enlarge the amount of valuable seeds for future reproduction.

It most be noted that such grazing is effective only under uniform and full pasture watering. The balance between pasture fodder and livestock quantity is a necessary condition as well.

In the desert zone with its sharp ammual forage crop fluctuations the collective farms store has specified the amount of forage on irrigated lands, ensuring full-value fodder for cattle in spite of weather conditions. The greatest attention is paid in the CIS countries to the improvement of forage by enriching the species composition and rising forage productivity. The technologies are developed at present for establishment of permanent, polycomponent 3—4-stage pastures of spring-summer, autumn-winter, multiseasonal types for the conditions of wormwood-ephemeral, gypseous and sand desert. Among them are:

— Method of establishment of autumn-winter pastures in the piedmont regions. Establishment of pastures based on Cochia prostrata, Artemisia badhysi, Salsola orientalis, Aellenia subaphylla and other plants recommended on plowed strips, alternating with virgin sites, occupied by ephemerid vegetation. The improved pastures allow to eliminate forage deficiency during autumn-winter period, increasing total yield 2—3 times.

— Method of establishment of pasture-protection forest strips based on Haloxylon aphyllum. It is recommended for pasture areas where the depth of ground water does not exceed 12—15 m; it provides for total increase of fodder production by 15—20%.

— Method of establishment of sown pastures of a number of cultivated and wild fodder plants. It is recommended for improvement of forage productivity of pastures in the piedmont regions 2—4 times.

— Method of improvement of fodder prooductivity of halophyte pastures 4—6 times. Another efficient technology in the system of arid fodder production is the establishment of pasture-protection, geen umbellate, umbelliferae plants. The efficiency of this technology is proved on the basis of establishment of black saxaul pastures in Uzbekistan at an area of 300 000 ha (Mukhamedov et al., 1994).

Today we are dealing with adaptive approach to the arid fodder production, when wide use of ecological and biological potential of the natural flore plant types — xerphytes, halophytes and psammophytes is anticipated.

Widespread methods of pasture watering include the search of fresh ground water and digging of storage wells up to water aquifers. At present the walls of storage wells are often reinforced by concrete pipes. The depth of wells is different. Major part of wells is dug in the places where ground water occur at a depth no more than 30 m. Such wells make up 98% of their total number in Central Asia.

Water of unconfined artesian aquifers, occuring at a depth of several hundred metres, is widely used as watering places. Unfortunately, there exists an opinion among a considerable part of stock breeders about inexhaustability of artesian wells, therefore they are not equipped with water-regulating fixtures, and water is poured out into surface freely. Such wells are often met in the Karakums of the Aral Sea coastal region, and in the north of the Kyzylkum desert. Traditional methods of water extraction by the use of local runoff are related to most economic. The simplest of them is the accumulation of local seasonal runoff in shallow water reservoirs by the establishment of dams in the channels and mouths of small watercourses. Such water reservoirs and ponds are often met on the piedmond plains, where ephemeral watercourses are available. However, this method has a number of disadvantages: it can be applied only on the piedmont plains with temporaty seasonal runoff. In the deserts water flows, filling in small water reservoirs, bring a large amount of silt, clay and sand, and water bodies are quickly silted. During very wet years there is a hazard of dam breaching. Water losses for evaporation and seepage are often extremely large.

The methods of collection and storage of local runoff on the takyrs are economic and promising. These methods were applied form ancient times and based on the fact that the surface of takyrs is distinguished with poor water permeability and water stand too long at them during wet seasons. The most primitive method of takyr runoff collection is its storage in small rain-fed holes, dug out in the lowest point of the takyr. In these holes ("khakhakhs") water is conserved within 3—5 months, but its quality is low. More advanced method is water storage in the dug deep filling wells ("chirle") or in complicated covered structures — sardobas. The methods of takyr runoff collection into special subsurface water reservoirs are developed nowadays.

2.3. Efficient Use and Conservation of Water Resources. Watersaving Technologies with Irrigation Agriculture. Irrigated farming occupies the first place in agricultural desert reclamation. During the Soviet power period the system of arid land irrigation has been radically changed. First of all, this changing involved radical technical reconstruction of old irrigation network, which greatly increased irrigated land productivity. Simultaneously the projects of complex utilization of Central Asia great rivers stream flow were developed and put into practice too a great extent. This alloved to attack the desert actively by means of irrigating and utilization of ancient irrigated lands and start reclamation of new virgin lands.

Dozens of large irrigation projects have been built as a result of these measures. They are Amubukhara, Karshi, Big Andizhan and Big Namangan, Garagum canals, Large hydraulic structures, dozens of storage water reservours with capacity of 15,7 cubic km are under exploitation. Irrigated areas in Central Asia occupy 7,4 M. ha. The irrigation is carried out by traditional methods, slightly changed in comparison with formely used. They do not provide for efficient use of water and cause degradation of irrigation and drainage conditions, development of secondary salinization of soils. Out of total area of irrigation today about 4,5 M. ha are soilted to this or that extent. Over 20 km$^3$ of drainage water are discharged annualy from the irriqated field of Central Asia.

A part of drainage waters is discharged into the rivers and canals, used as the sources of irrigation, which has extremely objectionable consequences: mineralization of river water is increased. At present, due to disposal from the fields, water mineralization of the major part of the rivers of the arid zone in the lower reaces 1—3 g/l. Apart from salts, the river waters contain biocides and metals. By no means water discharge into the rivers results in saving of water. On the contraty, the discharge of saline irrigation water is higher than the discharge of fresh water at the same irrigated areas. The increase of mineralization of irrigation water by 0,1 g/l requires the increase of water amount required for irrigation of 1 ha by 1000 m$^3$.

The other way of drainage water discharge is their diversion into drainless depressions in the desert. Annual chaotic discharge of nearly 3,0 km$^3$ of drainage water into the desert has caused inundation, water-logging and salinization of pastures at an area of about 530 000 ha, and discharge of 3,6 km$^3$ into the rivers and water bodies results in sharp deterioration of surface water quality. Owing to this, vast lakes with water mineralization from 5 to 20 g/l are formed. The chain of such lakes in Central Asia are stretching out along the northern edge of the Bukhara oasis, lower reaches of the Tedzhen and Murgab deltas, on the margins of the Khorezm and Tashaus oases. The largest disposal water bodies are the Sarykamysh and Arnasai (the area of each is more than 3000 km$^3$). Due to entrance of large amounts of organic matter these lakes tending to overgrowing with water-coastal vegetation, however due to intense fluctuations of water levels in the lakes this process can not be revealed often. The fluctuations depend not on the natural causes, but on the intensity of irrigation within a certain season or year. (Babaev et al, 1984)

In connection with drainage water seepage in the vicinities of water disposal lakes the solonchaks are formed, often close in the area or exceeding the lakes in size. The removal of agricultural areas (pastures, lands promising for irrigation) is rather significant. Only at the plains of Central Asia the area of water disposal lakes makes up 6171 km$^2$.

A number of methods and approaches is developed for their secondary use for irrigation and freshening. However, till now they are comparatively expensive and require further improvement. The methods on improvement of effuecient use of water resources for land irrigation are known long ago: improvement and reconstruction of irrigation systems, introduction of seepage control linings (only in Uzbekistan the total length of irrigation and drainage canals makes up 180 000 km. In this case only 12% of the canal extension are lined), replacement of the open irrigation network, introduction of more advanced methods of irrigation (sprinkling, drop irrigation), reduction and differentiation of irrigation rates with regard for natural features, weather conditions and crop vegetation. During a short period of independence there can be noted the shifts in the last. Actually, the irrigation rate per complex hectare made up 13,5 th. m$^3$/ha in 1992—1994 against 17,5 th. m$^3$/ha in 1976—1980. In its turn it results in shifts in siltation control. Although the efficiency of irrigation and drainage networks remains rather low, especially interfarm (Khabibulaev et al., 1994).

Intermittent (pulsed) technology of irrigation is most promising on the way to increase the efficiency of surface furrow irrigation. The main idea of this technology is water delivery in series of pulses, ultimate for the conditions of subsoil outwashing, alternating with pauses and subsequent "additional moistening" by reduced water flow, most fully corresponding to the target of water saving.

The advantages of pulsed water supply are revealed in the reduction of deep seepage beyond the boundaries of the root zone, regularity of moisture distribution along the furrow length, establishment of the conditions for uniform development of agricultural crops with minimum water losses. This technology is oriented towards gravity irrigation network with insignificant command over irrigated area. As studies shown, the zone of most efficient application of this technology — nonsaline or slightly saline irrigated lands, levelled for inclined (0,002—0,008) plane with uniform slope in the direction of irrigation with average water permeability of subsoils.

The results of tests point to the fact that intermittent water supply can provide the reduction of productivity of irrigation water use by 35—55% (in comparison with traditional), and reduce by 27—37% the expenses for irrigation water per one centner (100 kg) of agricultural produce.

Futher trend for improvement of the technology of intermittent irrigation is high-frequency irrigation of row agricultural crops as an alternative to power-consuming drop irrigation.

2.4. Use of Solar and Wind Energy. Natural energy resources are far above the requirements. Thus, annual power generation of 1 M. kW by traditional electric power station is contained in solar rays of Central Asia, falling on the square with the side of 2,3 km. Apart from that, there are wast reserves of wind energy, biomass and other nontraditional and renewable sources of energy.

Development of pover engineering will take a course due to establishment of local power-engineering systems, providing for agricultural, industrial, settlement and urban electric and heat supply.

The application of solar energy in the national economy now follows on the line of use of low-potential heat. Solar power plants designed for these purposes could release 50—60% of fuel used at present for the needs of small-scale power engineering in southern regions of the country.

The use of solar energy is especially important for water desalination and water supply of dispersed users in arid and low-water regions of the deserts. Apart from simple solar distillers of greenhouse type, used recently, the solar energy is utilized in more advanced distillers of membrane type and multiple-effect evaporation, furnishing a sharp increase of their productivity.

In this connection, a new promising trend of studies — combined use of solar and wind power with the help of a heat pump in the multipurpose plants (drying, heating, cooling, electric power generation, water desaltation). Combined solar power and wind power plants are more efficient, their total power generation is increased, the schedules of its generation and use are balanced, and the number working hours and reliability of power supply are increased. To transform wind energy into electric one, use is made of wind-power plants with nominal capacity from 0,14 to 30 kW. Apart from that, wind-power plants are used for water lifting from the wells and bore holes, and from opened water sources. The productivity of plants is from 0,3 to 6,0 $m^3$/hour with 30 m height of rise. Diaphragm, displacement and screw pumps are used. Till now, although there were developed pilot-industrial solar and wind-power plants, they were not widely introduced into use.

3. Conclusion

Catastrophic ecological situations in the desert zone were the result of the priority of engineering and technological decisions, with suprimacy of political. First and foremost this is the Aral tragedy of the drying sea and forming of the new sand-solonchak desert with the area of 4 M. ha in Uzbekistan and Kazakhstan. It is also siltation and inuudation of the zone of 1400 $km^2$ of the Garagum Canal in Turkmenistan. This is a vast degrading desert in Kazakhstan in the conventional triangle of Aktubinsk — Semipalatinsk — Almaaty.

For rehabilitation of natural environment the development and export of new technologies will be required.

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沙漠研究 5S, 127-129(1995)
Journal of Arid Land Studies

# Sutdy on the Techniques of Oil-Transporting Highway Construction in Taklimakan Desert

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Abstract - Tarim Basin in Xinjiang is expected to be China' s oil production core in the future, great efforts have to be made to construct various preparatory works.

Key words: Oil-transporting highway Construction techniques

## 1. The Necessity of Building Highway in Desert Area

Tarim Basin, with an area of about 0.56 million $km^2$, is China's largest oil-bearing basin, also one of the untapped oil-bearing basins in the world. In the past five years, some major oil-traps have been found in Tazhong-1, Tazhong-4, Tazhong-6, Tazhong-10 and Tazhong-16 structures in Taklimakan Desert. Oil reserves in the basin show an encouraging prospect.

With the expansion of oil exploration and development, the transport and communication in the desert area become a troublesome problem. At present, most of freight transport are done by helicoptors and imported desert vehicles, their freihgt charges are rather high. Accordingly, there is an urgent need to build a cross-desert highway so as to meet the requirement of large scale oil exploration and development in the interior of the desert.

## 2. Geomorphological Conditions

The landform types along the highway line are as follows:

(1) Old and new alluvial plains of Tarim River They are one hundred kilometers wide from north to south, with Populus euphratic forests and sand dunes scattered in them. There are also high and dense barchan chains, low dunes and blowouts alternately distributed on the ancient riverbed of Tarim River.

(2) High complex barchans They are about 30km wide and 30—50m high. Viewed from aerial photographs, there are also dome dunes. Most of barchans have steep slipslopes and cover an area ranging from 1—3$km^2$.

(3) High compound dune ridges They are 70km from north to south and 50—70m high; single dune ridges are 1—1.5km wide, 10—15km long and display a NNE—SSW orientation.

## 3. Route Selection

Rational route selection can not only avoid wind-sand hazards to the highway but also reduce the construction and maintenance cost. According to natural conditions in Taklimakan Desert, the following principles of route selection should be taken into consideration:

(1) The route to be selected must be a shortest one. Construction of highway in sandy desert is a very arduous task. With huge maintenance engineering and high construction cost. Therefore, it requests to shorten the route length and reduce horizontal curve as much as possible.

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(2)The route should keep away from serious disaster-hit areas.

(3)The route should run parallel to the resultant wind direction or intersect the resultant wind direction at asmall angle.

(4)In the light of local terrain conditions reduce the cut or fill engineeringn volume. The existing terrains are balance outcome of long-term deflation and deposition, we should keep the disturbance of orignal surface to a minimum.

(5)The route must be close to building material sources.

(6)The route selection should have a comprehensive benifit. For this purpose, the route selection must be combined with a layout of oil pipeline and water pipeline, communication and greenig projects so as to form a "multifunctional corridor".

(7)The route selection should have an optimal ecological benifit. Great efforts have been made to protect existing vegetation, water resources, land resources and wildlife to maintain ecological balance along both sides of the highway.

## 4. Prevention of sand damages to the highway

In the light of severity of sand damages to the highway we can atopt different measures, including "fixation", "block" and "transport" to eliminate sand damages. The combination of "fixation", "block" and "transport", laying emphasis on fixation, has proved to be most effective method to halt sand damages. Generally, a comprehensive shelterbreak system consists of the following five measures.

(1) Establishing high-upright fence at outmost edge to check wind-sand flow and small advancing dunes, which finally form into a high sand-dike.

(2) Erecting reed checkboard barriers between the high-upright fence and the road in sepcifications of 0.75m×0.75m, 1m×1m, 1.5m×1.5m, 1m×2m.

(3)Sand dune stabilization with chemicals Three kinds of chemical stabilizers have been tested along the highway but they have prohibitive prices.

(4)Biological dune stabilization This is a relatively permanent measure. Some drought-resistant species have been selected and planted in the areas with favorable water conditions.

(5)Maintenance of the road sideslopes A better maintenance of road sideslopes will contribute to check wind erosion of subgrade and let wind-sand flow cross over the embankment smoothly.

## 5. Road construction techniques

According to the natural conditions of the desert, the Xinjiang Highway Traffic Institue and Changqing Road Construction Company proposed a high-velocity and low-cost road-building scheme, its subgrade consists of sand subbase, geotextile, gravel base coarse and wearing coarse. Sand subbase is easy to be compacted under natural moisture-content condition. The most effective compaction method for loose sand is vibro-compaction, while the static compaction method can only make the top layer compact.

The spreading of geotextile is a key procedure. It can be spread in longitudinal direction with 40cm wide strip covering over the joints. Once the geotextile has been spread over sand subbase, the lorries can directly run over it and unload aggregate autonomously, thus speeding up the road builging pace.

The subject "Study on the engineering techniqes of oil-transporting highway in Taklimakan Desert" has been listed in the state' s 8th 5-year key project. China National Petroleum Corporation and Tarim Petroleum Exploration and Development Headquarter are jointly in charge of the implementation of the project. The project involves seven subprojects four of which are undertaken by the Lanzhou Institute of Desert Research and the Xinjiang Institute of Biology, Pedology and Desert Research. After working 1008 days from september 5, 1991 to June 9, 1994, the 219km highway stretched from Xiaotang to Tazhong-1 opened to traffic. This engineering totally transported about 3.2 million $m^3$ of shifting sand, consumed 0.57 million $m^3$ of aggregate, 10387 ton of asphalt, 2.62 million $m^2$ of geotextile and 9855 ton of reed, in the mean while erected 13.14 million $m^2$ of straw checkerboard barriers and 328km of upright fences. It has been proved that the highway has an obvious economic effect, the transportation expense of common trucks only corresponds to one thirteenth of that of special vehicles and the capital outlay can be recouped in two to three years.