New Technologies for the Rehabilitation of Arid Areas

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Desertification of Agricultural Land, Arid Climate, Crop Growth and Prevention of Sand Movement in Xinjiang of Northwest China

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Abstract - Greening is increasing, however, desertification is more increasing in Xinjiang, Northwest China. Micro-meteorological observation related to the climate conditions in arid lands were carried out at Turpan. The direction of sand movement was observed at Turpan and in Xinjiang. It is suggested that forest and net windbreaks and straw-mat network 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, Forest and net windbreaks, Meteorological alleviation, Straw-mat network

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, Northwest China from 1990 to 1996.

Relation among desertification, movement of sand dunes, prevention of wind erosion, alleviation of arid climate in agricultural field by forest and net windbreaks, increase of crop production and improvement of crop quality were investigated in Xinjiang.

It was demonstrated that the 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 mixed trees, the polyethylene Russell net windbreaks and straw-mat network under very dry conditions.

2. Observation Methods

Meteorological elements of wind speed (U) at 1.5 m, air temperature (T_a) and relative humidity (RH) and absolute humidity (AH) at 1.0 m, and surface soil temperature (T_s) at 0 m were measured for 4 rows of forest windbreaks made of mixed trees of Ulmus pumila L., Elaeagnus angustifolia L. and Populus euphratica Oliv., and 2 rows of net windbreaks.

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

The sand moving direction in small area at Turpan was observed on 7 m-high sand dune from 1990 to 1996, and that in wide area in Xinjiang was obtained by several times of ground investigation, satellite data and references, i.e., Xinjiang Inst. Bio. Ped. Des. Res. (1978).

3. Results and Discussions

3.1 Meteorological observation with four rows of forest windbreaks (Fig. 1)

Four rows of windbreaks made of mixed trees 8 m in height and 450 m in length with the forest density of 70%. Ur decreased at 39% and 33% by the first and second windbreaks (Fig. 1). T_s and T_a decreased inside and close to the windbreaks, however, increased around 2 to 5 H in the leeward sides of the 2nd. RH increased at 2% to 3% and AH at 2 g/m^3 from the 1st to 2nd accumulatively based on the evapotranspiration from trees, crops and ground (Maki et al., 1995b). This phenomenon is important as a climatic improvement or alleviation at the arid land.

Wind speed was decreased by the 1st, recovered near the 2nd and further decreased after, i.e., the decrease in wind speed was accumulative as the number of windbreak rows increased. Excessive increase in air and soil temperatures near the windbreak had a negative effect on crops during the daytime in

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summer. However, there was a positive effect on the decrease of temperatures between both windbreaks during the nighttime.

3.2 Meteorological observation with two rows of net windbreaks (Fig. 2)

The windbreaks consist of net 1.85 m in height, 30 m in length and 50 m in distance with two rows of same net density of 40% shown in Picture 1.

U_r decreased by the first net and was small at the area between both nets, but decreasing area was not wide in the leeward side of the second net (Fig. 2). Ts and Ta increased near the nets in both windward and leeward sides, however, decreased at just close to the net. RH showed the reverse change of T_a or T_s (Maki et al., 1993). These changing patterns of U_r, T_s, T_a and RH for net windbreaks are similar to that for forest ones.

3.3 Plant height observation with the windbreak of young poplar trees

The windbreak consist of young poplar trees 5.0 m in height and 57 m in length with forest density of 60%. The increase of plant height is sufficient from 1 to 9 H for sorghum and cotton, but insufficient from 6 to 9 H for cotton in short windbreak or edge or due to the oblique or side wind (Fig. 3).

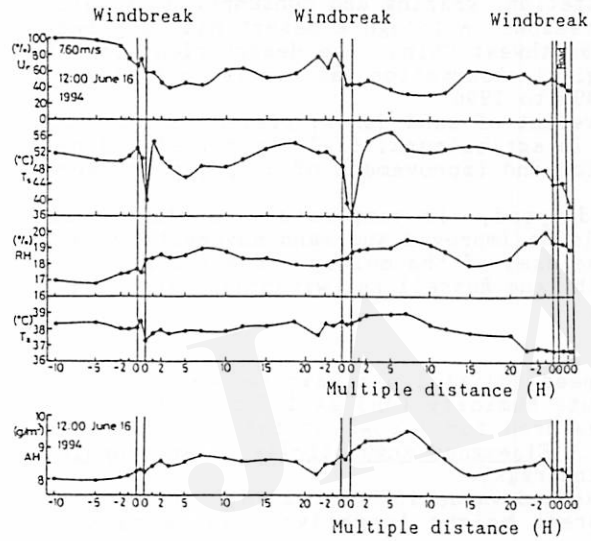


Fig. 1. Horizontal variations of 5 meteorological elements caused by 4 rows of forest windbreaks made of main 3 mixed trees at Turpan. 12:00 June 16, 1994

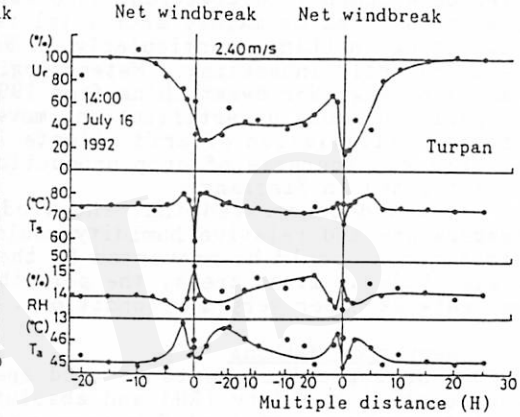


Fig. 2. Horizontal variations of 4 meteorological elements caused by 2 rows of net windbreaks at Turpan. 14:00 July 16, 1992

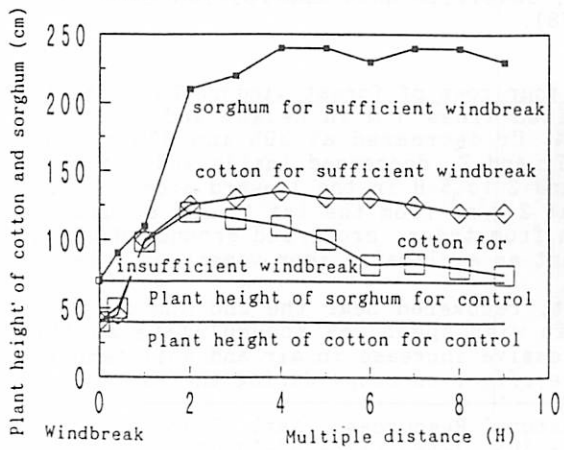
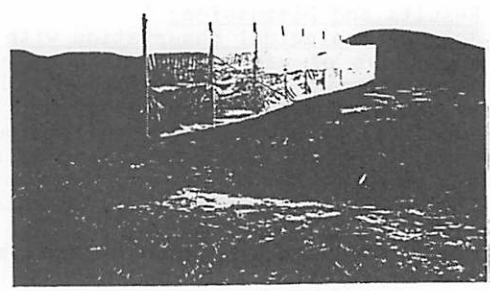


Fig. 3. Horizontal variation of plant heights of sorghum and cotton caused by young poplar windbreak at Turpan.



Picture 1. Net windbreak made of polyethylene Russell net.

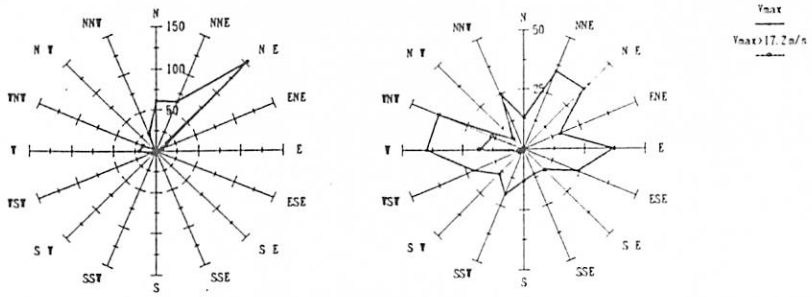


Fig. 4. Frequency distribution of wind direction during a year at Turpan.

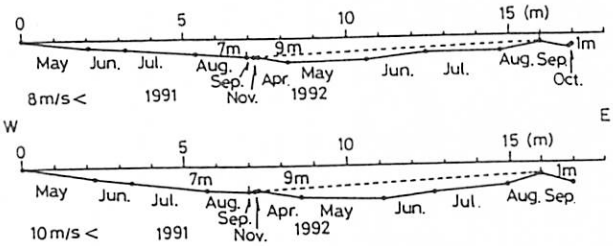
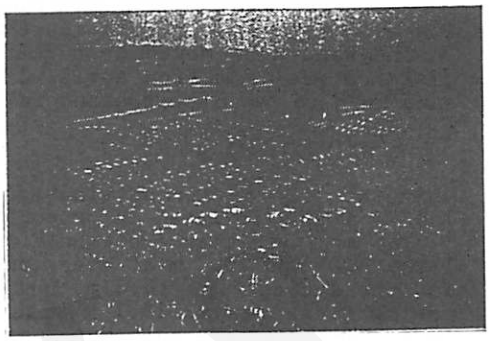


Fig. 5. Moving direction of sand dune at Turpan from Apr. 1991 to Oct., 1992.



Picture 2. Straw-mat network setting in Taklimakan Desert.

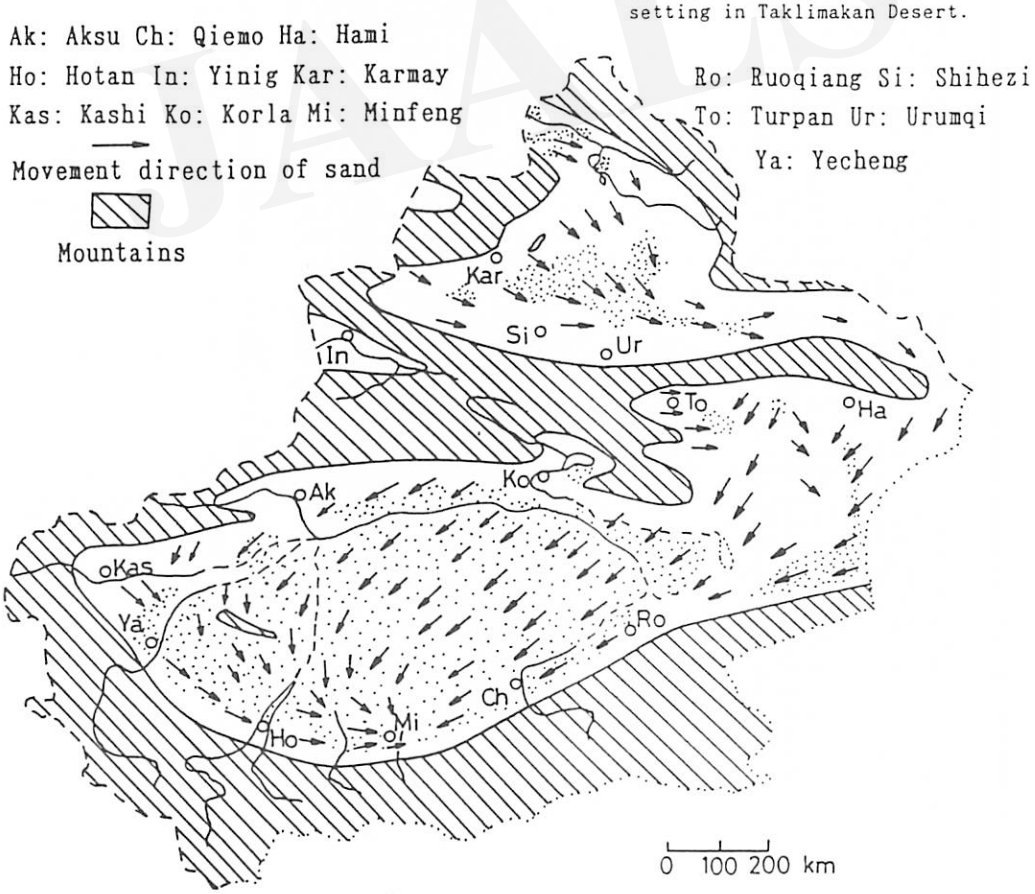


Fig. 6. Moving direction of sand dune or wind direction in Xinjiang, China.

3.4 Straw-mat network

Setting straw-mat network shown in Picture 2 on sand area is very effective for prevention of wind erosion, accumulation of sand, alleviation of arid climate, growing of arid weed and so on. The picture shows the straw-mat network made of reed at the middle of the Taklimakan Desert.

3.5 Observations of wind speed and wind direction (Fig. 4)

Prevailing wind direction at Turpan is NE direction during a year (Du and Maki, 1993). The value of N, NNE and NE is 78%, but strong wind over 17.2 m/s is W and WNW for 49 and 38%, respectively. The most frequent wind direction of U_{max}; daily maximum 10-minute mean wind speed is W, however, wind directions are scattered. The most frequent wind direction over 8 m/s of U_{max} is W and the second is WNW.

3.6 Observation of movement of sand dune (Fig. 5)

The sand dune of barchan type 7 m in height was used for observation near Turpan Desert Research Station (Maki et al., 1995a).

The sand dune moved E to ESE by W to WNW wind directions and its moving distance was 17 m from April, 1991 to October, 1992. The moving distance of sand dune (d, m) is expressed in the next equation.

$$d=7.3\cdot10^{-5}t\cdot u^{3.18}$$

where t: time of strong wind speed over 5 m/s (hr) and u: wind speed (m/s). The sand dune is moved in proportion to the 3 power of wind speed.

The moving distance of the 7 m-high sand dune at Turpan was 9.5, 9.0, 12.0, 11.0, 10.0 and 10.0 m at every one year from autumn in 1990 to summer in 1996, and the average was 10.3 m. But at about 20 years ago of 1973 to 1978, mean moving distance was 28.1 m with the variation of 10.0 m to 67.5 m per year (Pan, 1988). Active sand dune was 34 in 1959 and 10 in 1990, and it is nothing in 1996.

The desertification around the region of Northwest China has been expanding, however, the observed active sand dunes themselves have been decreased mainly by the windbreak trees recently planted at the leeward edge of the desert.

3.7 Distribution of sand movement in Xinjiang (Fig. 6)

The recent movement of sand dunes was figured in Taklimakan and Gurbantunggut Deserts, Xinjiang, China (Maki et al., 1995a). The map expressed the moving sand direction or strong wind direction is shown in Fig. 6. The direction was NW in Gurbantunggut Desert, and NW to N and NE in the west and east part of Taklimakan Desert, respectively. The changing region of moving sand direction was found in the middle-south side area of the desert, Minfeng or Yawatongguzlangar.

4. Conclusions

(1) Windbreaks made of multiple rows of mixed trees with Ulmus, Elaeagnus, Populus etc. are suitable for making agricultural fields or oases in arid land of Northwest China.

(2) Various effects of net windbreaks are similar to those of forest windbreaks.

(3) Forest windbreaks, net windbreaks and straw-mat network are effective in meteorological improvement or alleviation, growth and quality improvement of crops, prevention of wind erosion and sand accumulation in arid land in Northwest China, particularly at Turpan.

(4) Sand dunes are moved in proportion to the 3 power of wind speed.

(5) Sand moving direction is E to ESE in Turpan and its speed is 10.3 m per year from 1990 to 1996.

(6) The recent movement of sand is figured in Taklimakan and Gurbantunggut Deserts.

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Developing Environmental Rehabilitation and Arid Farming Systems: A Research Project in Kalgoorlie

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Abstract - In Japan, several new elementary techniques have recently been developed which are expected to help prevent the spread of desertification, which is one of the most serious problems on the earth. A model project which integrates the techniques has been established. An experimental field site of 6.8ha has been under construction in Kalgoorlie since December 1996. Preliminary experiments and seedling trials are progressing.

1. Introduction

One third of the whole land on the earth is arid or semi-arid land. Expansion of these areas is one of the most serious problems for the global environment and world food production. Though Japan has no arid land, several new techniques, called elementary techniques, have been developed. In most cases, these techniques are applied separately or in isolation, and in some cases they are not very effective(Matsumoto, 1995).

A Japan-Australia joint project for integrated use of the techniques has started with the aim of recovering vegetation and developing sustainable agriculture in degraded areas. In this presentation, the background of the establishment of the project and the experimental field are explained.

2. Western Australia Desert Development plan; WADD

In 1993 the project to create a model area of desert development in Western Australia (Western Australia Desert Development plan; WADD) was proposed by The Society for the Study of Desert Development (Provisional name). The aims of the plan are food production, an information base, rural development from the view of research, protection of desertification, and positive use of desert. Kalgoorlie was selected as a suitable place for the plan for the following reasons:

1)Interest from the Western Australian Government and Kalgoorlie region was higher than our expectation.

2)The Western Australian Government recognized that international cooperation was an important theme in view of providing results of research obtained by joint projects between the Western Australia and Japan to the developing countries.

3)Western Australia had experience in introducing technology and information about arid-land agriculture to developing countries which have desert areas; such as Libya

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and middle-east countries.

4)Social and economic conditions in Australia were favorable (no time difference with Japan while the seasons are reversed, the government is stable and public peace and order are good, public living facilities are well arranged, etc.).

In the plan, the site was partitioned into the following five zones:

a. Research zone

Researchers and engineers not only of Australia and Japan but of developing countries will be able to use the research zone. Subjects for research may include the following:

• Agriculture, • biotechnology, • engineering, • energy, • meteorology, • geology

b. Production zone

Results obtained in the research zone will be applied here to the field. Useful plants will be planted in this zone and consumed not only in the city, but in other regions or other countries.

c. Information zone

Information regarding present conditions of desertification in the world will be collected and collated. A database of research about deserts and desertification will be built and information will be broadcast via conferences and the Internet.

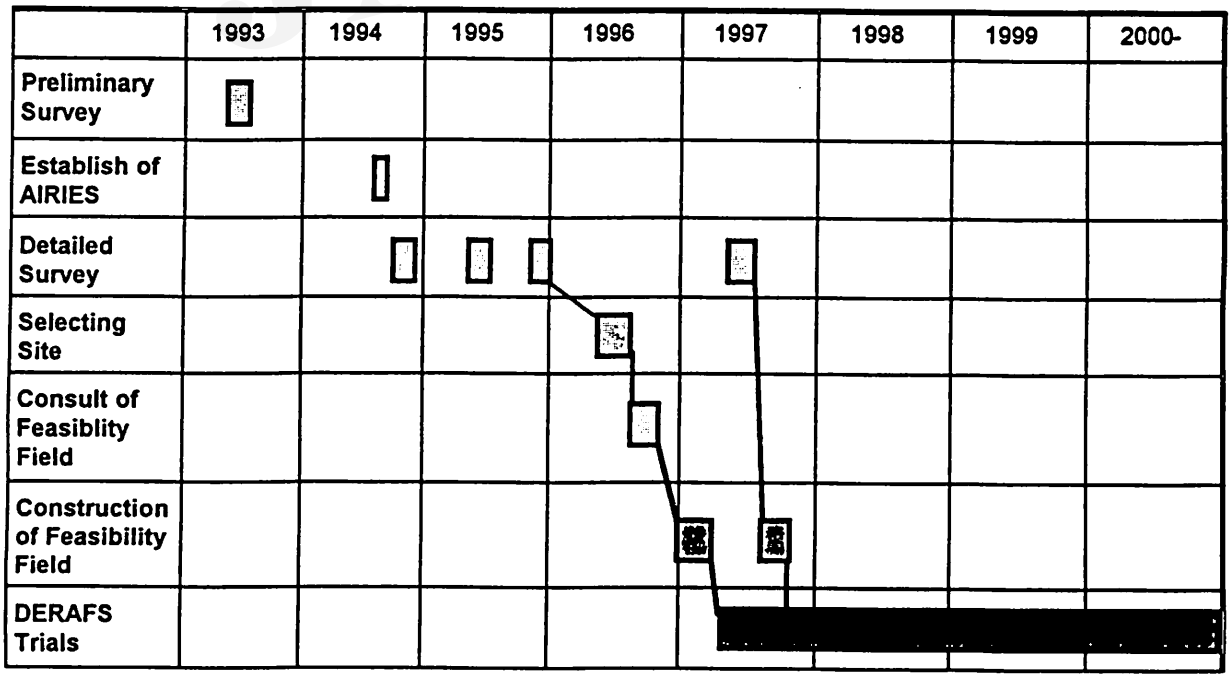
d. Accommodation zone

Houses for people working in the field

e. Town zone

Public facilities such as a hospital and school which from community infrastructure are placed here in the zone.

The schedule of the plan is shown in Fig.1. In 1994, an official organization of The Society for the Study of Desert Development(Provisional name) was established as the Association of International Research Initiatives for Environmental Studies (AIRIES) Western Australia Rehabilitation Project team. Kundana Goldmine Pty Ltd. was selected as the experimental field in 1996 and the preliminary experiment was named Developing Environmental Rehabilitation and Arid Farming Systems(DERAFS).



(Fig. 1) Time Schedule of WADD

3. DERAFS

DERAFS is a Japan-Australia joint project between The University of Tokyo, seven Japanese companies (Kubota Co., Idemitsu Kosan Co., LTD, Mitsubishi Chemical Co., Showa Shell Sekiyu K.K., Mitsuboshi Belting LTD, Obayashi Co., Science Co.), Curtin University of Technology, and the Goldfields Esperance Development Commission(GEDC). A project partnership with groups in the Eastern Goldfields of Western Australia(Williams, 1996) made it possible for staff to be in place on site to facilitate the project. In the first stage, the project focuses on the combination of elemental techniques such as water management or soil improvement. The techniques are to be integrated for use in developing countries.

- Shallow drainage with Sheet-Pipe
- Desalination technique using solar energy
- Vesicular-Arbuscular Mycorrhizal fungi(VAM), and root nodule bacteria
- Water storage ponds using Mizu-Sheet
- Super Water Absorbent Polymer; SAP
- Humic phosphate fertilizer

4. Elementary techniques

Some of the above techniques are explained in detail.

4.1 Solar Desalinater

A Solar desalinater is a container for saline water in a sealed box that has reclined transparent roofs made of glass or plastic. The water is vaporised by solar radiation coming into the desalinater through the roof and condenses to pure water on the surface of the roof.

In the world, a lot of desalinaters have been made for experiment purposes and for water supply. The mean amount of collected water was 2 to 3L:m^{-2}:day^{-1}.

A newly developed sheet is utilized in this project, which is laminated from polyethelene terephthalate for firm structure and from hydrophilic sheet for acceleration of condensed water flow. It will be confirmed in the project whether the sheet is effective in increasing water condensation.

4.2 Shallow drainage

Underdrainage is often used to reduce water-logging. Most drainage is buried after digging ditches, which is quite a heavy task. Sheet pipe method is much easier than the conventional one. The pipe is shaped from a sheet rolled around a smaller pipe, like a paper roll. As the sheet enters the ground, the edges of the sheet connect and it forms a tube. Before installation, the sheet pipe is in the form of a roll that is easy to carry and needs little storage space. A special ripper cuts a narrow trench 2 or 3 cm wide, into which the pipe is laid. This means the soil disturbance is minimum. In the project, it will be confirmed whether the pipe is effective under saline silty soil conditions.

4.3 Vesicular-Arbuscular Mycorrhizal fungi(VAM)

VAM is a microorganism, symbiotic with plants that helps plants to absorb slightly soluble phosphate acid. Once VAM infects plant roots, plants can absorb a larger quantity of nutrients and can survive under harsher circumstances; such as salty or drought conditions. They are utilized for minesite rehabilitation in arid lands(Jasper, 1994). In the project, it will be confirmed whether VAM developed in Japan can benefit plants in arid conditions.

5. Experimental Layout

The experimental field is located in Kundana Goldmine Pty Ltd which is approximately 25km west of Kalgoorlie, Western Australia. The annual rainfall averages 265.4mm and the soil is calcareous loam (Aylmore et. al.,1995). The field is roughly divided into three blocks, and each block is divided into four sub-blocks. Treatments of each block are shown in Table.1.

Table.1 Field treatment

Blocks	Area(m^2)	Water resource	Plants	Planting method
A-2	2,000	irrigation	tree + vegetable	seedling
A-3	2,000	irrigation	tree + vegetable	seedling
A-4	2,000	irrigation	tree + grass	seed
A-5	2,000	irrigation	tree + crop	seed
B-1	5,000	irrigation	tree + shrub	seed
B-2	5,000	irrigation	tree + shrub	seedling
B-3	5,000	rainfed	tree + shrub	seed
B-4	5,000	rainfed	tree + shrub	seedling
D-1	5,000	irrigation	tree + shrub	seed
D-2	5,000	irrigation	tree + shrub	seedling
D-3	5,000	rainfed	tree + shrub	seed
D-4	5,000	rainfed	tree + shrub	seedling

Construction of the field has two phases, A-2, A-3, and D blocks were constructed in December 1996 to February 1997. The rest of the field is to be constructed from July 1997.

The irrigation water is a mixture of treated water (less than 500ppm dissolved solutes) and storage water in the unused open pit(10,000ppm dissolved solutes).

In the A block, vegetables are planted. Native shrubs are planted in the B and D blocks. The effects of the treatments +/-irrigated, +/-SAP, +/-VAM, +/-Fertilizer are examined within the blocks.

6. Future

DERAFS is in the early stage, and it will be continued for several more years. It is expected that significant and valuable results will be obtained as the project progresses.

Acknowledgment

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Dispersion coefficients of unsaturated sand determined by salt accumulation analysis

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ABSTRACT -The movements of salt water through both unsaturated sand during evaporation and saturated sand were traced by column experiments and the flow and transport analysis. In this analysis, salt accumulation in soil surface could be analyzed by calculating mass flux at the surface from the surface salt concentration and evaporation rate. The analyzed longitudinal dispersivities of unsaturated sand while water in soil moved up to the surface were about one tenth of the test scales. This was in agreement with experiments under saturated conditions when water went down. As dispersion coefficients while water moved up or down were the same, salt water movements under both saturated and unsaturated conditions were the same.

Key words : Evaporation, dispersion, migration analysis, longitudinal dispersivity

1. Introduction

Salt accumulation in soil is a serious problem for agricultural areas in arid and semi-arid lands. Therefore, in order to rid soil of excess salts, it is necessary to clearly define salt water movement during evaporation. Especially, during evaporation salt water moves up to the soil surface through unsaturated sand. Water only evaporates from the soil surface and as a result salt remains there. In this study, we performed two types of tracer tests and determined dispersion coefficients both when there was salt water movement toward the soil surface from a lower position during evaporation under unsaturated conditions and when water went down under saturated conditions. The movement of salt water through both unsaturated sand during evaporation and saturated sand was traced by column experiments and flow and transport analysis. Salt accumulation in the soil surface during evaporation could be analyzed by calculating mass flux at the surface from surface salt concentration and evaporation rate.

Samples used in both tests were composed of Flattery quartz-sand, from Australia. Mineralogical analysis, using an X-ray diffractometer determined that Flattery sand was 99 percent quartz. For the sample, the true gravity density and dry density were 2.7 and 1.6 g cm^{-3}. The porosity of the sand was calculated to be 41 percent.

2. Saturated sand

2.1 Method

Quartz sands were placed in an acrylic resin cylinder with an inner diameter of 5 cm. The height of the compacted sample was adjusted to be 2.9 cm to achieve a fixed dry density, 1.6 g cm^{-3}. Before a tracer solution was pumped into the column, the sample was saturated with distilled water. Figure 1 shows the laboratory test apparatus. To determine longitudinal dispersivity, tracer solutions containing 145 ppm Br^- were pumped into the column under constant flow rates. Flow rate was maintained at a constant level through the manual adjustments of the nitrogen cylinder valve. The volume of effluent solution was measured to determine the flow rate. The tracer concentration of the effluent solution was analyzed using ion exchange chromatography.

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2.2 Analysis

Laboratory test, conducted under a constant head condition, resulted in the production of tracer breakthrough curves. Actual velocity and dispersion coefficients were calculated using breakthrough-curve data with the following analytical solution of the one-dimensional advection-dispersion equation (Ogata and Banks 1961) :

$$\frac{C}{C_0} = \frac{1}{2}\left\{\mathrm{erfc}\left(\frac{L - Vt}{2\sqrt{Dt}}\right) + \mathrm{erfc}\left(\frac{L + Vt}{2\sqrt{Dt}}\right) \times \exp\left(\frac{VL}{D}\right)\right\} \qquad (1)$$

where; C : concentration, C_0 : initial concentration , L : length of sample, D : dispersion coefficient, t : time, and V : actual velocity. The initial and boundary conditions are given as;

C_0 = constant, at all times ; C = 0, X = ∞, at all times ; C = 0, X > 0, at t = 0.

From the actual velocity (V) and the monitored constant flow rate (Q), the cross-sectional area of void through which the pore water passed (A) was calculated by the equation $A = Q\ V^{-1}$. The effective porosity (ε) was then calculated, using the equation $\varepsilon = A\ A'^{-1}$ based on the Depuit-Forchheimer assumption. A' represents the total area of the sample cross section.

2.3 Results

The hydraulic conductivity was 9×10^{-5} cm sec^{-1} calculated from the result. Figure 2 shows a breakthrough curve obtained from laboratory tracer test data. The line represents the regression curve using the analytical solution. Using equation (1), the actual velocity and the dispersion coefficient for the tracer were calculated to be 0.00043 cm sec^{-1} and 0.00012 cm^2 sec^{-1} according to the relationship between elapsed time and the effluent tracer concentration normalized by initial tracer concentration. As a result, longitudinal dispersivity was 0.28 cm which was about one tenth of the test scale (2.9cm).

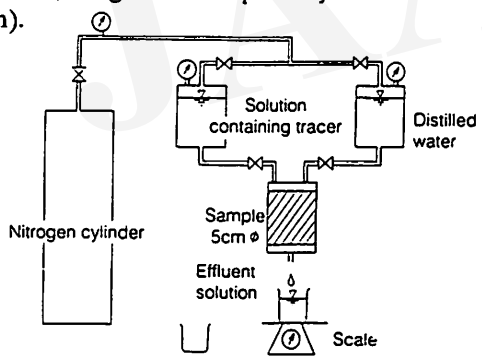

Fig. 1 Laboratory test under saturated condition

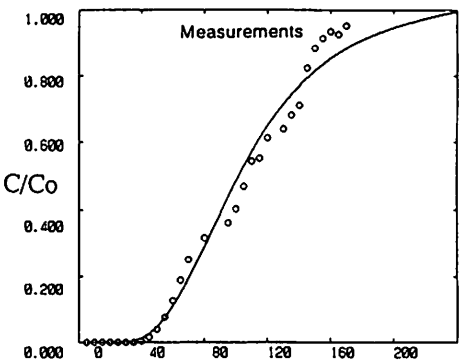

Fig. 2 Breakthrough curve under saturated condition

3. Unsaturated sand (Evaporation process)

3.1 Method

Figure 3 shows the laboratory test apparatus. Quartz sands were placed in an acrylic resin cylinder with an inner diameter of 5 cm. The height of the compacted samples was adjusted to be 9 cm to achieve a fixed dry density, 1.6 g cm^{-3}. After the sample was saturated with distilled water, the sample was connected with a tracer solution containing 280 ppm Cl^- under constant head. The test

apparatuses were dried in the room whose temperature was fixed at 35 °C. Under this condition, the evaporation rate from water in a pan with a 62.7 mm diameter was 3800 mm per year. During the experiment, the weights of the tracer solution were measured. Average evaporation rate from the sand was 600 mm per year.

After 41, 71, 73, 101, and 143 hours, the test apparatuses were dismantled and separated. Distributions of water content were determined by weights in both water saturated and dry conditions. Cl^- concentrations were determined by ion exchange chromatography. Although water content near water table was over 24 %, water content at each depth was about 22 % except the neighboring water table.

We used three-dimensional coupled groundwater flow and an advection-dispersion code using FEM (MIGR3D) developed by Kawamura (1987). The details and results of bench mark tests of the code were described by Kawamura.

3.2 Flow analysis

The equation governing steady-state groundwater flow in a three-dimensional system is generally given as uniform medium,

$$\frac{\partial^2 \phi}{\partial x^2} + \frac{\partial^2 \phi}{\partial y^2} + \frac{\partial^2 \phi}{\partial z^2} = 0 \qquad (2)$$

where ϕ : piezometric head, and x, y, z : Cartesian coordinates

The system boundaries are impermeable excepting the surface of sand and bottom of sand. Boundary conditions can be given as follows,

$$\phi = \phi_1 \quad \text{at the surface of sand,} \quad \phi = \phi_2 \quad \text{at the bottom of sand} \qquad (3)$$

where ϕ_1, ϕ_2: steady-state piezometric head level. When ϕ_1 and ϕ_2 were assumed to be 1 and 2.85 cm, evaporation rate became 600 mm per year calculated from ϕ_1, ϕ_2, and hydraulic conductivity (9×10^{-5} cm sec^{-1}). A flow analysis was performed using FEM in equation (2). The analysis was simplified using the boundary conditions described by equation (3). These values were used to make a numerical transport model.

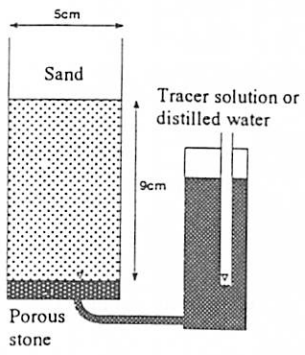

Fig. 3 Laboratory test under unsaturated condition

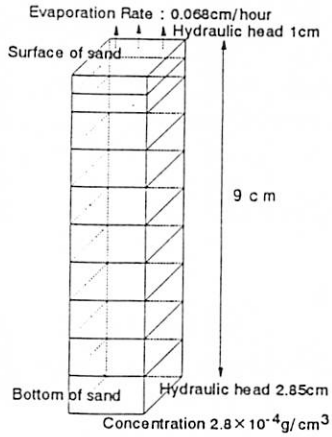

Fig. 4 Analytical model

3.3 Transport analysis

Figure 4 shows the numerical model for transport analysis. A coupled equation governing groundwater flow and advection-dispersion in a three-dimensional system is given as follows,

$$\frac{\partial C}{\partial t} = \frac{\partial}{\partial x}(D\frac{\partial C}{\partial x}) + \frac{\partial}{\partial y}(D\frac{\partial C}{\partial y}) + \frac{\partial}{\partial z}(D\frac{\partial C}{\partial z}) - \frac{\partial}{\partial x}(VxC) - \frac{\partial}{\partial y}(VyC) - \frac{\partial}{\partial z}(VzC) + \frac{F}{\varepsilon} \quad (4)$$

$$Vx = vx/\varepsilon, Vy = vy/\varepsilon, Vz = vz/\varepsilon, \; D = \alpha \mid V \mid, \; V = \sqrt{Vx^2 + Vy^2 + Vz^2}$$

where ε: effective porosity, C : concentration, D : dispersion coefficient, α: longitudinal dispersivity, Vx, Vy, Vz : actual velocity in the x, y and z directions, and vx, vy, vz : apparent velocity in the x, y and z directions. The system boundaries are impermeable except at the surface of sand and bottom of sand.

$$F = F_0 \text{ at the surface of sand, } F_0 = C_t \times Vz \times S \times \varepsilon, \; C = C_0 \text{ at the bottom of sand} \quad (5)$$

where F : flux of mass ($\Delta C / \Delta t$), F_0 : flux of mass at the surface of sand, S : square of the surface, and C_0 : concentration of solution, C_t : surafce concentration. A transport analysis was performed using FEM and the boundary conditions described by equation (4) and (5).

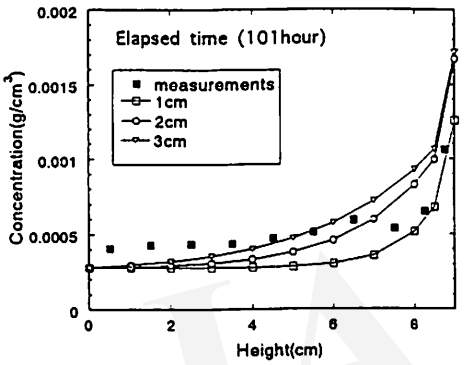

Fig. 5 Breakthrough curve under unsaturated condition(101 hours)

3.4 Results

Figure 5 shows an example of the correlation between the Cl^- concentrations of sand and the calculated breakthrough curve after 101 hours. All calculated results indicated that longitudinal dispersivity values were determined to be 0.5 to 1.5 cm according to the relationship (Ohtsuka et al., 1997). They were in agreement with one tenth of the test scale (9 cm).

4. Discussion and Conclusion

We performed two types of tracer tests with both saturated and unsaturated conditions using column. Under the unsaturated condition, water in soil moved up to the surface during evaporation process. Laboratory results were analyzed and longitudinal dispersivity values were determined by flow and transport analysis. As a result, the analyzed longitudinal dispersivities of both saturated and unsaturated sand were about one tenth of the test scales. This was in agreement with experimental results under saturated conditions according to Ii, 1995. Therefore, salt water movements under both saturated and unsaturated conditions were the same because dispersion coefficients while water moved up or down were the same.

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Quantitative Studies of Soil-plant Relations in the Eastern Goldfields of Western Australia

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Abstract - Plant communities near Kalgoorlie were studied as part of an investigation into soil-plant relations in the Eastern Goldfields of Western Australia. The study utilised quantitative methods in soil and plant surveys, and multivariate statistical methods including cluster analysis and discriminant function analysis. Site elevation and soil exchangeable Ca were the primary environmental discriminants between the plant communities identified by cluster analysis on a small 27.4 ha study site. Using these two variables, sample points were classified into one of the four plant communities based on Mahalanobis distances. The two methods of classification matched well, with classification based on the two environmental variables providing an indication of which plant community would be most likely to establish in disturbed areas. In a further survey of an area of 100 km^2, soil exchangeable K and Na were the primary environmental discriminants. This type of information can be important to revegetation programs in the region, guiding the use of appropriate plant species under different rehabilitation conditions.

Key Words: environmental variables, plant communities, multivariate analysis, classification, revegetation.

1. Introduction

Mining is one of the most economically important land uses in Australia. However, it is a temporary land use and rehabilitation of mined areas must be consistent with the projected future land use of the area. In the Eastern Goldfields of WA the main obstacles to effective revegetation of disturbed areas are low rainfall, high soil salinity, low nutrient levels, and wide variations in soil pH (Campbell, 1994). These conditions have precluded the use of many plant species present in the vegetation of the surrounding areas. As a consequence the number of different species used in revegetation procedures is usually quite low, being predominantly saltbushes (*Atriplex* sp), bluebushes (*Maireana* sp), and salt and drought resistant eucalypts (Jennings *et al*, 1989; Barrett, 1994). It is not known how long this limited array of species will provide stable plant cover, or whether it provides suitable initial conditions for subsequent successional processes.

Relatively little is known regarding the soil and plant relations of the region. There have been no studies in quantitative plant ecology investigating which soil characteristics are the most important influence on vascular plant species distribution, or on the species composition of different plant communities. We have conducted studies designed to investigate these relations, initially utilising a study site that contains a number of different vegetation types within a relatively small area. Further field work at a larger study site has been completed. The data generated can help to elucidate the soil factors that are important in determining the structure of plant communities in this semi-arid region. It is anticipated that this type of data will be of value in improving revegetation programs; guiding the use a wider range of appropriate plant species under different rehabilitation conditions.

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2. Methods

The smaller study site is a 27.4 ha (ca 660m x 400m) leasehold property located at 30°47'S 121°24'E, approximately 10 km west of the city of Kalgoorlie-Boulder. Seven transect lines were marked out at 100m intervals at the study site, running in east-west direction. Along each transect line 8 pegs were placed, beginning 25m in from the fence line and thence placed at 50m intervals. The 56 pegs marked the sampling points and formed a systematic sampling grid for the plant and soil survey. At each sample point a belt transect of nine contiguous 1m by 2m quadrats was used to obtain a frequency score (0-9) for each vascular plant species. A number of soil and environmental variables were also measured (see Table 1).

The larger study area covers approximately 100 km^2, extending north and west from the initial survey. The area surveyed includes a wide range of plant communities and contains an apparent gradient in soil salinity, culminating in areas of saltbush and salt flats in the northern and western extremes. At each of 41 sampling sites nested quadrats (largest quadrat 450m^2) were used to obtain an importance score (0-8) for each vascular plant species.

The ecological distance between sample points was calculated as 1 - Pearson's r, based on the frequency scores for all identified vascular plant species and the correlation in scores between pairs of sample points. Plant communities were identified by cluster analysis (Ludwig and Reynolds, 1988), using several different clustering strategies. Discriminant function analysis was used to determine which soil and environmental variables distinguish between the plant communities (Manly, 1994).

3. Results

At the smaller study site three different clustering strategies, Ward's method, weighted pair group averaging, and unweighted pair group averaging classified the sample points into four plant communities with almost complete agreement. The communities can be characterised as: 1) Jam Shrubland - dominated by dense stands of the medium shrub *Acacia acuminata*, 2) Grey Gum Woodland - dominated by *Eucalyptus griffithsii*, 3) Salmon Gum Woodland - dominated by *Eucalyptus salmonophloia*, 4) "Ground Covers" - no dominant upper story species, characterised by the presence of generalist herbs, low shrubs and weeds.

The contribution of each soil and environmental variable to the discrimination between the plant communities is shown in Table 1. The first two variables in the table, exchangeable Ca and site elevation, make strong and highly significant contributions to the discrimination between the plant communities. The next group of variables (pH, slope, exchangeable Mg and Na, $EC_{1:5}$) make weaker contributions that are significant or nearly significant. The last group of variables on the table (N_5, soil depth, exchangeable K, P) make weak and non significant contributions to the discrimination. Site elevation and exchangeable Ca were then used to classify the sample points. A group centroid for the two variables was determined for each community identified by cluster analysis. Each sample point was then classified as belonging to the community where the Mahalanobis distance from the group centroid was smallest (Manly, 1994). The classification matrix (Table 2) shows that a high percentage of the Jam Shrubland and Salmon Gum Woodland sample points were correctly classified according to Mahalanobis distance. The classification was less precise with the Grey Gum Woodland. The "Ground Covers" were mostly classified as Salmon Gum or Grey Gum Woodlands.

Table 1. Contribution of each soil and environmental variable to the discrimination between the four plant communities identified by cluster analysis.

Variable	*Partial Lambda*	$F_{(3,42)}$	*P*
Calcium[b]	0.704	5.89	0.0019
Elevation[a]	0.729	5.21	0.0038
pH	0.798	3.54	0.022
Slope[a]	0.799	3.51	0.023
Magnesium[a]	0.829	2.89	0.046
Sodium[b]	0.834	2.78	0.053
$EC_{1:5}$[a]	0.856	2.36	0.085
N_5[b]	0.881	1.89	0.146
Depth[c]	0.916	1.29	0.292
Potassium	0.977	0.32	0.809
Phosphorous	0.999	0.20	0.996

Superscripts indicate data for a variable were transformed to obtain a normal distribution: [a] ln, [b] $\log_{10}$, [c] reciprocal. N_5 is soil penetration resistance.

Table 2. Classification matrix of the communities according to cluster analysis and allocation of sample sites to the community types for which they have the minimum Mahalanobis distance from the group centroid. The variables soil exchangeable Ca and site elevation were used to calculate Mahalanobis distances. The last column (Percent Correct) shows the percentage of the allocations according to Mahalanobis distance which agree with the classifications according to the cluster analysis.

	Community According to Mahalanobis Distance				
Community Identified by Cluster Analysis	Jam Shrubland	Grey Gum Woodland	Salmon Gum Woodland	"Ground Covers"	Percent Correct
Jam Shrubland	17	1	0	0	94
Grey Gum Woodland	3	15	0	2	75
Salmon Gum Woodland	0	0	9	1	90
"Ground Covers"	0	4	2	2	25

Preliminary analysis of the data from the larger survey indicates the sample sites fall into four groups as identified by cluster analysis. The results of the discriminant function analysis are shown in Table 3. Soil exchangeable K and Na made the strongest and the only significant contributions to the discrimination between the plant communities.

Table 3. Contribution of each soil variable to the discrimination between the four plant communities identified by cluster analysis of the larger study area..

Variable	*Partial Lambda*	$F_{(3,31)}$	*P*
Potassium[a]	0.650	5.56	0.0036
Sodium[b]	0.729	5.21	0.0038
Calcium[c]	0.888	1.30	0.291
pH[d]	0.910	1.03	0.394
Phosporus[e]	0.918	0.92	0.441
$EC_{1:5}$[f]	0.983	0.18	0.909
Magnesium[f]	0.997	0.03	0.992

Superscripts indicate data for a variable were transformed to obtain a normal distribution: [a] $\sqrt{}$, [b] reciprocal, [c] cosine, [d] hyperbolic sine, [e] $\log_{10}$, [f] sine.

4. Discussion

This study shows how soil and environmental variables can be used to guide the establishment of plant communities in disturbed or degraded areas. Within the range of conditions at the smaller study site, only the variables elevation and exchangeable Ca were required to provide classifications which matched well with the communities identified by cluster analysis (Table 3). The misclassifications occurred in the border between the Grey Gum Woodland and the Salmon Gum Woodland. This is not surprising since in these sample points conditions are probably transitional between those favouring one plant community or the other. The misclassification of most of the "Ground Covers" sample points is consistent with these sites being in disturbed areas where the characteristic plant communities have not re-established. Furthermore, the classifications based on elevation and exchangeable Ca indicate which type of plant community is most likely to be successfully established in these areas. In the survey of plant communities which occur over a wider range of soil conditions, exchangeable potassium and sodium were identified as the major determinants of community structure. The results of this study indicate that in the Eastern Goldfields of Western Australia measurement of a relatively small number of environmental variables may be sufficient to determine the most suitable plant species mix for revegetation programs.

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New Technologies for the Rehabilitation of Arid Areas

Papers Not presented at the Conference

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Advances in the Control of Salinisation in Xinjiang

Ji Fang*

Abstract - In Xinjiang, China, three stages in the control of salinisation have been implemented: 1) "dry drainage," 2) external drainage, 3) comprehensive measures. At present, the length of anti-seepage irrigation channels has been up to 53,600 km and made up 17.7% of that of total irrigation channels. Gross irrigation norm has been gradually reduced from 15,000 m^3/ha in the early 1980's to 13,500 m^3/ha in the middle 1990's. Vertical well and closed drainage, and drip and sprinkle irrigation have been practised in some areas. It has been shown that comprehensive measures are considerably effective in the control of salinisation.

Key Words: salinisation, control, comprehensive measures

1. Introduction

Xinjiang is situated in the inland arid areas of the temperate and warm temperate zone (34° 25′ N~49° 11′ N, 73° 40′ E~96° 18′ E). It is covered with various desert soils, including a large area of salt-affected soils due to intensive accumulation of soluble salts in soils under conditions of low precipitation and high evaporation. The area of land affected by salinisation is 14.58 million ha, occupying 8.8% of that of the total lands in Xinjiang. The lands that have been reclaimed and will have been reclaimed are mainly on piedmont plains. On these lands the development of agricultural production presents problems with soil salinisation. People have experienced the processes from partly understanding about salinisation to being acquainted with its genesis. They have been searching for some methods to try to bring soil salinisation under control. Some achievements have also been gained in recent several decades. It will be beneficial to the sustainable development of agriculture to sum up advances in the control of salinisation.

2. Developmental Stages in the Control of Salinisation

2.1 The controlling stage of "dry drainage" The term "dry drainage" as used in this paper, refers to removing the salt from cropped soils by means of micro-relief discrepancy. The process is as follows: first, the salt in cropped soils is leached towards the profile bottom, then it is transported to adjacent uncultivated land through evaporation of capillarity. The adjacent uncultivated land finally is taken as "dry drainage" salt accumulation place of the cultivated land. The cultivated area of Xinjiang was only 1.21 million ha in 1949, but land was rapidly reclaimed on a large scale and the area greatly increased from the 1950's to the early 1960's. The "dry drainage" was still dominated during the period. It is obvious that "dry drainage" is related to agricultural production characterised by dispersion, small scale, low investment capacity. With the development of agricultural production, some problems, for example wasting land and inefficiently removing salt, gradually occurred. More economic, effective methods are needed to resolve the problems in the control of salinisation.

2.2 The controlling stage of external drainage While the regular pattern of water and salt movement was understood better and the investment was increased in Xinjiang, external drainage was gradually adopted from the late 1960's to the 1970's in the control of salinisation. In order to

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change the condition of irrigation accompanying with no drainage, arterial drainage channels were developed in most regions. Compared to "dry drainage", arterial drainage channels obviously lowered ground-water table and effectively removed salt from irrigated area.

2.3 The controlling stage of comprehensive measures Comprehensive measures include five aspects: (1) irrigation, that is to strengthen irrigation management, improve its techniques and build anti-seepage channels; (2)drainage, it refers to perfecting drainage systems, particularly external drainage, and recommending vertical well and closed drainage; (3) levelling the ground, that is to rebuild and level the plots that have been cultivated; (4) fertilising, it refers to dressing manure, planting alfalfa and green manure; (5) planting, that is to plant protective forest. Comprehensive measures have been progressively applied to the control of salinisation since 1980 in Xinjiang. The investment of water conservancy construction was 3232.4 million yuan and the length of anti-seepage channels built was 26,850 km from 1986 to 1993, both more than the sum from 1949 to 1985 (Table 1). As comprehensive measures were implemented, the salinisation damage to agricultural production was greatly diminished. Taking No. 12 state farm for example, Table 2 shows that the percentage of crop growth obviously stunted and crop death affected by salt damage changed from 10.8% and 8.3% in 1960 to 4.2% and 1.5% in 1993 respectively. The facts indicate that comprehensive measures are considerably effective in the control of salinisation.

Table 1. The change of the total investment of water conservancy projects and the length of anti-seepage channels built in different periods

Periods	1949	1950-1955	1956-1965	1966-1975	1976-1985	1986-1993
Total investment of water conservancy projects (10^6 yuan)	-	120.0	583.9	513.7	1227.3	3232.4
Length of anti-seepage channels built (km)	30	670	7670	5490	12910	26850

Table 2. The change of the percentage of crops growth obviously stunted and crop death affected by salt damage from 1960 to 1993 in No. 12 state farm

Year	Crops cultivated area (ha)	Crops growth obviously stunted by salt damage		Crops death affected by salt damage	
		Area (ha)	% of crops cultivated area	Area (ha)	% of crops cultivated area
1960	2154	232	10.8	179	8.3
1966	3026	369	12.2	369	12.2
1972	4805	1010	21.0	840	17.5
1974	4957	735	14.8	517	10.4
1978	5315	563	10.6	321	6.0
1980	5541	405	7.3	353	6.4
1983	5770	497	8.9	421	7.3
1988	5357	413	7.7	180	3.4
1990	6157	472	7.7	165	2.7
1991	6609	401	6.1	121	1.8
1992	7126	347	4.9	127	1.8
1993	7220	305	4.2	107	1.5

3. Some Concrete Measures in the Control of Salinisation

The area of croplands affected by salinisation was 31.1% of that of total croplands in Xinjiang in the early 1980's (Ji et al., 1991). Up to now, the statistic data show that about 592,000 ha salinized croplands have been transformed with comprehensive measures.

3.1 Perfecting drainage systems In Xinjiang, there have been a series of changes in the drainage ways in recent several decades. The drainage systems were designed from no drainage to arterial drainage channels, and then to complete connection between arterial, secondary, and tertiary drainage channels. The interval between drainage channels changed from original 500 m to present 250 m or 200 m. As a result, total length of external drainage channels in different levels reached about 60,000~70,000 km in the middle 1990's and the drainage efficiency was raised.

Drainage by vertical well was developed in some regions of Xinjiang such as Usu, Fukang, Manas, No. 22, 101, 222 state farms. The number of electromechanical wells was 25,500 and the volume of ground water extraction was 2,000 million m^3 in 1993. Total area of drainage by vertical well was 20,000 ha.

The closed drainage has been practised in No. 29 state farm since 1990. Its area was 5,000 ha. Average salt content within one meter column has been reduced from more than 9 g/kg before using closed drainage to less than 7 g/kg at present.

In addition, the maintenance method of drainage systems was improved. Instead of artificial dredge, 3 dredge machines were used in No. 12 state farm after 1990 and the drainage efficiency increased significantly. Average salt contents of the plots within one metre column were lower in 1995 than that in other years (Table 3). It suggests that drainage systems perfection and reasonable maintenance play very important roles in the control of salinisation.

Table 3. Comparison of salt content in the plots of No. 12 state farm

Year	Average salt content with 1 m column (g/kg)			
	No. 42 plot	No. 77 plot	No. 43 plot	No. 38 plot
1958 (before reclamation)	76.1	36.2	73.9	75.1
1961	4.10	12.5	8.90	23.4
1965	7.91	8.48	8.27	-
1974	8.40	29.1	6.20	15.8
1982	10.1	3.27	6.23	14.0
1995	2.90	1.38	5.21	1.15

3.2 Improving irrigation methods and strengthening channel's anti-seepage In Xinjiang, border check and furrow irrigation have replaced wild-flooding irrigation now. Gross irrigation norm was reduced from more than 16,500 m^3/ha before the early 1970's to 15,000 m^3/ha in the early 1980's, and 13,500 m^3/ha in the middle 1990's. The area of the croplands with standard border check irrigation was up to 2 million ha in 1994. Drip and sprinkle irrigation were also practised in some areas and the irrigation area was 61,000 ha in 1994. Besides, the technique of irrigation on-plastic film was rapidly spread for cotton cultivation after 1980, the area with irrigation on-plastic film reached 513,000 ha in 1994.

Irrigation channel's anti-seepage has also been enhanced. Anti-seepage measure was carried out not only on arterial channels, but also on secondary and tertiary channels. At the same time the standard of irrigation channel's anti-seepage was gradually improved. The length of anti-seepage channels of Xinjiang sharply increased from 26,700 km in 1985 to 53,600 km in 1993 and the water conveyance efficiency was obviously raised.

3.3 Other measures In addition to the improvement of drainage and irrigation, other measures, such as raising rice for leaching salt, levelling the ground with machine to replace manual work, raising alfalfa and green manure for the improvement of fertility, planting artificial forest for the protection of oases and drainage through evaporation and so on, are still indispensable in the control of salinisation in Xinjiang.

3.4 The simultaneous development of land reclamation and salinisation control A new method has been adopted since the early 1990's. While the virgin lands that belong to salt-affected soils are reclaimed, irrigation channels with anti-seepage, drainage channels, and protective forest are simultaneously built. After the lands are levelled, they will be divided into small plots (30×30 m), then the plots are irrigated for desalination. The land reclamation was operated according to that model in No. 14 state farm. The results indicated that soil salinisation has been controlled to some degree in the region. This promotes the development of agricultural production in Xinjiang.

4. The Issues Related to the Future Control of Salinisation

In Xinjiang, the development of salinisation in cropland is divided into four types (Fan, 1996), stable desalination, unstable desalination, alternation of desalination and salt accumulation, salt accumulation. The types of stable desalination and salt accumulation only distribute in limited areas, whereas types of unstable desalination, and alternation of desalination and salt accumulation are dominated in most areas. Hence soil salinisation still poses a threat to the development of agricultural production. At present, the length of anti-seepage channels in different levels is 17.7% of that of total irrigation channels. On the whole, it is obvious that water conveyance efficiency is still low in Xinjiang and the level of agricultural production is not high enough to invest heavily in the control of salinisation. In addition, in the Tarim basin of south Xinjiang, the content of mud and sand in river water is 1~5 kg/m^3 in irrigation seasons, so the applications of drip and sprinkle irrigation on a large scale are limited by fund and techniques. For the reason of relief, farm drainage along the Tarim River imported a large amount of salt to the river water (total volume of farm drainage is 706 million m^3 and total salt weight is 3.73 million tons each year), which results in increase of degree of mineralization. In Aral station in 1991, degree of mineralization of river water was more than 1 g/L in all the months and more than 5 g/L in April, September, November (Fan, 1996). All of these imply that much work still needs to be done in the control of salinisation in Xinjiang.

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Desertification Control on the Fringes of Oases in Xinjiang, China

Lei Jiaqiang*

Abstract - In Xinjiang, desertification on the fringes of oases, resulting from excessive human activities under the dry and windy climate and sandy ground surface, has occurred heavily. On the basis of large scale surveys and long term tests, some measurements to control the desertification on the fringes of oases is summarized, such as protecting vegetation in the desert, restoring vegetation with floodwater and rainwater, setting up a protective systems and using local conditions to afforest and so on. All of these play an important role in desertification control in different regions.

Key Words: Desertification Control Fringes of Oases Xinjiang

1. Introduction

Desertification as one of the most serious global environmental problems occurs in arid, semi-arid and dry sub-humid areas, which affects or threatens the daily life of human beings. China is one of the countries affected by the most serious land desertification. About one third of the land is affected by desertification and around 400 million people are suffering from land desertification. Xinjiang, situated in the Northwest of China, has an area of 1,650,000 km^2, of which about 47.7% is occupied by desert and desertified land and only 3.6% is oases. Actually, the oases in Xinjiang are encircled by deserts or face on to sandy deserts directly. In this case, the desertification on the fringes of oases, resulting from excessive human activities under the circumstances of the dry and windy climate and sandy ground surface, has occurred heavily. At present, there is an area of desertified land of 6,300 km^2 caused by wind erosion in Xinjiang and mainly distributed on the fringes of oases around the Taklamakan Desert and the Gurbantunggut Desert, here agricultural fields have been covered by dunes or eroded by wind and people suffer from the desertification. In order to control the desertification on the fringes of oases in Xinjiang, some research work has been done in different regions on the basis of large scale surveys and long term tests.

2. Environmental Background of Desertification on the Fringes of Oases in Xinjiang

2.1 Dry and Windy Climate Because Xinjiang is situated in the centre of Eurasia and surrounded by mountains and plateaus which block the moisture-currents from the oceans to Xinjiang the climate is characterized by less precipitation and higher frequency of strong winds.

According to the meteorological observations from weather stations, the average annual precipitation on the fringes of the Gurbantuggut Desert in Northern Xinjiang is 100-200 mm; on the fringes of the Taklamakan Desert in Southern Xinjiang it is 20-70 mm while the average annual potential evapotranspiration is, respectively, about 2,000 mm and 2,100-3,400 mm. The ratio of annual precipitation to potential evapotranspiration falls within the range from 0.05 to 0.10 in

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Northern Xinjiang and less than 0.02 in Southern Xinjiang. In such circumstances, vegetation in a vast area of Xinjiang is very poor and sparse and the eco-environmental system is very simple and fragile. This arid and fragile eco-environment in Xinjiang, especially in the peripheries of desert where the oases scatter provides the natural background for the desertification.

The high frequency of strong winds and the air current directions are determined by atmospheric circulation and topographic conditions in Xinjiang. Under the action of the Mongolia Anticircle and the Westerlies, the prevailing wind direction is NE in the eastern part of the Tarim Basin and W or NW in the western part of the Tarim Basin; meanwhile, under the action of the Westerlies and the air-current from the Arctic Ocean, which passes through the mountains in the western Junggar Basin, the prevailing wind directions are W and NW. The annual number of days of wind that makes sand grains start moving (over 6 m/s) reaches 30 days (highest 90-110 days) in the Tarim Basin and is about 20 days (highest 50-60 days) in the Junggar Basin. Particularly in spring, the frequency and the strength of wind are more than in the other seasons while the surface soil is dry, which intensifies the process of the desertification on the fringe of oases.

2.2 Abundant Sand Source Abundant sand source serves as a material base for the desertification caused by wind. In Xinjiang, the Gurbantunggut Desert and the Taklamakan Desert occupy the centres of the Junggar Basin and the Tarim Basin respectively. Around these two deserts, oases are mainly distributed. The Taklamakan Desert is mainly composed of moving dunes and the sand grains are fine and very fine. Under the action of wind, the dunes and the shifting sands erode the oases in periphery of the desert. In the Gurbantunggut Desert, although the dunes are fixed and semi-fixed ones, the dunes in the margin tend to be mobilized. That means the mobilized dunes provide the sand source for the desertification.

2.3 Irrational Eco-social Activities The census of July 1990 shows that the density of population in oases in Xinjiang reached 240 persons/km^2, greatly exceeding the "critical norm" of the population in the arid areas (7 persons/km^2). Thus the desertification caused by irrational human activities is serious.

2.3.1 Unplanned Utilization of Water Resource In Xinjiang, although the irrigation networks play an important role in the middle reaches to develop the oases, the original balance of water distribution along the rivers has been upset. As a result, the rivers shorten and the lakes at the ends of the rivers shrink or dry up entirely. For example, Xinjiang had an area of lakes of 9,700 km^2 in 1950's, but only 4,748 km^2 at present. The desertification, therefore, happens in the lower reaches seriously.

2.3.2 Unreasonable Reclamation of Land Resource Reclamation by destroying forests was more severe in 1950's and 1960's in Xinjiang. In some areas, especially in the lower reaches of the rivers, the reclamation not only destroys desert vegetation on sandy land but also loosens sandy ground surface, which provides the conditions for desertification.

2.3.3 Excessive Utilization of Biological Resources In general, plants such as *Tamarix* and *Haloxlon* are still the principal energy in the vast countryside in Xinjiang. Large-scale felling of plants in desert area not only lessen the coverage of vegetation but also cause the desertification. For instance, the coverage of vegetation in Mosuowan on the southern fringe of the Gurbantunggut Desert has been reduced from 25-35% in the 1950s to 5-8% today because of gathering firewood. Thus the natural vegetation in the oases on the southern fringe of the Taklamakan Desert suffered serious damage such that the dunes were reactivated and mobile sand invaded oases.

3. Current Situation of Desertification on the Fringe of Oases in Xinjiang

Desertification on the fringes of oases in Xinjiang is mainly existed in both the southern peripheries in the Gurbantunggut Desert and the Taklamakan Desert, as well as the lower reaches of the rivers.

The desertification in the periphery of the Gurbantungnut Desert shows itself mainly in the transformation of fixed and semi-fixed dunes into mobile ones, namely, the mobilization of dunes. The area affected by the mobilized dunes rose from 3%, or 1,500 km^2, in the late 1950s to 15%, or 7,500 km^2, in the early 1980s. Now in the southern periphery of the Gurbantunggut Desert, there exists a 10-20 km wide belt of mobilized dunes, in which some dunes move to oases at a speed of 0.5-2,5 m/year under the action of winds.

In the Tarim Basin, there is about 24,200 km^2 of desertified land lying in the periphery of the Taklamakan Desert. One of characteristics of the desertification on the fringes of oases in the Tarim Basin is to expand to oases at a high speed under the action of higher frequency of strong winds. The result of successive observation shows that the movement of dunes reaches 10-20 m/year.

4. Some Methods to Control Desertification on the Fringe of Oases

4.1 Protecting Desert Vegetation from Cutting In Xinjiang, desert vegetation around oases plays an important role in protecting oases from the desertification caused by wind and blown sand. In the past, however, the function of desert vegetation was neglected. As a result, vegetation in the periphery of oases was seriously destroyed, such as excessive grazing and cutting vegetation in the desert. At present, a series of measures to protect desert vegetation have been carried out. For example, desert vegetation management and protection stations have been set up and restrictions placed on cutting the fuelwood in the desert. In addition, as the economic condition of farmers improving, they use coal instead of wood fuel in winter. The result of investigations on the fringe of oases in the western and northern part of the Taklamakan Desert shows that more than 90% of families use coal in winter and the average amount is 1.8 ton/year. That means the farmers reduced the amount of vegetation cut in the desert.

4.2 Restoring the Natural Vegetation in the Peripheries of Sandy Desert Generally speaking, the peripheric area of oases where desert vegetation was destroyed becomes a sand source to harm oases

under the action of wind. Therefore, it is imperative to restore desert vegetation in order to stabilize sand there. In Cele oasis located in the southern margin of the Taklamakan Desert, for example, the vegetation coverage in the periphery reduced to 3-5% under excessive use and the land degraded into one scattered with 3-5 high dunes. As a result, shifting sands expanded quickly and did serious harm to the oasis. In this situation, the method to use floodwater for irrigation to restore the vegetation was adopted because of less precipitation there. After 3 years' work, the average vegetation coverage rose to over 60%. Other work was carried out in the Mosuowan oasis in the southern periphery of the Gurbantunggut Desert where there is more than 100 mm precipitation. After 7 years of covering sand area by facilitating the growth of grass, the vegetation coverage rose from 3.64% to 15.75%.

4.3 Setting up Protective Systems on the Fringes of Oases In Xinjiang, most oases face on to sandy desert directly. It is important to set up protective systems on the fringes to prevent wind and shifting sand disasters to the oases. In general, the protective systems used include the grass belt, the bush forest and the sand-break forest. The function of the grass belt with the dense grasses and bushes is to stabilize sands, increase the roughness of land surface and reduce the sand content of the blown sand flow in a large area. The bush forest, with its height, is intended to further keep wind off further, stop the sands that have intruded into the system after crossing over the grass belt and make the suspended sand grains in the air fall to the ground. The main role of the sand-break forest, which is made up of the narrow-belt and multi-belt arbors, is to combat strong wind and block sands from entering oases. The results of observation show that more than 90% of sands are blocked in the protective systems and the 1 m high wind speed over the protective system reduces to 45% and 80% of that in open country in Cele and Turpan respectively.

4.4 Using local Conditions to Afforest the Fringes of Oases There is some abandoned farmland on the fringes of oases in Xinjiang, which provides a passage for the intrusion of shifting sands to oases. It is therefore imperative to afforest here for the sand-stabilizing, the sand-break and the woodfuel. Because of the different natural conditions in Xinjiang, the methods to afforest on the abandoned farmland are different. In Cele oasis, for example, more than 600 ha of abandoned farmland has been afforested using summer floodwater for irrigation. Because of the shortage of irrigation water in Spring in Mosouwan, the afforestation was carried out on abandoned farmland using surplus water from farmland in autumn. In addition, some attempts to afforest, such as afforestation to catch rainwater on the ground in Mosouwan and to cut off sand supply and afforest around dunes with floodwater in Cele, have made considerable headway. All of these measures to afforest on the abandoned farmland have achieved remarkable social, economic and ecological benefits.

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Demonstration of the Environment Improvement in the Coal Development Region

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Abstract - There are abundant oil and coal resources in the northwest of China. A few years ago, it was proven that there was a large coal field with an area of 31171.9km² and high quality coal reserves of 2800 billion tons. At present, the coal field has the annual mining capacity of 10 million tons. However, because the coal field is located in a fragile ecological region in which the soil and water losses and wind/sand storm are severe, the environmental condition is very serious. In order to protect the environment, many different measures have been adapted, which have satisfactory effects in the coal field.

Key words: Coal field, Environment, Demonstration

1. Environmental background

It has been proven that a large top quality coal field with an area of 31171.9 square kilometres and reserves of 2800 billion tons of high quality coal with low ash, sulphur and phosphorus contents and high combustion value was located in the region adjacent to Shaanxi province, Shanxi province and Inner Mongolia Autonomous Region in the middle reaches of the Yellow River in China. The coal in the coalfield is easily mined because of the thin earth layer and the simple geological structure. In the past decade, the coal field had approached the annual mining capacity of 100 million tons. Meanwhile, the networks of highway and railway for the coal transport had been completed in the region. The coalfield will become an important energy resource and chemical industry base in the 21st century .However, geographically, the coalfield is located on a plateau with an elevation of 1100-1300 metres, in the inner continent, which is characterised as the typical sand-covered hill and gully loess region. Climatically, the characteristics of the region are described as semi-arid and arid continental monsoon with an annual evaporation of 1300 mm and an annual precipitation of 368.2 mm, 53.1 per cent of which falls in July and August. Because the region is controlled by the Mongolian cold high pressure air mass in the winter and spring, the northwestern wind is prevailing. The annual wind velocity is 2.5-3.6m/s, the maximum is 19-20m/s and the over force 8 wind on the Beaufort Scale lasts as many as 22 days. The ground matter is composed of Quaternary wind-borne sand and the weathering residual of shale, which contain coarse particles with few nutrients and readily suffered from wind and water erosion due to its loose structure. In addition, both the natural and artificial vegetation was sparse in the region because of the long-term reclamation and over grazing. The drought, wind storms, loose surface matter and the sparse vegetation resulted in the rise of clouds of dust, flood disasters and serious wind erosion with the module of 7500-15000 tons per square kilometre. Therefore, the environmental problems had become the restriction to the coalfield exploitation.

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However, in order to construct an advanced coalfield rapidly, it is necessary to protect the environment in this region.

2. Parallel progress in the course of the development of coal field and environmental improvement

According to the report on Shenfu-Dongsheng coalfield overall design approved by the state, the individual environmental protection designs were worked out for the key coal mine under construction. The environmental protection project kept pace with the coal mine construction. The processes from coal mining site, coal dressing to loading by means of belt transport were carried out in a closed system, to reduce the coal dust pollution. The stack-yards were established for the and gangues. while those waste materials were piled up in the yard, part of yard was covered and turned into land for farming and forestry by reclamation techniques. The wastewater treatment plants were built to treat the water discharged from the coal pits, coal dressing plant and the thermal power station as well as the residential quarters. The treated water was reused by the coal dressing plant, which further saved the water resources. Furthermore, the grassland and wood land could be irrigated directly by with wastewater, making the environment greener.`

3. Environmental improvement on the periphery of the mine zone

The total area of the coalfield is more than 300 thousand square kilometres and the principal mine zone under construction covers that of 100 square kilometres. The safe operation of the mines depends upon the periphery of the mine. Therefore, it is very important to take the environment harnessing project along the mine periphery with a width of 5 kilometres as the example of environmental rehabilitation. In order to improve the environment, some measures have been adopted in practice. These are introduced as follows

3.1 River administration involving dredging, block removal, sandbagging revetment and flood control.

The Wulanmulun River flows through the coalfield. The key pits spread along the bank of the river. The annual runoff volume of the river is two billion m^3 and flood runoff volume accounts for 97 per cent of the total volume. The average annual sediment delivery volume is 28.3 million tons and the average annual sediment delivery module is 7106t/km^2. These were directly related to the softness of the pits, transport network and the lower reaches of the Yellow River. Because the mine development was not administered properly, a great quantity of the rocks and earth had been put into the river. For example, the designed sectional flood volume of the No. 1 bridge, built across the river in 1986, was 7160m^3/s. But in 1994, the average thickness of the sedimentation was 2.38 metres, the maximum was 4.05 metres under the bridge. The designed pier over the river was 3.3-3.6 metres tall, but the present pier was 0.4-1.4 metres tall because of the serious sedimentation in the river. Therefore , the environment harnessing project of the mine zone had to focus on the dredging and revetment besides wind protection and sand fixation project as well as soil and water conservation in the upper reaches of the river. In order to insure the safety of the No.1 bridge, the solution to the accretion removal under the bridge had been worked out since the completion of the No.2 bridge across the same river. Therefore, above all, the open coal mine in the site of the river bed was forced to close

and was refilled with the stripped top layer, which could make the river bed smooth and enlarge the width of the river bed. Secondly, the barrier in the channel had to be removed. One billion tons of silt had been carried away from the river by means of the machines before the flood season every year. Moreover, 8.53 kilometres of embankment and 30 thousand square metres of slope bank had been strengthened in Huojitou, Bulianta and Majata, respectively, so as to guarantee the flood to flow safely and to avoid the flood disaster up to a one in one hundred year event.

3.2 Creation of farmland by means of reclamation

The coalfield development had brought about influences on the agro-ecological system. A lot of arable land had been occupied by the sand and gravel stripped from the open coal mine, gangues and the life refuse. The self-combustion of the coal cinder in the gangues gave off a great deal of smoke dust which polluted the air. In order to solve the problems and demonstrate the harnessing processes, an open pit was filled with the slag and 100 centimetre thick layer of sand and earth placed on top according to a plan worked out by the Commission of Natural Resources Comprehensive Investigation under the Chinese Academy of Sciences in 1993. This measure reclaimed 13 hectares of arable land of which four hectares were used as forestry land and six hectares of the land were used as the grass land. A greenhouse was set up in the remaining land. Vegetables were grown in the greenhouse, which has been of great economic benefit. The stack-yard for gangues was flattened by machines in Daliuta coal mine zone and more than 7000 trees such as *Populus opera Pinus sylvestris var mongolica* had been planted in the yard and the survival rate of trees was 90 per cent. Average growth was 10-15 centimetres tall. These techniques have been applied on a large scale in order to control the pollution of the gangue stack-yard .

3.3 Construction of shelter forestry belt

It was well known that the landscape was the desertified and the environment was very fragile in the region. The sand moved with the wind and the dust flew up. This made the living conditions unpleasant for the people. Therefore, afforestation was necessary in the region. The ways between the coal mines were ties for work, production and the people's activities. In order to keep the ways from the damage caused by the sand storms or the flood, the protection measure was to mainly adopt the biological approach besides the engineering measure. The step was to dig large holes in which manure was applied and Populus opera, *Pinus tabulaeformis* were planted according to the land surface feature. The survival rate of the little trees was over 90 per cent. When the *Populus opera* grew up they were alternated with needle-leaf pine. A mixture of shrubs such as *Amorpha fruticosa and Sabina vulgaris* was alternated with *Sabina vulgaris*. According to the measures above, the shrubs and grasses were planted in a belt 0.5 kilometres wide in the sand land along the highway and the shrubs and trees were planted in the sand land far away from the highway. At present, according to the afforestation plan, 806000 trees have been planted and the sand land has been planted along the 48 kilometres long highway.

3.4 Quick afforestation of the desertified land.

It was of prime importance in improving the environment to reafforest

the desertified land within five kilometres in the coal mine zone. The total planned afforestation area in the zone was 1000 hectares. At present, the afforestation demonstration has been carried out in one tenth of the area. The planting approache was that the seedlings of *Pinus tabulaeformis. Pinus sylvestris var. mongolica. Platycladus orientalis* were planted in 40-60 centimetres deep holes in weathered rock residual covered by a thin layer of sand. The holes were distributed like the scales of a fish, which could trap the rain water. But the seedlings must be watered in the dry season. The survival rate of the seedlings was over 80 per cent. Ten thousand seedlings had been used in the trial and the seedling were one metre tall. However, the cost of this practice was too high. Therefore, This practice was only adopted in a small area. In sand land with a thick sand layer and the hill and gully loess region, the moving sand dune should be fixed by the two by two metre square grid blocks which could also trap the sand dust or by the firewood covering the surface of the sand land, and then the grass and the trees were planted in the sand land. This measure could fix the moving sand dune rapidly. In the semi-fixation sand land, according to the high standard and quality, leguminous shrubs and grasses such as *Hedysarum scoparium. Hedysurum mongolium, Melilotus albus, Astragalus adsurgens*, etc were planted in the rainy season. In the coming year, the shrubs would be about 50-80 centimetres tall and grow well, which could improve the sand land and prevent the sand land from wind or water erosion and protect the main plants. Three or four-year old 25 centimetres tall trees such as *Pinus tabulaeformis, Pinus sylvestris var mongolica* with their strong roots were planted between the grass belts or the free sand land. The trees were watered about 2 or 3 times in the dry season. The survival of the trees was more than 80 per cent. The growth was 5-10 centimetres. In order to conserve water, three or four litres of water was used per tree. A plastic mulch was applied, which could control the water evaporation and keep the soil wet for 10-20 days and insure the trees would grow well. The demonstration forest with an area of 20 hectares, planted in 1996, grew very well, and the trees are about 30 centimetres tall on average. The afforestation techniques above are being applied on a large scale for the purpose of making the environment better in the coalfield.

4. The guarantee of the environment improvement in the coalfield-laws and funds.

Both the laws and enough funds are the important guarantee of the development of China's energy base. The environmental improvement programme should be included in the overall construction plan of the coalfield. State administrative institutions and the Research Institute should engage in the environment harness project, according to the administrative regulation or laws. The money drawn from the coal sale in proportion to 1 percent of the income per ton of coal was used for the environment improvement, which financially guaranteed the environment improvement to be carried out.

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How to Deal with Sand Vegetation Problem Caused by Oil and Gas Fields Development in Shaanxi, Gansu and Ninxia

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Abstract- This paper studies the sand vegetation problem caused by the first phase of the $3.0 \times 10^9 m^3/a$ project of oil and gas fields in the middle of Shaanxi, Gansu and Ninxia, makes an overall investigation on the destruction of soil and vegetation caused by oil and gas fields development which is now under basic construction. According to the soil types and the concrete conditions needed for the development of oil and gas fields, the present paper meanwhile puts forward some measures for regaining vegetation and protecting the development of oil and gas fields.

Key words: Vegetation problem, Countermeasure

The Maowusu desert, which is one of the seven biggest deserts in China, is located in the arid areas of the northwest. The desert with the total area of 32, 000km^2 is rich in many mineral resources such as coal, oil and natural gas. Therefore it will be the energy resources base in the 21th century for China. Exploiting the mineral resources in the arid desert where ecological environment is extremely bad, it is very important to protect environment. How to exploit the resources on the condition that environment is protected is a new research subject. For this reason, we have made an overall investigation on destruction of sand vegetation and soil structure caused by Shaanxi-Gansu-Ninxia oil and gas fields which is within the Maowusu desert. At the same time, we have put forward some constructive suggestions and technical plans for restoring the damaged vegetation, which is not only of great importance to exploit oil and gas fields and to avoid desertification in the development area, but also of great reference value to the similar areas.

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1. Background

The first phase of the $3.0 \times 10^9 m^3/a$ project of Shaanxi-Gausu-Ninxia oil and gas fields (To be abbreviated to "the project area"thereafter) is located in Jinbian and Henshan of the northern Shaanxi, and Wushenqi of Inner Mongolia Autonomous Region. The project area relates to 11 townships of 3 counties within Shaanxi Province and Inner Mongolia Autonomous Region and its geogrophical location is 37° 37′ -38° 04′ north latitude and 108° 41′ -109° 13′ east longitude. In the project area, the general height of the dune is 5-8m; for some parts of area, the height of the dune is 15-20m. The most of dunes have turned into fixed or semifixed sand lands, owing to over 40 years' forestation. Some of dunes are still drifing just because of their being big and dry. The project area belongs to continental monsoon climate zone, which is characterized by being dry, windy and sudden change of temperature. There is not much rainfall, and the rainfall is also not well distributed. The annual average rainfall is 395.4mm. The total rainfall of July, August and September accounts for 63.6% of the annual average rainfall. The annual maximum rainfall is 526.7mm and the minimum is 319.6mm. The maximum rainfall is 1.6 times as much as the minimum rainfall.

Wind: The annual average wind speed is 3.2 m/s and the maximum speed is 24 m/s. On an average, there are 21.6 days of force 8 or over force 8 wind and 19 days of sand storm per year. For this reason, the saying goes like this: "There is a wind every year that can last from spring to winter."

Temperature: The annual average temperture is 7.6℃. The maximum temperature is 38.9℃ and the minimum one is -32.7℃. The harsh natural conditions and strong wind erosions make the eco-invironment very bad. It is well known that the famous historical Tongwan Castle which was buried in oblivion by sand long ago is located in the centre of the project area. Therefore it is very important to protect environment so as to avoid repeating the historical tradedy of the Tongwan Castle while exploiting

oil and gas fieles.

2. Present Situation of Development

The total proved reserves of gas fields are 320 billion m^3. At present, the most of gas wells for the project have been driven ready. The 19 gas purifying factories and gas collecting stations are under construction. The 186.8km pipeline is being laid. The 280.2 km of working roads have been built in the project area. The 750km of pipelines to three cities (Xian, Beijing and Yinchuan) have been laid in sand area. The natural gas development not only decreases the related cities'air pollution and makes the cities clean and modern, but also promotes the local economic development.

The eco-environment problems arise with the development of gas fields. After the foundation of the People's Republic of China, the people in sand areas have been planting trees for nearly 50 years. The rate of plant cover is increased to present 39.8% from 2% during the early days of the foundation of new China. The 800,000 ha of sand fixing forests have been prevented. These forests not only play an important role in sand control and sand prevention, but also improve the physical and chemical nature of the soil. The amount of total accumulated fallen leaves reaches 15.4-27.3T/km^2. Within the 0-60cm topsoil, the content of the soil organic matter is increased by 4.6-7.0 times compared with the drifting sand lands without plant cover. Owing to the improvement of the soil and eco-environment, many wild plants grow in the forests, which have formed a new plant community. In rainy season, 1-2cm of the green cover with bryophyte and algae have been formed in the surface of lands. In dry season, the green cover has wilted and formed a hard skin, which is conducive to fixing the sand and improving the eco-environment in sand area.

Howvever, 2420 ha of sand vegetation have been damaged by the development of gas fields. The laying of pipelines and the building of

roads have damaged the sand vegetation soil structure and formed new drifting sand. Since the factories, stations and pipelines can be found all over the desert, the area of drifting sands becomes bigger and bigger and the eco-environment in the sand fixing forest becomes worse, and a new desertification occurs. In order to regain vegetation, control further desertification, protect the eco-environment and ensure the healthy development of gas fields, the remedy measures must be taken in the project area.

3. Control Measures

"To suit measures to local conditions" is the basic principle of sand control. According to the investigation of the environmental conditions of different factories and stations as well as of different soils through which the pipelines and roads pass, Table 1 is compiled.

In order to develop gas fields safely, prevent sand and wind erosion. and protect the eco-environment of the project area in light of different soil conditions which the different factories and stations have, some measures which are listed in Table 2 can be taken.

The long and narrow belt of sand vegetation is damaged by laying the pipeline. Since the sand area is very dry and short of water as well, the damaged vegetation is very difficult to be recovered naturally. If the vegetation can not be recovered, the pipeline's safety will be threatened. For example, the pipeline in Leilongwan has been uncovered by wind erosion. from which we should draw a lesson. Although the belt of the pipeline is long and narrow, soil conditions are bad, which have added much difficulty to the recovery of the damaged vegetation, it's absolutely necessary for us to pay a high price for revovering vegetation.

The working roads in the project area damaged the vegetation most seriously. According to the different soil structure in the different road sections, the different control measures can be taken. We can either plant trees or make blocks on both sides of road.

Table 1. The soil conditions and features of the project area

Soil Type	Code of related factories and stations	Features
driftingdune	M-3 N-1 M-4 M-5	drifting and semidrifting dune, vegetation: 〈20% serious wind erosion and sand cover
fixed dune	W-1 purifying factory	almost fixed dune, vegetation:〉40% no wind erosion and sand cover, sand soil again if vegetation damaged
dry beach	N-18 M-15	high ground water level, smooth terrain, mostly for farming
moist beach	M-9	high ground water level, smooth terrain salinized to some degree, mostly for grazing and farming
river valley	N-5	smooth land, abundant water, mostly used for high yield farmland
loess ridge covered with sand	N-16 M-12	loess hill and gully covered with sand, uncertain thickness of sand cover, fixed, semifixed or drifting sand cover
loess ridge	M-13 N-14	undulate ridge, narrower valley, gentle slope, gully
loess hill, gully	M-14	loess ridges, canyon and gully formed by water erosion

Table 2. The different control measures for different soil conditions

Number	Soil types	Code of related factories and stations	Control Measures	Remarks
1	drifting and semidrifting dune	N-1 M-3 M-4 M-5	Put up 1×1m, 1.2×1.2m, 1.5×1.5m firewood blocks. Plant salix, hedysarum, artemisia and populus in high density and mixture.	Control area:200m around factories, stations 100m on both sides of pipelines
2	fixed or semifixed dune	W-1 M-2 N-3 purifying factory N-6 gas collecting station	Put up zonal vertical firewood blocks with 2.5m of row spacing. Plant populus, artemisia, salix and hedysarum.	Control area:damaged vegetation area Use local material to prevent wind erosion and regain vegetation
3	dry beach	M-12 M-15 N-18	The same as No.1 and No.2	Prevent wind erosion and sand cover.
4	moist beach	M-9	Refill the ditch with soil	Afforest gas collecting station.
5	river valley terrace	N-5	ditto	ditto
6	loess ridge covered with sand	N-16	The same as NO.1 and No.2	Cover the sand with soil
7	loess ridge	M-13 N-4	The same as N.4	The same as No.4
8	loess ridge and gully	M-14	Plant water and soil conserving trees.	Prevent soil erosion

4. Conclusion and Suggestion

A. The first phase of the 3.0×10^9m/a project in the middle gas fields of Shaaxi-Gansu-Ninxia has greatly promoted the local economic development. Meanwhile, we should not overlook the protection of eco-environment. The development of gas fields and the protection of environment must go simultaneously. The historical lesson of Tongwan Castle being buried in oblivion by sand can not be forgotten.

B. When the working roads are built, some corresponding sand control measures must be taken in time. The simple working road built by bulldozer without any sand control measures is damaged seriously by wind erosion and sand cover, which will hold up traffic and start a new desertification.

C. At present, the development of gas fields is still in its early stage. The eco-environment of the project area will be damaged gradually with the development of gas fields and local industry. Therefore the positioning and monitoring station for eco-environment in the project area should be set up so as to provide scientific basis for sand control.

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Ways to Preserve Diversity of Tugai (Wetlands) Plant Communities and Species on the Desertified Deltas of the Aral Sea

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Abstract - In the situation of the man-made desertification of the Aral sea region wetland biocomplexes are degraded. Some of species and plant communities have been lost. Artificial watering within the natural deltaic area supports only 2/3 of the previous botanical diversity. Additional measures are: the structuring the irrigated landscapes, organizing reserves, and maintaining landuse control.

Key Words: Wetland, tugai, species, plant communities, desertification, conservation.

1. Introduction

The problem of preserving the wetland biocomplexes in the deltaic plains of the Amudarya and Syrdarya rivers is one of the most urgent problems in the Aral sea ecological crisis. Beginning in 1961 the sea level fell by 0,2 - 1 m every year, and since the middle of 1970 there has been no natural flooding. So, the main part of lakes was drained by new erosion-made channels. The ground water table fell to a depth of 6-10 m in 1980. The wetland area decreased from 10.880 to 1.280 km2. The desiccated area became takyr and solonchak, with salt bush and annual plant communities. The tugais are dead as a type of mesophylous vegetation, which is the reason for the first steps of water management in the Amudarya and Syrdarya deltas. The lakes were watered by drainage or river water or by mixture of these .

Under the framework of an UNESCO/BMFT of Germany scientific project in 1992-1995 botanical diversity and its contemporary changes in two deltas have been studied (Novikova et al., 1996). The task for these studies is to understand the ways for botanical diversity conservation. The first results are discussed in this paper.

2. Ecological-landscape basis of the botanical diversity in wetlands

"Tugai" is a wider term than "wetland". Tugai type includes vegetation from such landscapes as swamps, flooding areas and areas, where flooding is rare or absent now, but where the ground water table is higher than 3-5 m, and could be used by plants. Soil salinization varies from zero to solonchaks.

2.1 Diversity of species and plant communities in deltas

The botanical diversity in the wetlands of Amudarya and Syrdarya is presented by 293 plant species and 72 associations. Twenty four associations occur both deltas, but 31 are presented only in Amudarya and 17 only in Syrdarya. There are 27 dominant species. The most frequent in bog habitats are *Typha angustifolia, Phragmites australis;* in meadow are *Calamagrostis epigeios, Alhagi pseudalhagi;* in woody-bush in both deltas are *Salix songarica, Halimodendron halodendron, T. ramosissima;* in Amudarya only are *Populus ariana, Elaeagnus turcomanica* and in Syrdarya - *Elaeagnus oxycarpa;* in wet solonchaks are *Halostachys belangeriana, Tamarix hispida, Kareinia caspia* etc.

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2.2. Ecological basis of the botanical diversity.

The region of the Aral sea is very dry, with an average annual precipitation in the Amudarya delta of about 80 mm. So, biodiversity in these extreme conditions is the poorest in Middle Asia, with α -diversity of about 3 species on 10 m^2. Under the conditions of the wetlands this coefficient is higher, and changes from 5 to 9 (Fig.1). The middle-age woody communities with tugai-meadow soils support the highest number of species. The least number of species is in reed monocoenoses on swamp sites and in saltbush communities on solonchaks. β-diversity (changes in species composition from one site to an other within the same kind of landscape), usually is not high, because these landscapes are ecotones.

Under conditions of ground water depth from 0 to 0.5 m with long duration of floodings, and from 0.5 to 3 m without floodings, α and β-diversities are very low. Most tugai plant communities and species are adapted to conditions of ground water depth from 0.5 to 3 m with short duration flooding in most years.

2.3. Floristical diversity within different landscapes.

There are ten main types of deltaic landscapes, and their potential species diversity has been studied and presented in Figure 1.

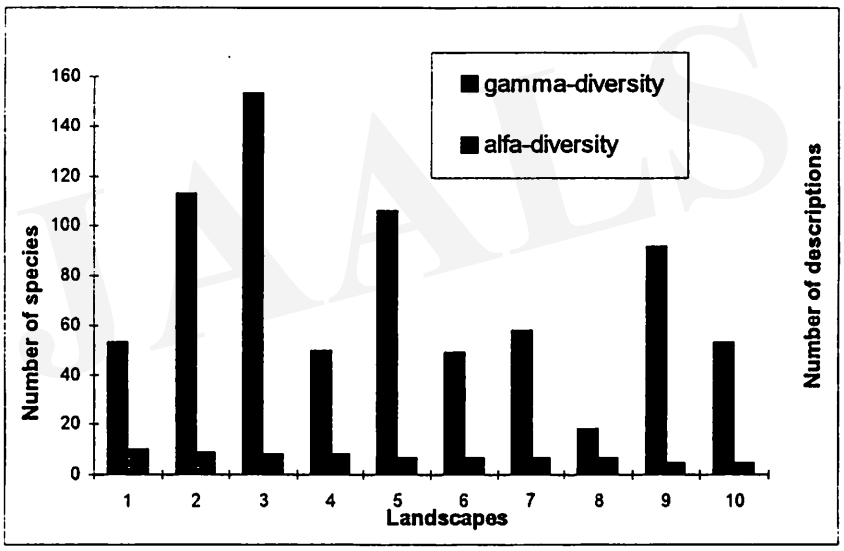

Fig.1. Floristical diversity of the landscapes in the Amudarya delta
Landscapes: 1.Lake shores; 2.Tugai forest massifs; 3.Oases; 4.Iselbergs; 5.Levees; 6.Interriver lowlands; 7.Seashore plains; 8.River's cone of 1960 year; 9.Dry bottom of the Aral sea; 10. Parts of the delta of Holocene age.

γ (gamma)-diversity is the flora of landscapes. Species lists have been obtained by field investigation and gathered from science publications for every kind of landscape. The more extensive number of species (the highest γ-diversity) is typical for irrigated lands (oases), tugai forests, levees and dry sea bottom (Fig.1).

α (alfa)-diversity shows us the number of species on a site (10x10m). It is higest in the landscapes of lake shores, tugai forests, oases and least in the parts of deltas of Holocene age.

Correlation between floras of the main kinds of landscapes in the Amudarya delta (Fig. 2) shows us, that there are two groups, which have very high coefficients of similarity. The first one is typical wetlands (1,6,7,2,5,3) the second one (4,10,9) is desert landscapes.

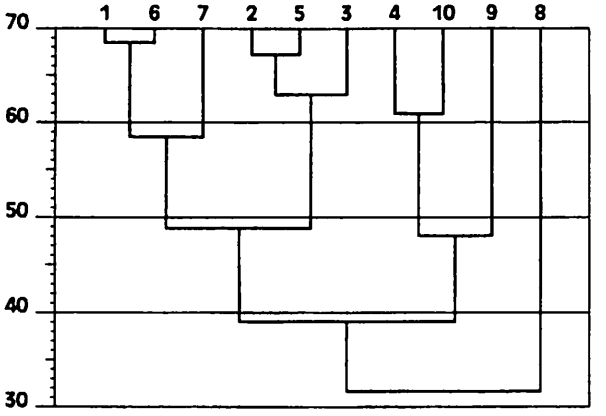

Fig.2. Cluster analysis of species similarity (by Sorensen - Index) between the landscapes of Amudarya delta (Designation in Fig.1)

3. Contemporary Botanical diversity of wetlands.

The data presented in this paper was gathered in the expeditions from 1992 to 1995.

3.1. Botanical diversity within natural landscapes.

At this time the interriver lowlands, dry lake basins and sea gulfs are filled by river and drainage water. River branches are reconstructed in canals. On shores, bottoms of these artificial lakes as well as on the levees some tugai plant communities and 64 species are conserved.

Shores of constant lakes with river water or fluctuating levels form ecotone systems, which support the existence of more than 20 species and 5-10 ecological communities varying from hygromorphic to halomorphic, and dominated by *Typha spp., Phragmites australis, Tamarix spp., Halostachys belangeriana, Salsola dendroides.*

Shores of constant lakes with drainage water form ecotone systems, which support the existence of only 5-7 halophylous plants and 1-2 plant communities, dominated by *Phragmites australis, Halostachys belangeriana* and annual salsolas and suaedas.

The best results were registered in the ecotone system of levees and lake shore, formed by river canals and lakes with fresh water. Under these conditions the ecotone system supports the largest part of typical tugai plants and communities. There are woody-bush, bush and meadow communities dominated by *Salix songarica, Populus ariana, Elaeagnus sp.sp., Halimodendron halodendron,Alhagi pseudalhagi, Lycium ruthenicum, Tamarix spp., Phragmites australis, Typha spp.* etc.

One-year's flooding on the dry sea bottom led to sedimentation of fertile loam nearly 5 cm thick. This showed the possibility of renovation of the tugai plants within this kind of landscape.

Artificial watering within natural deltaic areas nowadays presents us with only one way to preserve tugai biocomplexes, but it is not enough, because this way only conserves about 18 associations, and about 2/3 of tugai species. To conserve tugai plant species and communities as a whole we need to use some additional measures.

3.2. Botanical diversity in irrigated landscapes.

Investigations of the scientists in Poland showed (Balary et al., 1994; Stachov, et al., 1994) that in landscapes dominated by agricultural land use, biodiversity is maintained by both seminatural structures and arable land. Results of our recent studies in Amudarya and Syrdarya deltas have shown that the diverse structure of irrigated landscapes, composed of small cultivated fields, shelterbelts, meadows, small ponds, irrigated and drainage canals in old oases, lead to much higher richness and diversity of biota than uniform structure of landscapes in the new-irrigated oases, having large arable fields devoid of other elements. There are nearly 25 species in fields, 15 - 20 between them, 5-12 on long fallows and the main part of the species within forest massifs.

The studies indicate that we need to organize the management of landscape structure by introduction or restoration of non agricultural natural elements. Based on these ecological principles we suggest creating landscapes of wildlife refuge and buffer areas.

4. Other ways as perspectives.

We could suggest some additional measures, which could help to conserve botanical diversity in deltas: landuse control, organizing reserves, and phytomelioraton.

4.1. Landuse control.

Pasturing is the eldest and most negative form of landuse for botanical diversity of tugais. Studies of the species composition in forest sites without pasturing shows us the growing number of species (α - diversity) from 3 to 6-7. There is the typical negative example: 1-1,5 km around the villages. Usually this is the area with moving sands without any plants. These badlands formed because cattle go to pastures and comes back to villages every day without direction. So we need to control stock movement and try to rehabilitate these areas with native plants.

4.2. Organizing reserves.

It is very urgent to preserve tugai communities within natural and irrigated areas. More than 5 forest massifs are on the levees of the main river bodies of the Amudarya and 3 are in the Syrdarya delta. We need to organize additional artificial watering and drainage. The next goal is to preserve natural tugai patches within deltaic areas from its transformation into arable fields.

5. Conclusion

The problem of conserving the botanical diversity of wetlands could be solved by a combination of several methods: by organizing landscape structure with hydro- and phytomelioration within natural and irrigated areas, by creating a system of reserves, and conservating areas with fragments of the natural tugai vegetation, and by landuse control.

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Phytomelioration of the Aral Sea dried bottom and Amudarya delta

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Abstract. Results of investigations on phytomelioration of salt-marshes of the Aral Sea dried bottom and seaside part of the Amudarya delta are given in this paper. Bioecological peculiarities of several valuable and perspective for these conditions phytomeliorants are presented.

Key words: sea, bottom, seaside, saline, phytomelioration.

1. Introduction.

The bottom of the Aral Sea in Uzbekistan is uncovered on the area of 2,1 mln ha. There appeared a new saline desert in this territory. After drying the surface of this sea the botton accumalations which consist of sand, silt, salts are scattered over adjoining regions of the Aral basin. They are toxic for the life activity of all living beings.

Some parts of the Amudarya delta (about 1 mln. ha) have been subjected to anthropogenic desertification.

35 years ago the Aral Sea coast was characterized by wide spreading of littoral-aquatic vegetation presented in general by hydro and hydrophilous of Thypha anqustifolia and Phragmites australis and their complexes. As a result of sea level sinking they have disappeared from vegetation cover. Thinned out brushwoods of Tamarix hispida, T.ramosissima, Haloxylon aphyllum, Salsola richteri, Halostachys belangeriana, Karelinia caspia or their complexes appeared instead of them. Heavily salinized hilly sands and salines without vegetation are frequently met. Thinned out phytocenoses of anual Salicornia europaca, Suaeda crassifolia, Climacoptera aralensis, Bassia hyssopifolia, Atriplex fominii, Salsola nitraria plants and others in the complex with the above-mentioned communities are found on the dried sea bottom. Vast areas of clayer saline bands without vegetation are also frequently met on the dried bottom.

Aridization in the lower reaches of the Amudarya caused transition of soil formation of hydromorphous type into semi- hydromorphous and in general into automorphous ones as a result of the flood meadow mesophilows types of vegetation have disappeared. For example, Nymphaea candida and Salvinia natants have completely disappeared from flora. Areas of tugais - Potamophyta are greatly reduced. According to A.I.Ganitov's data (1970) in the 50th years of our century the purely tugai forests Potamodendra occupied an area more than 100 000 ha, by the 70th their area were reduced to 52300 ha (Bakhiev, 1985). In 1965 Glycyrrhyzeta glabrae occupied an area of 18000 ha (Bakhiev, 1976). In connection with the use of Glycyrrhyzetta roots in the national economy, the condition deterioration of moistening and the soil salinity increase, the area of its brushwoods have been reduced more than 9 times. (Bakhiev et al, 1980). In the 60th the Phragmiteta formation occupied an area of about 1 000 000 ha. 600 000 ha of them were of industrial character (Ovchinikov et al, 1960). It reduced to 251 100 ha to 1965 (Tadjitdinov, Meniakhmedov, 1967), and it was only 100 000 ha (Bakhiev, 1985) to the 80th. The areas of disappeared phytocenoces were occupied by formations of Salicornia europeae, Suaeda crassifolia, Climacoptera aralensis, Bassia hyssopifolia, atriplex fominii and other species and also by Tamariceta hispidae, T.ramosissimae Halostachyseta belangerianae, Halocnemeta strobilaceae, formation and other representatives of halophilous vegetation. The process of desertification in the Aral basin is going on rapidly. Population living in this territory is exposed to different diseases leading to different genetic changes.

All the above- mentioned processes resulted in heavy changes in the natural ecosystems of this region and negative consequences in the ecological and social-economic aspects. Due this an acute necessity arose to work out the scientific basis and the preventive methods against the

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negative consequences of the Aral Sea regression. In connection with this it is necessary to find different ways of anchoring the unovergown surface of the uncovered Aral Sea bottom and the seaside part of the Amudarya delta with the help of drought and salf-resistant plants. It should be noted that this complicated problem having aroused before the science has no analogues both in our conntry and abrcad. The difficulty of solving this problem lies not only in the methodical novelty but also in the vast area of the drying sea bottom with variability of its lithologo-geomorphological structure.

2. Background.

Data on the natural conditions of the research region and phytomelioration of the southern part of the Aral Sea dried bottom are given in the work (Kamalov, 1995). The results of 3 year investigations on phytomelioration in the seaside part of Amudarya delta and Aral Sea dried bottom are presented in the paper of Khasanov, Kamalov, Tadjiev. The uncovered sea bottom is found out to be overgrowing with natural vegetation but it proceeds very slowly. Kurochkina and Makulbekova note that stable overgrowing is expected to be from 30 till 70% (depending on the region structure) not early in 2000. Results of our investigations showed thad this process will be going on for a longer period of time. One should conduct phytomeliorative works for hastening the process of overgrowing.

3. The result of the investigation.

Since 1988 to 1989 the experiments on phytomeliorative anchoring the Amudarya Sea dried bottom and the sea-side part of Amudarya delta with drought and salt resistant plants were conducted. More than 40 species of aboriginal and contiguous drought and salt resistant plants of wild flora referred to 26 genera and 8 families were selected and tested. As the soils of experimental plots were heavy saline (crust-plumpy salines), they were well washed with river or lake water (mineralization of water was 2,5-5g/l;norm was 7000 cubic metre/hestare (4000 at once and 3000 m^3 after a week) befre the sowing.

As soils of experimental plots were heavy saline (crust-plumpy salines), they were well shed with river or lake water (mineralization of water was 2,5 - 5 g/l; norm was 7000, cubic - metre/ hectare (4OOO at once and 3000 m^3 after a week)) before the sowing. We took into account the experiments conducted by scientists from Turkmenistan, USA, Mexico, Canada, Israel, India, Australia and other countries on utilization of mineralized (10 g/1), surface, subsoil and sea water for irrigation of fodder fields of arid zone (Krylova, 1989; Kamalov, 1995; R.K.A. Djasvani, 1996). When normal soil humiditv has been achieved, we ploughed the land by cultivator to a depth of 15 - 20 cm and sowed seeds at a depth of 0,5 - I cm.

The following species were found to be perspective ones: Ceratoides eversmanniana (Stschegl et Losinsk.) Botsch. et Ikonn., Kochia prostrata (L.) Schrad., Haloxylon aphyllum (Minkw.) Iljin, Halothamnus subaphyllus (C.A.Mey) Botsch., Halostachys belangeriana (Moq.) Botsch., Halocnemum strobilaceum (Pall.) M.B., Tamarix hispida Willd., T. ramosissima Ldb., Glycyrrhiza glabra, Crambe amabilis Butk. et Majlun, Phragmites australis (Cow.) Trin ex Steud., Karelinia caspia (Palil.) Less., Salicornia europaea L., Suaeda crassifolia Pall., Bassia hyssopifolia (Pall.) Kuntze, Climacoptera aralensis (Iljin) Botsch., Atriplex fominii Iljin, Sameraria boisseriana (Rchb.f.) Nab., Kochia scoparia (L.) Schrad.

In the seaside part of the Amudarya delta the above – named speices were also perspective ones and in addition to them Agropyron fragile (Roth), Condargy, Secale derzhavinii Tzvel., Artemisia sogdiana Bge., A.ferganensis H. Krasch., Salsola orientalis S. Gmelin, S.dendroides Pall., Medicago sativa L., Melilotus officinalis Dsr. and others.

In the second year of vegetation all these species passed all the development stages with the exception of Haloxylon aphyllum. It entered into the generative stage in the third year. And average productivity of dry fodder mass in five-year-old culture was 20-35 c/ha depending on plant species, i.e. 2-3 times higher than productivity of these plants in adjoining natural brushwoods. Tree-five-year-old cultures of the above-cited phytomeliorants covered 65-80% of area. Self-revegatation of phytomeliorants in culture was observed on the dried sea bottom and in the seaside part of the Amudarya delta. This is a positive feature, because it shows the stability of creating phytocenoses. Biomorphological characteristics of several perspective phytomeliorants are given below:

3.1.Haloxylon aphyllum (Minkw.) Iliin - an undersized tree or shrub with branchy trunk. Being sown in November it gives seedlings at the beginning of April. Year – old seedlings reach 5 - 40 cm in height. Rooting depth is 40 - 50 cm. They are tap root with small rootlets. Two-year-old plants begin to vegetate from the end of March. In autumn they were 80 - 100 cm in height. Rooting depth was 95 - 110 cm. Three - year - old plants were in blossom by the end of April, bore fruits in October and early in November. Shrub height was 150-170 cm. Length of year–old seedlings was 50-60 cm. Tap root penetrated at a depth of 190 cm forming the lateral roots of the 3 - rd order. 80% of individuals enter into the generative stage. Flower buds are set opposite in two, three lower nodes of generative shoot. Flowering begins when generative shoot produces 4 - 5 segments 2 cm long and is proceeding for 10 - 15 days. Ovary develops in August, samaras appear in September. At the end of September embrio is already formed. Seed maturing is observed at the end of October and early November. All 4 - 5 year - old plants enter into the generative stage of ontogenesis. Plants are 190 - 200 cm in height, rooting depth is 210 cm. Plants accumulate 30 - 35 centners of fodder mass per hectare. This is observed at the age of 9-10 under natural conditions.

3.2.Kochia prostrata (L.) Schrad.– a semi-shrublet, one of the most valuable fodder plants. Being sown in November it produces mass seedlings at the end of March. Cotyledoneus leaves are preserved for a month. Stem development is very slow. Tap root penetrates at a depth of 20 - 25 cm forming the lateral rootlets. The development of stem and its branches liven up at the end of May and is going on during June -July. Mas flowering is observed in June- July, fruiting in August - September, seed maturing at the end of September and at the beginning of October. In the first year rooting depth is 50 cm, in second year - 70 cm, third - fourth year - 100 - 150 cm. Stem height is 30, 60, 100 - 120 cm, respectively. Plant productivity is 2 - 4, 12, 25 c/ha, respectively.

3.3 Crambe amabilis Butk. et Majlun perennial grassy valuable fodder plant. Being sown in November it produces seedlings in the middle of March. In the first year 8 - 10 radical rosellate leaves are formed 20 - 25 cm long, 10 - 12 cm wide, stem is 20 - 30 cm in height. In florence globulose is formed on the stem. Tap root penetrates at a depth of 120 cm. Flowering and fruiting is observed in 25-30% of individuals in the first year. In the second year plants grow at the end of March. At the end of April stem is 75 - 90 cm in height and has 15 - 18 rosellate leaves 30 - 35 cm long, 13 - 15 wide. Flower bud formation is observed at the end of April, flowering in the middle of May, fruiting in June and the middle of July (fruit maturing). Shrub is 100 - 110 cm in height. Rooting depth is 150 cm. In third - fourth year the growth is observed in the middle of March. Other phenostages coincide with stages in two-year-old individuals. Rooting depth is 170 cm. Plant productivity is 8 c/ha in the first year, in the second year-12, posterior years-15-20 c/ha.

3.4 Ceratoides eversmanniana (Stschegl. ex Losinsk.) Botsch.-semi-srub. Being sow,7-n in November it gives mass seedlings at the, beginnig of 3^{d} ten-day period of March. In the first year 60-80% of plants entered into the generative stage and achieved 50 - 70 cm in heigt. In the second and third year flower bud formation was observed in July, flowering - in the beginnig of August, mass fruit-bearing-in the end of August and beginning of September. Plants were 115- 120 cm in height. Root system penetrated at a depth of 150 cm forming a lot of lateral rootlets. Productivity of dry fodder mass in the 1 - st year of vegetation was 10-12, in the 2-nd and 3-rd year-30 c/ha, 3-4 times higher than productivity of natural thinned out brushwoods.

3.5. Artemisia ferganensis H.Krasch. - a semi-shrublet. Mass seedlings emergence is observed in the middle of March. Being 35 cm in height, 10% of plants entered into the generative stage in July. In the 2-nd year at the beginning of September the bud formation was observed in about 70% of plants, fruiting-in October-November. By this time an average plant height was 60-70 cm, rooting depth-85-90 cm. Productivity of dry fodder mass was 3 - 6 c/ha in the 1 - st year and 14 - 16 c/ha in the 2 nd year.

3.6. Secale derzhavinii Tzvel - a laxy caespitose, perennial grass. Seedings emergence was observed at the end of March. 90% of plants enter into generative stage in their first year.. To the middle of June an average plant height was 60-80 cm, 6-14 generative shoots were formed. Stooling is distinguished from the middle of May, earing at the end of May, flowering - in

June, fruiting - in June - July. Rooting depth is 60-70 in cm. Average productivity of dry fodder mass decreased to 10 - 15 c/ha due to drought.

3.7. Agropyron fragile (Roth.) Condargy - a laxy caespitose, perennial grass. Seedlings emerge at the end of March. Generative stage was observed in 10 - 15% of plants in the first'year of vegetation in favourable 1990 and almost all plants remained in immature state in unfavourable 1989. Height of generative shoots is 55-60 cm. Stooling is observed in the beginning of June, earing - in the second half of this month, flowering and fruiting-in July-August. Rooting depth is 70-80 cm. Productivity of dry fodder mass in the first year of vegetation is 5-6, in the second one - 13 - 15 c/ha. 70% of plants bore fruits in the 2 - d year of vegetation.

Conclusion. Thus, from more than 40 species belonging to 26 genera and 8 families, 27 species belonging to 22 genera and 8 families have stood the test. These species are ecologically formed of various life forms of plants. Halophytes are the main body. They fixed soil surface in experimental plots and stopped removal of silt - and salt formations. On the other hand, pastures and hay-filds were developed because a lot of species are valuable fodder plants. Productivity of fodder mass is 20 - 35 c/ha.

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Growth response of *Acacia auriculiformis* and *Casuarina equisetifolia* in quartz sand dumps from cement factories

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Abstract: Floatation reject from cement factories consists of 90% quartz sand. Its dumps are barren with no vegetation as the soil is poor in nutrient status and water holding capacity. Dumps were amended with inorganic fertilizers, biofertilizers and water holding materials like Coirpith and Jalsakthi and planted with *Acacia auriculiformis* and *Casuarina equisetifolia*. *Acacia auriculiformis* is soil amended with *Rhizobium* + Phosphobacteria + Gypsum and *Casuarina equisetifolia* is amended with Coirpith + *Frankia* + VAM + Gypsum showed the best growth response.

Key Words: Floatation reject, Soil amendment, Rehabilitation

1. Introduction

Floatation reject is quartz sand, which occurs as an impurity in calcite used in the manufacture of cement and is obtained as a waste product. Its dumps have occupied an area of about 30 ha. in the area adjoining the quarry of Associated Cement Companies Ltd., at Madukarai, 25 km from Coimbatore and their depth ranges from 50cm to 4m. Every year the area of dumps is increasing at the rate of 1 ha. Most of the plantation programmes in these areas have failed due to lack of nutrients, high pH, and low water holding capacity which are incapable of supporting plant growth. Reclamation of these dumps requires plantation of suitable species and amendment of soil for improving the physical, chemical and biological properties.

Biofertilizers like AM fungi, *Rhizobium* and *Frankia* are important in revegetation of disturbed habitat (Chandra and Jamaluddin,1994). However, in such areas natural dispersal, survival and population of these microbes are insufficient. Hence, the objective of this study was to evolve a package of soil amendments improving the physical, chemical and biological properties to ensure higher survival and growth of plantations raised on this area. *Acacia auriculiformis* and *Casuarina equisetifolia* were selected for the present experiment, as these species fix nitrogen, improve the soil and tolerate salinity and acid spoils (Tewari,1995).

2. Materials and methods

The study was conducted at floatation reject dumps mentioned above. The dump consisted of rock debris mixed with some finer particles of sand (85.2%), silt (6.8%) and clay (8.0%). The matrix was found to be quite high in pH (8.9), with an electric conductivity of 0.12 $dScm^{-1}$, organic carbon content of 0.3% and soil moisture content of 0.39%. The soil was analyzed for available nitrogen

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(Jackson,1973), Phosphorus (Olsen et al., 1954), Potassium (Jackson, 1973) which were found to be deficient . The available N was 0.05 ppm, P was 10 kg ha^{-1} and K was 47 kg ha^{-1}.

The study was set up in a completely randomised block design (CRBD) in 30x30 cm pits with 3x3 m spacing between adjacent pits. The following soil amendments were made:

1) Control
2) Coirpith + *Rhizobium / Frankia** + VAM + Gypsum
3) Jalshakthi + *Rhizobium/Frankia* + VAM + Gypsum
4) Coirpith + *Rhizobium/Frankia* + Phosphobacteria + Gypsum
5) Jalshakthi + *Rhizobium/Frankia* + Phosphobacteria + Gypsum
6) *Rhizobium/Frankia* + VAM + Gypsum
7) *Rhizobium/Frankia* + Phosphobacteria + Gypsum
8) Coirpith + Urea + Single super phosphate + Muriate of potash + Gypsum
9) Jalshakthi + Urea + Single supper phosphate + Muriate of potash + Gypsum
10) Urea + Single supper phosphate + Muriate of potash + Gypsum

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**Rhizobium* was added for *Acacia auriculiformis* and *Frankia* for *Casuarina equisetifolia.*

The quantity of materials added for enhancing the nutrient status, microbial population and water holding capacity in the above treatments are as follows: Coirpith (1 kg), Jalshakthi (50 g), *Rhizobium* (25 g), Phosphobacteria (25 g), VAM (50 g), Urea (50 g), Single super phosphate (SSP)(75 g), Muriate of potash (MP) (25 g), Gypsum (200 g),*Frankia* suspension (10 ml).

One hundred and fifty day old, uniform, healthy seedlings of *Acacia auriculiformis* and *Casuarina equisetifolia* were transplanted into the pits after carrying out the soil amendments in the month of February 1995. Survival and growth measurement of plants were recorded every 30 days upto 210 days. Biomass index was calculated using the formula, Biomass index= d^2h, where d is the collar diameter and h is the height of the plant (Estrada-Torres and Valdes, 1986).

All the data were subjected to analysis of variance (ANOVA) and the means were separated by Duncan's New Multiple range test ($p< 0.05$)

3. Results and discussion

Generally soil amendments resulted in higher biomass index compared to control both in *Acacia auriculiformis* and *Casuarina equisetifolia.* Maximum biomass index of Acacia auriculiformis was observed in soil amendment with *Rhizobium* + Phosphobacteria + Gypsum from the 150 th day onwards. In *Casuarina equisetifolia*, maximum biomass index was found in soil amendment with Coirpith + *Frankia* + VAM + Gypsum at all stages (Table 1).

In *Casuarina equisetifolia*, the addition of organic water holding material like coirpith has a definite positive effect on biomass index, but the addition of Jalshakthi an inorganic water holding polymer has not contributed to any positive effect. Though both the materials help in reducing the soil bulk density and increasing the soil microporosity, the organi[illegible]e seems preferable.

Table-1. Effect of soil amendments on biomass index of *Acacia auriculiformis* and *Casuarina equisetifolia* in quartz dumps (Floatation reject)

Treatment	Days after planting 30	90	150	210
Acacia auriculiformis				
T1	21.94 a	42.79 abc	157.38 a	484.45 a
T2	30.23 a	45.91 abc	149.32 a	326.78 a
T3	29.30 a	42.07 abc	116.52 a	346.78 a
T4	15.44 a	19.68 a	49.65 a	118.83 a
T5	25.70 a	69.47 c	138.92 a	271.08 a
T6	21.00 a	27.29 ab	85.55 a	197.68 a
T7	27.29 a	43.26 abc	394.98 b	964.60 b
T8	33.86 a	59.61 bc	164.10 a	379.81 a
T9	20.37 a	34.46 abc	194.13 a	413.51 a
T10	14.80 a	35.09 abc	122.70 a	209.82 a
Casuarina equisetifolia				
T1	24.74 ab	79.59 bcd	234.49 a	686.92 a
T2	50.26 b	92.18 d	346.13 a	2302.52 c
T3	23.55 ab	43.51 ab	190.73 a	343.42 a
T4	26.24 ab	48.47 abc	267.32 a	2067.59 bc
T5	33.99 ab	84.51 cd	275.09 a	1102.56 ab
T6	45.00 ab	78.19 abcd	171.38 a	596.46 a
T7	32.09 ab	72.15 abcd	246.36 a	791.47 a
T8	21.51 a	66.13 abcd	324.70 a	968.87 ab
T9	20.36 a	38.89 a	232.54 a	413.83 a
T10	22.61 a	62.33 abcd	437.27 a	486.40 abc

Means in a column followed by the same letter are not significantly different according to Duncan's multiple range test ($P<0.05$)

Note: T1-Control, T2-Coirpith + *Rhizobium / Frankia** + VAM + Gypsum, T3-Jalshakthi + *Rhizobium / Frankia* + VAM + Gypsum, T4-Coirpith + *Rhizobium / Frankia* + Phosphobacteria + Gypsum, T5-Jalshakthi + *Rhizobium / Frankia* + Phosphobacteria + Gypsum, T6-*Rhizobium / Frankia* + VAM + Gypsum, T7-*Rhizobium / Frankia* + phosphobacteria + Gypsum, T8-Coirpith + Urea + SSP + MP + Gypsum, T9-Jalshakthi + Urea + SSP + MP + Gypsum, T10-Urea + SSP + MP + Gypsum

**Rhizobium* was added for *Acacia auriculiformis* and *Frankia* for *Casuarina equisetifolia.*

In the case of *Acacia auriculiformis*, the physical and chemical amendments do not seem to have any effect, probably because of the hardy nature of the species

and its tolerance to adverse physical and chemical properties of the soil. Only the inoculation of biofertilizers like *Rhizobium* and Phosphobacteria has resulted in 99% increase over the control, indicating the beneficial effect of biofertilizers. The positive effect of biofertilizer in reclamation of mine wastes has already been reported (Ganesan et al., 1991; Mishra, 1992) and the present study confirms this.

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Challenges for the Future

Keynote Address

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Landuser Participation in the Development of Technology for Sustainable Use of Arid Areas

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Abstract - Desert technology cannot create a sustainable world. The technology has to be used by farmers, pastoralists, miners and others. These decisionmakers are subject to a wide range of pressures from markets, population change, community norms, climate, competition, land tenurre systems, etc. Many of these decision makers are more concerned about surviving the current season than about their long term prospects. Clever technologists, concerned to promote sustainability, must work beside land users to develop measures that can be successfully applied in the land users' contexts. The resulting technologies can be demonstrated by the land users to work and they can join with the scientists in pressing governments to change the context to favour the technology and sustainability.

Scientists must recognise that land users are very knowledgable about their production system as a result of generations of decisionmaking for survival. New technology will be treated with caution and subjected to a wide range of checks, informally perhaps, before acceptance. The characteristics that will favour adoption include the ability to make money for rural people with a low cost per hectare initially and thereafter, a low capital input and ease of application with only local resources and institutions. The land users should be able to use the technology themselves without resulting in an unfavourable income distribution.

The first step for scientists seeking sustainable solutions in a particular situation should be to discover from land users what their priorities are and then to work together in 'participatory technology development' to find solutions. Examples will be given of successful and unsuccessful innovations from a number of countries.

Key words: Sustainability, participatory technology development.

1. Land degradation

Arid areas are used by people for many purposes, including, pastoralism, tourism, agriculture, irrigated agriculture, flora and fauna conservation, hunter gathering, mining and weapons testing. Many of these uses impose pressures on the environment which are not sustainable. The colonisation of Australia by Europeans has over a period of 200 years resulted in extensive land degradation (Burton, 1992). The forms of land degradation include, water and wind erosion, secondary salinity, irrigation salinity, scalding, soil acidification, soil structural decline and weed and feral animal infestation. Of 1600 species of terrestrial vertebrates nearly 300 are now considered endangered (Recher and Lim, 1990). Types of change include, complete removal of the vegetation and disruption of ecological processes as in urban development and mining, replacement of vegetation with crops , pastures or managed forests and imposition of management systems such as pastoralism on the natural vegetation (Hobbs and Hopkins, 1990).

Australia is not unique and it is estimated (Dregne, 1983) that three billion hectares of the world's arid lands (81%) were affected by desertification in 1983. This was a worsening condition and Berry (1988) presented evidence for rangeland deterioration in 23 out of 25 countries in the Sudano-Sahelian zone since the United Nations Desertification Conference in 1977. The condition is likely to continue to become worse. The population of arid lands as a whole increased by 81% from 1960 to 1985 whereas the increase for the world was 56% for the same period (Eyre, 1988). At least 149 million people (36% of the total for arid lands) are reported to be trapped in the lowest quartile for gross national product and future resource potential. Population pressure pushes people onto marginal land and into steep mountains as overgrazing causes a decline in productivity (Al Sudeary, 1988; Fischer, 1997). Some improvement in rangeland condition is reported in U.S.A., Australia and some developing countries (Box, 1988) but not countries where the problem is most critical.

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2. Causes of failure to reverse desertification

The critical situation in arid lands has persisted despite the efforts of nearly 100 countries represented at the United Nations Desertification Conference (United Nations, 1978) at which a Plan of Action and 28 recommendations were produced. Some reasons for the failure of the world community to deal with the problem have been identified (Batisse, 1988; and Dregne, 1983) as:

- lack of knowledge in particular areas;
- knowledge in an unsuitable form;
- knowledge of a sectoral nature, not applicable to complex problems with human, physical and biological aspects;
- lack of knowledge about the available technology and its use;
- inability to implement change;
- need for adaptive research and field testing; and,
- lack of incentive.

Reviewing the conclusions of the arid zone conferences of 1955, 1969, 1977 and 1985, White (1988) concluded that there has been a great loss of opportunities resulting in continuing degradation with some exceptions. He challenged scientists to find out why they have been so inept at applying the available information.

More specific causes of failure must be identified if we are to reverse desertification trends. Adequate attention must be given to social aspects. For example, population increase negates attempts to reduce the pressure on arid land.. Investment priorities need to be switched from commercialised high yielding agricultural projects to those based on drought resisting local food crops, yield stability, soil stability and the conservation of moisture, to upgrade traditional farming practices (D'Souza and Shoham, 1985). Problems of land tenure need to be addressed (Thomas et al, 1986). Attention must be given to the knowledge of land users (Hobbs, 1988). Traditional knowledge systems used in the management of communal rangelands have been recognised to be often very sophisticated (Johnson, 1991). Imported ideas that do not take account of this knowledge will be strongly resisted. 'Development and management proceed best when they are attentive to the grassroots concerns of indigenous folk rather than arbitrarily imposed from central institutions' (Johnson, 1991).

3. The need for fundamental change

There is an increasing concensus that there is a need for a fundamental change in the world economy if we are to avoid environmental disaster (Trainer, 1996; Theobald, 1997). The economic system is currently driven by the need for capital to provide a return. This motivation takes precedence over considerations of whether the goods being produced are satisfying important or trivial needs or causing social or environmental stress. It also results in a continuous movement of wealth to those who own capital from those who pay for the goods produced by capital investment. The increased wealth must then be invested and the search proceeds for products to produce in order to provide a return on capital in an eternal circle of consumerism.

Economic growth is essential for this system to proceed. The economic system favours producing goods which yield most profit and which the rich can be persuaded to buy, rather than essentials which the poor are unable to afford. The necessity to provide a return on capital results in over-production and over-consumption (Trainer, 1995). Vast quantities of food are produced in developing countries and shipped around the world rather than encouraging the poor to produce their own food. For example, in Africa, where many people are starving, vast areas are overgrazed by beef cattle raised almost entirely for export (Tokar, 1988) In developing countries the poor producing the goods for export rather than food for consumption receive minimal prices for their efforts and in the process they lose their independence. One quarter of the world's population consumes three quarters of the world's resources while the remaining three quarters of the world's population gets by on the remaining quarter (Trainer, 1995) There is in the world sufficient productive capacity to provide adequate living standards for all poor people but the market system prevents fair distribution. There will never be a level playing field while capital drives the market.

'The fundamental cause of the accelerating destruction of the global ecosystems is simply over-production and over-consumption.' (Trainer,1995) Additionally, as land is degraded (about 5-10 million hectares per year is lost from cropping to severe degradation, Fischer, 1997) the lost land is likely 'rapidly replaced by the desperately poor through the cultivation of adjacent new lands almost regardless of their suitability for cropping. Only elimination of poverty will stop the destruction of such marginal lands' (Fischer, 1997). The same scenario is described for the southern Mediterranean rangelands ((Boyazoglu and Flamant, 1991).

Fischer states that the only way to protect the global environment is to use high-yielding

chemical-consuming agriculture to save land for other uses. Those who are concerned about the effects of chemicals for us and our environment would probably prefer not to follow this course. Serious problems have been identified for the reproductive systems of a wide range of species, including humans, from chemicals which, at the time of their release, would never have been suspected to have caused trouble (Colborn, et al, 1996). Unfortunately, the high production levels in the western world and the resulting low off-farm prices on the world market make it difficult for developing country governments to afford the imported agricultural inputs necessary to apply Fischer's solution (Information Centre for Low-External-Input and Sustainable Agriculture (ILEIA), 1991). Traditional land owners are caught between research and extension services tuned to the new technology that they cannot afford, the loss of their traditional skills and serious degradation of the land resource. The answer for millions of land users and for the environment must be a radical change of the system. Trainer outlines a series of principles for third world development. These include aiming at adequate material (as distinct to luxury) living standards for everyone, abandonning economic growth, recognising the value of social conditions as distinct to material goods, and emphasising local cooperative village development with appropriate technology for both the developing and the developed world (Trainer, 1995). He provides great detail and many more suggestions and himself lives a conserver lifestyle.

In summary, there are (at least) two major changes that are suggested to make it possible to have a sustainable world:

- we must abandon consumerism and economic growth; and,
- we must work with landusers to develop locally self-sufficient communities.

There are two fundamental roles for scientists in this scenario. Scientists must examine the effects of consumerism and economic growth on our environment to determine whether it is sustainable and promulgate the conclusions of their work widely together with recommendations for action. They must also form partnerships with landusers to develop sustainable landuse systems. The second of these suggestions has already been the subject of workshops, discussions and publications and is considered in the next section.

4. Participatory technology development (PTD)

In some quarters there has already been a complete about face in the approach to the development of technology for land users. This change is based on the recognition that 'Modern science rests on the foundation of at least ten millenia of informal experimentation by farmers.' (Haverkort, 1991). This quotation is from a book (Haverkort, van der Kamp and Waters-Bayer, 1991) whose title 'Joining farmers experiments' sets the scene for a radical departure from the current practice of many scientists who ignore land user knowledge and wishes and risk being irrelevant.

The new approach, referred to as 'participatory technology development', has developed over the last ten years and been the subject of workshops in the UK and the Netherlands. It is the topic of at least two books and a periodical and is the continuing subject of work by the Overseas Development Institute, in London, the Information Centre for Low-External-Input and Sustainable Agriculture (LEISA) in the Netherlands and the Institute of Development Studies at the University of Sussex.

PTD is fundamentally different because for the first time it involves scientists acknowledging the role land users have had and must continue to have in developing sustainable land use methods. Recognition of the need for responsible land use is to be found in the oldest known written laws, The Code of Hamurabi 1792-1750 BC which states:

> 'If any man has opened his trench for irrigation and has been slack and so has let his waters carry away the soil on his neighbour's field, he shall pay....'

Scientists do not have a monopoly on wisdom and knowledge about land use and do not have the responsibility for the ultimate decisions about what will be done in practice. Moreover, technology may not be the answer to the problems of the small farmer whose constraints may be social, political or economic (Vel, et al, 1991).

Conventional research has focussed on irrigated agriculture and export crops for developing countries and has failed to improve the low-external-input systems on which most poor land users depend. Sometimes the new technologies have upset the equilibrium of the old methods and offer sophisticated systems that most farmers and herders have restricted access to and cannot afford (Havercort, 1991).

PTD involves taking a holistic approach rather than externalising environmental and social effects, focussing on synergy, complimentarity and integration,; building on indigenous knowledge and generating the principles of low-external-input sustainable agricultural systems from an increased understanding of site specific examples. Two hundred documented examples of PTD in practice were

reported at a workshop nine years ago (ILEIA,1988). The available literature is replete with examples of people's efforts to apply PTD in many different situations (e.g. Haverkort, et al, 1991). Many suggestions are made on how to start, and what approach to use. The first essential is to acknowledge the value of landusers' knowledge then to discuss with them the problems they face, the priorities they value and the possible use that technology may be to them. Joint action to test ideas can then be planned and executed.

5. Case Studies

5.1 Iranian rangelands. Many efforts are being made to improve Iranian rangelands. Extensive areas have been planted to forage shrubs and the protection given to these areas has allowed excellent annual cover to develop on the soil. There are however examples which illustrate the problems that may arise in tackling an enormous problem even in a resource rich developing country.

Rangeland reseeding is proceeding in some parts of the country using *Artemesia herba alba* . There is evidence in these areas of several *Salsola* species and *Eurotia lanata* surviving despite heavy grazing. *A. herba alba* is more frequent and less heavily utilised. Range scientists with whom I inspected these areas did not know the *Salsola* and *Eurotia* but a local farmer presented with pieces of each of five shrubs was immediately able to place them in order of preference for stock with *E. lanata* best and *A. herba alba* last. If the landuser had been consulted about the range reseeding programme it is likely the species mix would have been much different and the credibility of the programme would have been higher.

Atripex canescens, A. lentiformis and *A. halimus* have been widely planted in Iran as seedlings on rangelands which appear capable of growing good herbaceous pasture. The shrubs have grown well in many cases but seedling regeneration is a concern. Near Semnan, the three species are reported to have been planted for 13 years without any seedling regeneration having been seen (Malcolm, 1987). As a result the long term viability of the plantings is questionable. This indicates a serious lack of field evaluation prior to the commencement of planting. The methods of seedlng planting being employed in 1987 were highly inefficient indicating a need for the involvement of practical persons in the procedure. The plantings had been arranged by Government employees who were clearly proud of the excellent growth the shrubs had made but were loath to alow any use by locals who were excluded from using the enclosed lands and were resentful.

5.2 *Salicornia bigelovii.* This species occurs on the coast of the Gulf of California. Research at the Environmental Research Laboratory of the University of Arizonia has shown that the seeds of *S. bigelovii* have a high oil content (Glenn, et al, 1993). Over a number of years research has been conducted on the Gulf of California in Mexico to develop *S. bigelovii* as a crop to be grown using seawater for irrigation. Sandy soils are used to minimise salt build-up resulting in the need for high volume pumps to apply large volumes of water quickly. The crop has been grown and harvested on an extensive scale in research plots. Research has also been conducted on the use of the residue after oil extraction and it has been found that it can be fed to ruminants if the salt content is reduced by washing the residue with seawater. The technology has been taken to the Persian Gulf where similar large scale areas have been grown. Landusers have not taken up the technology and attempts have been made to sell the system to the Government of Pakistan. The programme developed from the hypothesis that the availability of sandy soils adjacent to the sea in many parts of the world offered an opportunity for productive use. Development of the technology has involved the investment of large amounts of money and the problem is now to find an end user who can afford to pay enough to justify the development costs. The costs for pumping and irrigation and the need for oil extraction and salt washing facilities are also a discouragement. Endusers should have been identified and consulted at an earlier stage.

5.3 Al Masab Al Am, Iraq. East-south-east of Baghdad is an area of grey silty clay loam plains which have remnants of halophytic shrub vegetation but are in general bare and eroding (Malcolm, 1990). The soil is salty and the surface has formed pseudo-sand which acts like sand and forms barkan dunes which travel across the plains. The eroding condition of the area is due to excessive landuse pressure for cropping, grazing and fuel collection. The windblown soil threatens roads, canals and drains and is regarded as a serious problem, although it is really the symptom. Solutions to the problem have concentrated on stabilising strips of land upwind of the most threatened infrastructure. This has been done by growing salt tolerant trees and shrubs using water pumped from the canals and drains. Also it has been found that bulldozing a cover of the soil of the plain over the

dunes stabilises them. These solutions are highly expensive and the barriers will probably be overwhelmed by the advancing dunes.. At least nine consultants were employed to advise on the problem. Most concentrated their efforts on treatment of the areas near threatened infrastructure. Failure to address the upwind degraded causal areas was seen as a problem by five consultants but only one offered practical solutions for treating these areas. Ultimately the solution to the problem must involve reducing the landuse pressure in the source areas by enlisting the cooperation of the landusers and stabilising the plains with plants, including the endemics which are still surviving. A reconnaisance of the area indicated that *Cornulacca* sp and *Seidlitzia rosmarinus* were growing in the area and had the ability to trap the moving pseudosand (Malcolm, 1990). A programme of field research was recommended for determining how to establish these species. It was recommended that attempts be made to reduce land use pressure in the source area by providing an area of irrigated forage downwind of the problem and encouraging the people to move.

The tendency to concentrate on protection of threatened infrastructure is typical of the response to similar problems in Morocco and Tunisia. These responses require the design of windbreaks, calculation of windbreak permeability, etc, all respectable scientific endeavours. The fact that they are band-aid measures is conveniently overlooked. But persuading the inhabitants of overgrazed source areas to modify their landuse involves social interactions with which the scientist is unfamiliar. It is vitally important for scientists and landusers to communicate.

5.4 Salinity in Western Australia By 1954 many Western Australian farmers had extensive areas of previously productive land made unproductive by salt encroachment. One farmer, Mr Bevan Parker, had discovered that on his farm, a locally occurring plant, *Maireana brevifolia*, was capable of colonising his saltland and providing valuable grazing for sheep. His sheep were also making use under careful management of an extensive natural stand of *Atriplex bunburyana* and *A. vesicaria*. Mr Parker's sheep were well grown, gave high cuts of wool of top price and he attributed the benefits to his *M. brevifolia*. *M. brevifolia* was promoted by the Department of Agriculture (now Agriculture WA) to other farmers but was not suited to all saline areas because of its sensitivity to waterlogging. A worldwide search for better species (Malcolm, et al, 1984) failed to find anything better than *M. brevifolia* for areas to which it was suited but located several *Atriplex* spp which were then recommended for other areas. Grazing experiments (Malcolm and Pol, 1986) indicated that *Atriplex* spp, which were capable of growing on areas which otherwise were of very low productivity could support sheep in acceptable condition during the autumn. One of the experiments was done on Mr Bill Diamond's property and he was consulted to determine when he thought the sheep should be removed from the experimental plots. He and his son were so impressed with the results that they sowed extensive areas on their property, a quarter of which is salt affected, and they are convinced that the planting of *Atriplex* spp has greatly increased their farm's carrying capacity. They have noted that the annual pasture understorey has improved as the shrubs have grown.

Detailed research (Warren and Casson, 1996) on the value of *Atriplex* spp for sheep showed that the condition of sheep on *Atriplex* spp pasture was no better than the condition of sheep on dry pasture. Officially this result was regarded as damning and promotion of *Atriplex* spp as pasture for saltland was stopped. Farmer reaction to this has resulted in the formation of the Saltland Pastures Association largely from the efforts of Mr Michael Lloyd. Mr Lloyd has a property of 2250ha of which about 700ha is salt-affected (Lloyd, 1996). He has sown *Atriplex* spp pastures on over 300ha and estimates that as a result his property can carry an additional 900 sheep. There has been insufficient communication between the scientists and the farmers. Farmers afflicted with large areas of salt-affected land are pleased to have it produce a forage which is capable of supporting sheep instead of a barren area. As astute sheep managers they are able to devise grazing systems that enable profitable use to be made of the new resource.

5.5 Salinity in Pakistan. Of Pakistan's 80.5mha, 20mha are cultivated, mainly under irrigation, and of that area 6.3mha is salt affected (Qureshi, et al, 1996). More than three billion US dollars has been expended treating the problem with engineering solutions with mixed results. The treatments incur the use of 347.34 million litres of diesel fuel and 1688 kwh of electricity per annum (WAPDA/ACRES, 1993). There remain about 3.7mha to which the engineering solutions do not apply and 60 per cent of the treated area ends up with saline-sodic soils being converted to sodic soils (a more deteriorated form) after leaching (Qureshi, et al, 1996). The enginering solutions are financed by loans from outside the country.

Research under four Australia/Pakistan cooperative research projects over the last nine years

has shown that it is possible to grow salt tolerant forage shrubs and trees on saline areas ranging from Peshawar in the north to Karachi in the south (Davidson and Galloway, 1991). In the course of the research programme experiments were located in several cases on farmers' land. The farmers participated in the work by raising plants, caring for the plots and harvesting in some cases. Farmers' interest was stirred by the performance of the plants on areas that they regarded as useless for their crops. One farmer was impressed with the fact that his animals willingly consumed the harvested forage after it had been weighed. He grew additional plants to those required for the experiments and planted them for his own use. Another, was overjoyed to see flourishing trees on land which he said had grown nothing for 40 years. The local extension officer was involved in the research programme in the Satiana distict and in cooperation with the research staff from the Agricultural University in Faisalabad arranged for a field day which was attended by several hundred farmers. A Satiana Saltland Users Association was formed and is helping to organise plant raising and distribution. Negotiations are now underway for the establishment of a major project to extend the technology to other landusers.

6. CONCLUSIONS FROM CASE STUDIES

The conclusions from the case studies may be summarised as follows:

IRAQ
- failure to deal with the cause of the problem
- use of short term band-aid approach
- inadequacy of consultant experts

IRAN
- failure to recognise landuser knowledge
- poor knowledge of range species
- inadequate evaluation of new plants
- poor practical application by scientists
- failure to involve land users
- failure to recognise landuser needs

SALICORNIA
- desire to put investment needs first
- failure to identify & contact end users

AUSTRALIA
- failure to consult landusers
- failure to put research results in practical context

PAKISTAN
- shortcomings of engineering solutions
- inadequacy of academic training
- successful farmer involvement
- successful on-farm research

These examples include developed and developing countries and they indicate the importance of consultation between scientists and landusers. They show the inadequacy of scientists in some practical situations and the limitation of their knowledge in areas where they should have known better. The knowledge and cooperation of landusers is shown to be important for the ulimate resolution of the problems. The advisability of developing technology in consultation with landusers rather than trying to transfer technology developed by scientists in isolation is apparent.

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Challenges for the Future

Session Papers

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Research and Control of Desert and Desertification in China

Xia XUNCHENG*

Abstract - Lanzhou Institute of Desert Research and Xinjiang Institute of Biology, Pedology and Desert, Chinese Academy of Sciences(CAS), through their scientist's industrious working over past 40 years, have obtained outstanding achievements in desert greening, shifting-sand stabilization and desertification control. All of these markedly improved desert ecological environment, bring about noticeable economic benefit and thus greatly contribute to desertification control in China.

Key Words: Desert research, Desertification control, Institutes of CAS

Desert and desertified land in China occupy 1.53 million km^2, or 15.9% of its total land area. Owing to natural and anthropogenic factors, desertification is continuing to expand, resulting in an economic loss of over 4.5 billion Chinese Yuan each year. In order to speed up desert rehabilitation and halt land desertification, the state set up the Lanzhou Institute of Desert Research and Xinjiang Institute of Biology, Pedology and Desert under Chinese Academy of Sciences. Through more than 40 years of industrious work the two institutes have obtained outstanding achievements, which greatly push forward the rehabilitation of desertification and improve the ecological environment of desert areas in China.

1. Achievements in basic study and desert rehabilitation

In aeolian sand landform and desert evolution respects, the two institutes found out the spatial distribution, types and characteristics of desert in China; made clear the causes of blown sand movement and revealed the formation mechanisms of various sand dunes and their depositional features. The two institutes published "Introduction of Desert in China", "Scientific Investigation and Research of Lop Nur", "Study on aeolian Sand Landform of the Taklimakan Desert", "Soil and Land Resources in Taklimakan Desert" and "Distribution Map of Desert in China" , etc. and made great progress in the aeolian sand landform, Quaternary sediment in desert areas and other relevant disciplines.

In sand drift physics respect, based on the theories such as instantaneous behaviors of wind erosion and wind deposition caused by wind-sand stream, constitutive behaviors, turbulent characteristics of wind-sand stream, ripple formation and dynamic mechanism of shifting sand stabilization, the two institutes put forward the principle and technique of "stabilization, blocked, transport and diversion" for establishing shifting sand control system and published such monographic works as the "Blown Sand Physics and Sand Drift Control Engineering" , etc.

In plant physiology and ecology respects, the two institutes found out the plant species and their distribution in desert and sandy lands of China, studied the physiological and ecological characteristics of desert plants, plant succession laws, water balance of sand-fixing plants, plant

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drought resistance and irrigation principle, fragile ecosystem features in mixed agropastoral region and its rehabilitation. In addition, they preliminarily mastered the plant cultivation techniques and rising yield techniques of farm crops in desert and desertified land areas of China. Their monographic works "Flora in Deserts of China", "Blown Sand Environment and Vegetation on Horqin Sandy Land" and "Study on Desert Ecosystem" were taken as classical and influential publications in China.

In water and soil resources respects, they systematically studied the formation, amount and exploitation status of soil and water resources in arid and semiarid zones of China as well as the environment changes resulted from resource use. They suggested that in arid areas of west China land reclamation scale should be decided in this respect with local water volumes, so as to keep water and soil balance within a basin. In addition, they successfully conducted a great deal of research work in water-saving irrigation and land amelioration in desert areas. Their monographic works "Water and Soil Resources and Their Rational Exploitation in Hexi Region", "Rational Exploitation of Water and Soil Resources in Heihe River Basin" and "serial maps etc. are highly valued.

In desertification research respect, they perfected the classification system of desertification, revealed the causes and mechanism of desertification, preliminarily made clear the distribution and characteristics of desertified land in China and put forward several rehabilitation models and techniques to combat desertification. They published such monographic works as "Desertification and Its Control in China", "Desertification and Control of Blown Sand Disasters in Xinjiang" and relevant maps, etc.

2. Achievement in desertification control

2.1 The sixteen experiment stations and demonstration plots for desertification control have been set up in different bioclimatics zones of China and thus obtaining a series of techniques to combat desertification, such as high sand dike and mechanical sand fence used to block shifting sand, chemical dune stabilization technique, biological dune stabilization technique, straw-checkerboard-barrier dune stabilization technique, increasing crop yield technique and fruit tree cultivation technique on sandy land, desertified grassland improvement technique, rice cultivation technique on film-bottomed sandy land and remote sensing monitoring technique of desert and desertified land, etc. Through comprehensive use of these techniques, they developed different desertified land rehabilitation models suitable for local natural and economic conditions and obtained noticeable economic and ecological benefits.

2.2 As examples, the Shapotou section of Baotou-Lanzhou railway passes through the high sand dune field at southeastern fringe of the Tengger Desert. Under the condition of the annual precipitation less than 200 mm, the Lanzhou Institute of Desert Research first developed the dune stabilization technique "laying emphasis on stabilization in combination with blockade", namely with vegetal dune stabilization as main measure in combination with mechanical dune stabilization, set up a stable sand control system on both sides of the railway. This ensured the safe passage of the railway over the past 40 years and achieved an economic benefit of 7.2 billion Chinese Yuan, hence the institute won the special prize of scientific and technological development of the state.

2.3 The Tarim desert highway crosses the Taklimakan Desert, the so called "sea of death", from north to south, of which 446 km passes through mobile dune area. The two institutes set up an effective sand control system on both sides of the desert highway, ensuring the safe passage of the dessert highway in the mobile megadune area greatly supporting the petroleum exploration in Tarim. To date, the highway has obtained an economic benefit of 198 million Chinese Yuan. Chinese government has listed this project as one of ten major scientific and technological achievements in 1995.

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2.4 The two institutes also made great progress in oasis reconstruction and desertification control. For instance, on the northern sandy land of Linze County at southern fringe of the Badan Jaran Desert, some 40 km of green protective system have been established and 4000 ha of new oases have been set up through rehabilitating sandy wasteland, which achieved a crop yield of 15 t/ha. This successful experience is now popularizing on a large scale in the Hexi Corridor of Gansu Province. In southern Xinjiang some 70,000 ha of tamarix forest were established, obtaining a new output value of 38 million Chinese Yuan; in the transitional zone between desert and oasis in Cele County, some 70.000 ha of land were revegetated, obtaining a new output value of 7.24 million Chinese Yuan; the increasing crop yield technique on sandy land, which was developed by the Yanjin Experiment Station, was widely popularized in north Henan Province, obtaining a new output value of 62 million Chinese Yuan; from 1989 to 1994, and hence won the "prize of outstanding scientific and technological achievement" of Hong Kong Seeking Truth Foundation. In the "sea of death", i.e. the hinterland of the Taklimakan Desert, with saline groundwater of 5g/l as irrigation water, some 2.5 ha of green land have been established and produced about 3000 kg of vegetable, which shows a bright prospect in the comprehensive use of desertification control techniques. In Rigaze area of Qing-Zhang plateau several techniques were used to improved sandy land and obtained higher wheat and melon yields by using plastic film and hole seeding techniques.

3. International cooperation

In 1978,with the backing of the Lanzhou Institute of Desert Research, UNDP set up the International Center for Research and Training on Desertification Control in the institute campus. Thus far, the center has organized 12 training seminars for developing countries and more than 150 experts from different countries participated in these training seminars. The two institutes also sent their experts to visit, give lectures or take part in international symposia in other countries, especially in 1988 and 1996 they sent expert groups to Mali in west Africa to conduct the study on desertification control.

The two institutes also conducted a series bilateral international cooperation studies on desert and desertification. For instance, the "study on desertification mechanism" was listed in China-Japan intergovermental scientific and technological cooperation plan and invested 10 billion Japanese yen; the "greening desert experiment using peat" also was merged in China-Japan scientific and technological cooperation JIC project. Other international cooperation projects including China-American wind erosion study project, China-Germany desert investigation project, China-Israel water-saving irrigation project and China-Sweden desertification monitoring project, etc.

Owing to outstanding achievements of the two institutes in desert transformation and desertification control, the Lanzhou Institute of Desert Research was selected to the Global 500 Honor Roll by UNDP in 1988 and the shifting-sand control and salty soil afforestation project conducted in the Cele Experiment Station of the Xinjiang Institute of Biology, Pedology and Desert won the "Saving the Drylands Prize" of UNDP in 1995.

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Mega-Projects of the XXI[st] Century in Central Asia Related to the Development of Desert Areas

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Abstract - The independent states of Central Asia have entered into a new stage of the development of desert lands, having inherited the economics of the former Soviet Union, oriented to the delivery of raw materials and one-crop systems of cotton and grain. This has detrimental environmental, social, and economic consequences. Multiple projects for the use of natural resources and development of infrastructure have been elaborated by the countries of Central Asia during this period of economic and political reorganisation. A brief description of regional mega-projects, aimed at greater economic independence, is presented in this report.

Key Words: Water transfer, Pipelines, Transport, Desert

1. Introduction

Following the acquisition of independence by the former Soviet Republics of Central Asia, a number of urgent and serious problems have emerged regarding the development of a market economy. The geographical environment, generally represented by the desert territories with extreme climatic conditions, aridity, and sparsely populated areas, is the background for this development. These problems are addressed in three ways:

1) Accelerated search for foreign markets for raw materials sales with purpose of establishing an economic basis for domestic development.
2) Minimisation of economic dependence on the former "senior brother", Russia.
3) Overcoming ecological and social consequences of the Soviet raw-materials economy.

2. Planned Projects

With available mineral resources, primarily oil and gas, the independent states of Central Asia are striving to use their geographical position to find the shortest ways to the world sales markets. Conversely, countries experiencing water management problems are forced to import from regions with excess availability of water resources. A number of large scale regional projects have been developed or are being developed for this purpose (Table 1).

All well known technologies for the efficient use of water resources have technical and economic limitations. Assessments show it is possible to provide central Asia with water until 2015-2020. During this period the total volume of water use by growing populations and priority branches of industry may exceed the available water resources of the basins of the Amudarya and Syrdarya rivers. This indicates a need to recharge these rivers.

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Table 1. Regional mega-projects.

Sphere	Mega-Projects	Member-country
Water transfer and water resources development	1. Partial diversion of the river flow of the Caspian Sea Basin (The Volga River - Aral Sea Canal)	Russia Kazakhstan Uzbekistan
	2. Water transfer from the Caspian Sea to the Aral Sea (The Caspian Sea - Aral Sea Canal)	Russia Uzbekistan Kazakhstan
	3. Water transfer from Siberian rivers of the Karsk Sea Basin into Central Asia (The SibAral Canal)	Russia Uzbekistan Kazakhstan
	4. Partial diversion of the flow of the Arabian Sea Basin into Central Asia (The Ind-Amudarya Canal)	Pakistan, Iran Afghanistan Uzbekistan
Pipeline transport (oil and gas pipelines)	5. Mary-Herat-Quetta-Karachi Gas Pipeline	Turkmenistan Afghanistan, Pakistan
	6. Tengiz-Turkmenbashi-Kharg Island Oil Pipeline	Kazakhstan Turkmenistan, Iran
Railroad transport	7. Astrakhan-Eraliev-Bekdash-Turkmenbashi-Bender-Torkamen. Middle Link of the Main Rail "North-South" (Murmansk-Persian Gulf)	Russia Kazakhstan Turkmenistan, Iran
	8. Kushka-Heart-Quetta-Karachi railroad	Turkmenistan Afghanistan Pakistan

2.1 Mega-project 1 The Volga-Aral Sea Canal. During the 70s and 80s alternatives to the diversion of a part of the Volga flow into Central Asia were developed (they differed by water intake points). The best alternative was withdrawal of water from the Volgograd Reservoir. In this case the 1600 km canal had a discharge capacity of 600-1000 $m^3.s^{-1}$. However, in view of problems with the water balance of the Volga River in recent years, and the changed geopolitical situation in the basin, such a diversion, even if realisable, can only be implemented with corresponding compensatory measures.

2.2 Mega-project 2 The "Caspian Sea - Aral Sea Canal" must solve two problems - save the Caspian Sea region from inundation by the rising level of the Caspian Sea (from 1978 the level has increased by 2.6 m), and revive the Aral Sea, which began drying in 1960 (the water level has decreased by 16.8 m). It is planned to run the canal from the northern part of the Caspian Sea at a length of 540 km with a discharge capacity of no less than 40 km^3/year. This addition to the 10 km^3 which are now received by the Aral Sea from the flow of the Amudarya and Syrdarya rivers should make it possible to revive the Aral Sea within 10 years. The level of the Caspian Sea will decline by 1 m. Since the Aral Sea is 80-100 m higher than the Caspian Sea the water supply can only be realised with the construction of a number of pumping stations. This will require a power

supply (Dumont, 1995). However, considering the fluctuating nature of the Caspian Sea's level, and the recent decline in its water level, construction of the canal may not be reasonable. Also, since the Caspian Sea is surrounded by five States, removal of water from it would require legal agreements between these states. An alternative way of controlling the rise of the Caspian Sea may be the inundation of adjacent depressions.

2.3 Mega-project 3 The controversial proposal for the diversion of a part of the flow of the Siberian rivers into Central Asia (The SibAral Canal) was "buried" in 1986. At that time planning and surveying works on 1270 km of canal from the Ob River to central regions of Kazakhstan were underway. Th e project is currently being reconsidered in connection with the Aral Sea problem. The present boundaries of the Aral Sea can be retained only with additional volumes of water resources and a supply of 25 km^3 from the first stage the Ob and Irtysh rivers. It was planned to withdraw nearly 80 km^3 by 2020 (USSR Acad. Sci., 1985). The figures are realistic in the context of global warming and climatic changes associated with high and low water periods. It is probable that in 2000-2010 the 30 year long wet period in this region will be replaced by a drier low water period. These climatic changes, rather than economic considerations, will instigate actions to address the Aral Sea problem. However, in a new geopolitical situation the river diversion project may involve unforseen political factors.

2.4 Mega-project 4 The Arabian-Aral Water Transport Tract (AAWTT) project proposes the access of Central Asian states to the Indian Ocean and rehabilitation of ecological conditions in the Aral Sea by the involvement of complimentary water resources. The withdrawal of free flood flow is planned from the Ind River downstream from Suk-kur. The length of this canal-tract is about 2600 km. The volume of water withdrawal is nearly 30 km^3. It is assumed that the regulation of flood flow can be realised through a system of channel reservoirs. It is planned to pump water to the Iranian Upland in Beluchistan (Pakistan) using a chain of powerful pumping stations. The AAWTT is envisaged as navigable to the city of Kushka on the boundary with Turkmenistan for the transit of ships of the "river-sea" type of 20,000 tonnage, and also for replenishment of the Amudarya River flow. The canal will make it possible to irrigate and develop the desert zones of Pakistan-Beluchistan, in Iran-Khorosan, Beluchistan and Sistan, and the Helgit-Argandobian Valley (Khamraev, 1995)

2.5 Mega-projects 5-8. The pipelines and railroad transits Increasing requirements for intercontinental transit between Russia, the independent states of Central Asia, and European and Asian countries, have forced consideration of a new alternative for railroad communications. A memorandum of agreement has been signed on the construction of the railroad Mangyshlak-Iran as a part of the Eurasia transit of the new main "North-South" (Murmansk-Persian Gulf). The railroad line Eraliev(Kazakhstan)-Bekdash-Turkmenbashi(Turkmenistan)-Bender-Torkeman(Iran) is recognised as a priority for the development of transport connections to neighbouring states. The transport corridor "North-South" is a strategically important priority task.

The cost of financing of the modernisation and construction of new and efficient railroad systems is estimated to be 11.0-11.5 billion US dollars. Financing will be

implemented with the participation of the World Bank of Development of the member countries of the Organisation for Economic Cooperation and Development (OECD).

It is planned to open the main line by 1999. It is expected that the total volume of the Eurasian transit through the "North-South" corridor will exceed 70 million ton a year within the first 2-3 years of its operation, and up to no less than 85 million ton per year in subsequent years.

The initiative for the establishment of the transit through Central Asia-Afghanistan-Pakistan with an access to the Indian Ocean, which will connect Termez(Uzbekistan) - Herat - Kandahar(Afghanistan) - Quetta - Karachi(Pakistan) was supported by the counties of Central Asia. This railroad of nearly 1100 km brings the economy of the whole of Central Asia closer to world markets. The expense for this project is assessed as approximately 5 billion US dollars.

One of the largest strategic "Trans-Asian" gas pipelines approaching realisation is the 1403 km pipeline from the south-eastern part of Turkmenistan (the region of Mary-Bairam-Ali) through Kushka(Turkmenistan)-Herat(Afghanistan)-Quetta to the Pakistani port of Karachi in the Indian Ocean. The total discharge capacity will be nearly 10 billion m^3 per year. The project investment will cost 10-11 billion US dollars. The American-Saudi Consortium ("UNOCAL" and "Delta") has already completed design works on the gas pipeline. Construction may initiated at any moment, after political complexities are resolved.

3. Conclusion

The mega-projects described above cover the vast territories of the most environmentally stressed deserts of Central Asia. Their realisation will demand the establishment of new generations, identified infrastructure, development of agriculture for food production etc. The top priority goals for the implementation of these projects are as follows: collection of data on a wider range of items; development of the innovations and technologies that will be required; implementation of environmental impact assessment studies; analysis of the economic effects; assessment of social issues; adjustment of interests among countries of the region; establishment of a structure for international cooperation. The political stability of the region, goodwill and cooperation between member countries, and the broad involvement of various investors can be used as a basis for further work on mega-projects.

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Water Resources Management in Eritrea: the Challenge

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Abstract - Eritrea is an arid/semi-arid country with particular problems related to its recent war of liberation, lack of infrastructure, low GNP and poor natural resources, including surface and groundwater. However, various means are being utilised to address the many serious issues confronting this new nation, and the provision of water supply and sanitation is regarded as one of the crucial problems. The major activities now taking place in the water sector include various large projects, the establishment of national databases on water resources and related factors, ensuring community ownership of all schemes, new national policy and legislation and using appropriate technology.

Key Words: Eritrea, arid, challenges, ICBM (Integrated Community Based Management), optimism

1. Introduction

Eritrea, situated in the Horn of Africa and neighbouring Sudan, Ethiopia and Djibouti, certainly qualifies as an arid/semi-arid country: 72% of its area is hot and arid, annual rainfall varies from well below 200mm to just over 700mm (and with huge variations from year to year), there are no permanent rivers and even the groundwater resources are limited. However there are some further special characteristics. Eritrea as a nation is only 6 years old and prior to liberation suffered a devastating 30 year war. Consequences of this struggle included the wholesale movement of communities, mostly to neighbouring countries, deterioration of a once thriving economy and infrastructure, exacerbated deforestation (wood was used to line and support trenches as well as for fuel and shelter) and huge losses of soil due to erosion. Now, as the population is on the increase and many returnees are settling in traditional as well as in new areas, the poverty levels are still extreme. The Government, donor organisations and communities are attempting to address the particular problem of water and sanitation facilities within this context..

2. The Present Situation

The picture at present can be viewed as grim: less than 10% of rural people have reasonable access to clean water and less than 0.5% have any sanitation facilities. Eritrea remains a largely rural country to date, with 80% of the people dependent on agriculture, livestock....and on food imports the level of which depends on each year's harvest. The urban situation is a little better, with about 30% of people having access to relatively clean water and some 10% with at least some means of disposing of excreta (ERIWESP 1997).

Water and excreta-related diseases (such as diarrhoea, skin diseases and malaria) have a huge impact on the population in Eritrea, with particularly serious effects on children under five years of age and on pregnant women. Various indicators demonstrate the poor health status of this country, for example, the average life expectancy is forty-six years and the infant mortality rate is about one hundred and thirty-five per thousand live births (UNICEF 1996).

Water consumption figures are strikingly low in some communities, at between 3-5 litres per capita per day, compared with the WHO standard of 20-45 litres per capita per day. Consumption is

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affected by the fact that more than a third of rural water sources become dry during part of the year. Other factors which are relevant include the particular problems in supplying water and ensuring adequate environmental sanitation to the nomadic people in Eritrea; the often long distances to water sources; the burden that travelling and queuing for water places on women and girls (to the point where they have little time for education or caring for the family); and the fact that contaminated water sources are common.

3. Dealing with the Issues

Various means of dealing with these seemingly intractable problems are being undertaken, including the following major activities.

- An extensive programme of water supply (primarily) and sanitation projects, including the Massawa, Keren and Ghinda town water supply schemes, the Six Lowland Towns project, the 50 Boreholes project, the Eritrean Rural Water Supply and Environmental Sanitation Programme, the Africa 70 Handpump Rehabilitation and Training project, the Water Allocation and Pricing Policy activity, the Eritrean Community Development Fund and the Toker Dam construction for the Asmara water supply. These projects are funded by various donor organisations in partnership with the Government of Eritrea.

- Establishing databases on water resources and related factors. This programme involves the setting up of hydrological and meteorological networks across the country; undertaking an extensive drilling project to assess groundwater resources; and mapping soil types, vegetation. land use and irrigation/agricultural potential on a national basis. These activities are part of the "Sector Study on National Water Resources and Irrigation Potential" which is funded by the European Union. The project is being undertaken by "Euroconsult" and will run from February 1997 to April 1999. At its completion, the databases will continue to operate, using the counterparts from the relevant ministries who have been trained as part of the Sector Study.

- Ensuring community ownership (not just community participation) in water supply and sanitation schemes, from the initial planning phase right through to the management, operation and maintenance stage. Suitable "pay for use" (whether this be cash or kind) systems will be introduced over time. There are many stories throughout Africa of failed water and sanitation schemes, often introduced with great goodwill and at huge expense. The major reason for their failure is the lack of community involvement, which then affects the choice of technology, the location of the facility, financing options and the means of sustainable operation, maintenance and replacement. The incorporation of Integrated Community Based Management (ICBM) into all water supply and sanitation projects is a key recommendation of the Eritrean Rural Water Supply and Environmental Sanitation Programme (ERIWESP) and already several pilot villages have been selected for introducing water and sanitation according to this ICBM approach.

- A draft Water Sector Policy (Water Resources Department 1997) has been developed. The mission is "The effective and efficient development and management of Eritrea's water resources so that this and future generations can enjoy optimal benefits within the framework of the Government's endeavours to spearhead equitable, economically viable and environmentally sound and sustainable development". The functional objectives of the Water Resources Department are " To evaluate the water resources of the country", "To establish a resource centre for water-related data" and "To improve the planning, assessment and management of the water resources of the country". This Policy, and the new Water Law which is currently being

prepared, will provide an appropriate policy, administrative and legal framework within which the water and sanitation sector can operate effectively.

- Using appropriate technology, for example, micro-dams made from local materials; spate irrigation techniques; simple hand, solar and motorised pumps (standardised types which are suitable for a particular country and its culture); and VIP or even simpler latrines. It is interesting to note the reasons rural people in Eritrea give for preferring the "bush toilet" to latrines. Latrines are perceived as unnecessary, expensive, liable to collapse, smelly and culturally unacceptable. Some ethnic groups require separate latrines for men and women. Hence it is crucial that any process of selecting technology takes various factors into consideration. These include: socio-cultural, economic, climatic, topographic and institutional , as well as technical factors.

- Various innovative methods to deal with the particular problems faced in the water sector Eritrea involve community-based catchment management measures, such as terracing; attempts to use low-technology means of desalinating sea water; fuel conservation techniques in cooking in order to reduce dependence on Eritrea's dwindling tree cover, with its effects on soil erosion and run-off; afforestation and reforestation with species other than the all too common *Eucalyptus* species; and information campaigns, in the local languages, which relate to the wise and most hygienic use of a limited resource.

4. Conclusions

Although the problems involved in utilising Eritrea's limited water resources in an efficient and sustainable way appear to be "challenging" to say the least, to Eritreans nothing is impossible. Already, in the six years since liberation the following achievements in the water sector can be noted. The first phase of activities involved the rehabilitation of water supply systems in most major towns, comprising the rebuilding of pipelines and extension works, upgrading of water yields and maintenance work. The second phase has upgraded other existing systems and implemented new water supply projects, such as in the capital Asmara and in Massawa, the major port. Over 600 wells have already been constructed and the inventory and documentation of rural water supply points is nearing completion. More than 200 new wells will be constructed and 520 hand and motorised pumps installed and subsequently maintained throughout the country over the next year. Although many problems still face Eritrea, the water supply and sanitation situation is definitely improving. Eritreans are an optimistic and resourceful people: they have accepted formidable challenges in the past and succeeded in overcoming them. This pervading spirit of optimism is evident in the water and sanitation sector in this country.

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Challenges for the Future

Poster Papers

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Research Project on Sustainable Settlements within the Centre for Arid Lands Science

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Abstract - The Remote Area Developments Group (RADG) conducts research and development projects in water supply, sewerage, revegetation, renewable energy and environmental health for remote Aboriginal communities in Western Australia. The Environmental Technology Centre, a 1.7-hectare technology park on campus, was established as a resource by RADG for research, development, demonstration and teaching. RADG has worked with international organisations in India, El Salvador and Indonesia where rural environmental education centres have been established as demonstration sustainable settlements. This approach has not yet been taken in Australia with remote Aboriginal communities. The proposed Centre for Arid Lands Science, RADG, Kalgoorlie College and the Goldfields-Esperance Development Commission could together develop a community-based education centre for the teaching, research and development of sustainable technologies. Outcomes could benefit all human settlements in arid lands.

Keywords: Sustainable settlements, Aboriginal, Arid, Technology

1. Service Delivery to Remote Aboriginal Communities

The Aboriginal population of WA was 42,000 or 2.7% of the total with some 257 discrete Aboriginal communities (Daube, 1994). The various types of remote, culturally-based communities that exist today include the former, comparatively large missions (e.g. Mt Margaret); government settlements (e.g. Coonana); town or 'fringedweller' camps (e.g. Nanny Goat Hill by Kalgoorlie) and the more self-determined outstations or homeland centres (e.g. Tjuntjun Tjarra). Other types of Aboriginal communities in the Goldfields include the enterprising Kurrawong Christian emu farm, those running cattle stations such as Warta Kutju Aboriginal Corporation on Morapoi Station and those established for rehabilitative services such as Wilson's Patch for juvenile offenders. Aboriginal Hostels Limited such as Trilby Cooper in Kalgoorlie provide accommodation for transients but town camps still exist due to overcrowding or the greater freedom they offer.

Remote communities were classified as permanent, transient or emerging by agencies such as the national Aboriginal & Torres Strait Islander Commission (ATSIC) and the Water Authority of WA (WAWA) (1994). This was the basis on which funds for capital works were allocated. In 1986 the Commonwealth and WA Governments had negotiated the Aboriginal Communities Development Program (ACDP) for WA to provide infrastructure and deliver services (water, sewerage and power) for five years to 48 of the larger, remote, permanent communities as well as retaining responsibility for all town-based reserves. These are listed in Table 1. However, after the ACDP expiry in 1992 and restructure of the utilities SECWA and WAWA into corporations these arrangements were thrown into doubt. The State Government had always refused to provide services to outstations.

Table 1: 48 Serviced Communities by Region and Respective Populations

East Kimberley	West Kimberley	Central Desert	Pilbara
Djugerari	Bardi (350)	Blackstone	Cheeditha (52)
GudaGuda	Bayulu	Irrunytju (Wingellina) (170)	Ngurawaana
Kadjina	Beagle Bay (242)	Kiwirrkurra (100)	Tjalka Warra (80)
Kalumburu (370)	Bidyadanga (La Grange) (600)	Mantamaru (Jameson) (110	Warralong
Kundat Djaru (123)	Djarindjin (248)	Tjirrkarli (77)	Yandeyarra
Lundja (Red Hill)	Imintji	Wanarn (80)	
Mulun (200)	Kupungarri (110)	Warakurna (280)	Midwest
Muludja (101)	Lombadina (50)	Warburton (385)	Burringurrah (101)
Ngumpan (25)	Looma (500)		
Oombulgarri (136)	Mindibungu	Western Desert	Goldfields
Warmun (450)	Mowanjum (240)	Jigalong (280)	Cosmo Newberry (120)
Wirrimanu (Balgo) (550)	Noonkanbah	Nganganawili (100)	Mt Margaret (150)
Woolah	Pandanus Park (50)	Punmu	Upirl Upirlila (Coonana) (205)
Yiyili (170)	Wangkajungka (325)		

Source: (Stewart, 1994 and IGWG, 1995)

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The population and services in all Western Australian (WA) communities were documented in the 1994/95 Aboriginal Environmental Health Survey (IGWG, 1995). Massive disadvantage was still evident in terms of lack of services and disrepair. Poor environmental living conditions were responsible for the high rate of infectious diseases and this did affect WA State Government policy.

A positive outcome of the changing policy framework was a shift from a 'medical model' (concerned with diagnostic medicine and gathering of health statistics) to an 'environmental health model' (concerned with health hardware, housing, infrastructure and gathering of living condition statistics). Unfortunately, despite the continued data-gathering activities, environmental health surveys, improved intergovernment coordination and planning for hypothetical projects there was still no commitment to meet the backlog of demand for essential services. Indeed, it became apparent that even though the number of communities in WA had exceeded 350 by 1997 the State Government would limit its service delivery commitment to 72 - at least an increase on the original 48.

There was a lack of political will to begin transferring environmental health programs and systems into Aboriginal control. Apart from the political climate government agencies are restricted from embarking on a genuine 'community development' approach in various ways such as by internal procedure (public sector professional conduct, reporting and accounting), statutory requirements (State Health Act, building by-laws, NH&MRC water quality guidelines) and public liability insurance. To date an approach to technology-practice in Aboriginal communities that integrates community values, regional commonalities, respect for culture, concern for nature and sustainable development has not been documented or implemented.

2. Sustainable Delevopment in Remote Communities

In contrast to the great attention of sustainable development theory and praxis to the Third World, very little attention has been paid to Fourth World situations. Indigenous people have largely been ignored with regard to discussions on sustainable development in industrialised countries such as Australia. The debate has been closely linked to the resource sector in Australia, yet Aboriginal people are seeking a way forward to ecologically sustainable development in remote areas. Stocker & Pollard (1994) found a number of common factors in successful community-based projects for ecologically sustainable development including a regional alternative technology centre and a remote Aboriginalcommunity.

Young (1995) argued that Aboriginal people need "support systems aimed at total development" and she adapted a model for sustainable development which corresponded with the three dominant aspects of Aboriginal society: the people (the social system), their means to survival (the economic system) and their environment (the biological and resource system). Although the economic growth paradigm in mainstream society may continue to detrimentally affect policies towards Aboriginal communities for some time Young (1995) explained that this could be offset by consultation at the grass-roots level, enough flexibility in the program to allow change midway through projects, and the need for Aboriginal people to sometimes take an adversarial approach towards government agencies.

To implement Young's strategies may require the support of non-government development organisations such as the Overseas Service Bureau, Community Aid Abroad, APACE, AREA, professional associations and research groups that are able to assist in trials of devices, maintenance programs and management systems. The majority of government funding, however, may need to be applied through regional Aboriginal organisations in blocks (not annually) as recommended by the Royal Commission into Aboriginal Deaths in Custody (recs #324-327) (Johnston, 1991). Technologists willing to take a "learning process" approach (Simpson, 1991), a "dedevelopment" approach (Hunter, 1993) and a "reversal in thinking" (Chambers, 1983) towards the Aboriginal belief system would contribute towards "community-building" development.

In the Water Report (Race Discrimination Commissioner, 1994) Dr Bruce Walker argued that certain technological approaches in urban mainstream Australia towards sustainability, such as sewerage systems based on economies of scale, water conservation and renewable energy, may not necessarily be appropriate in remote Aboriginal communities at a certain stage of their development. Zethoven (1991) had also identified the need of many Fourth World communities to continue with an economic growth paradigm until basic needs are met as part of a 'deep' model of sustainable development where industrially developed societies curtail economic growth and consumption.

3. Conceptual Models for Technolog y Transfer

A conceptual framework for technology transfer in service delivery for sustainable development was proposed by Anda (1996) in the form of three models: Community-building Technology, Community Technology and Regional Technology. Community-building Technology is a simultaneous process of service delivery and empowerment. In essence, it introduces technology to a community in a culturally-appropriate manner. Such an approach was demonstrated by some ATSIC Community Development Employment Program projects, the former on-site programs of Pundulmurra College, the Jim Sinatra RMIT approach to landscaping and housing on the Torres Straits Islands. Community-building Technology can be one process which contributes to the formation of an ensemble of sustainable technologies - Community Technology. As far as the authors are aware this model has not been fully implemented in any community. Community Technology relies on the mutually-supportive interaction of technology systems which would be difficult to achieve under the current arrangement of line agency responsibility for service delivery in both Aboriginal communities and mainstream Australia. The effect has been demonstrated in permaculture design (Mollison, 1988) and some 'eco-villages' around the world. These actions could be supported by the Regional Technology model. The technologist and community receive coordination, planning, design, training, construction supervision and financial administration support from regional organisations. In combination the three models provide a holistic framework for the technology transfer and community development process.

4. A New Demonstration Project

These conceptual models and associated technology research projects could be implemented through a collaborative project with an emerging Goldfields Aboriginal community which receives support from a regional Aboriginal organisation such as an Aboriginal Medical Service, a regional resource agency, or the Community Council/administration of a large established settlement. By focussing on a small, emerging community such as an outstation an alternative town planning and servicing methodology can be developed that addresses the needs of these communities which may soon be abandoned altogether in State Government service delivery responsibilities.

An important aspect of project planning would be accepting the legitimacy of a range of Aboriginal community types. This has been described as a "new approach" by Peter Cuming for rural settlement planning. A "hierarchy of settlements" are catered for and the methodology has been promoted by the New South Wales Department of Planning and Urban Development (1995). This would define the scale of technology systems and the interactions between them by addressing the population sizes, lifestyles and placement of each community type in relation to a regional centre such as Kalgoorlie or a large settlement such as Coonana or Warburton. The project could be supported by the Centre for Arid Lands Science, RADG, Aboriginal Affairs Department (AAD) and ATSIC.

Table 2 provides a brief outline of some research, development and demonstration projects that could be conducted in the context of the settlement's activities.

Table 2: Possible Projects to be Implemented

Information Services	A great need for technical information services exists in remote and regional areas to assist Aboriginal communities and organisations make appropriate technology choices for their development (Anda, 1995). In the context of this proposal regional workshops would serve to disseminate information to community members and establish priority of research projects.
Town Planning and Development Methodologies	Alternative methodologies may be needed to implement Community Technology. It will be necessary to assess the viability of regional community planning methodologies such as the "new approach" by Peter Cuming for rural settlements and the town camp development methodology by Anda (1997) adapted from Daube (1994).
Water Management	The sustainability of groundwater resources used by remote Aboriginal communities is an area that requires further research. The "Solarflow" solar-powered reverse osmosis desalination unit has been developed by RADG and Venco Products for treatment of brackish water at 400 and 1,500 l/day outputs and can be trialed for small community's drinking water supply. Disinfection technologies alternative to chlorination need to be trialed. Further trials of the water supply bacteriological test kit and the hydrogen sulphide paper strip for Salmonella detection developed by RADG can be done. High levels of water hardness in many remote communities results in blockages and breakdown from precipitates depositing inside kitchen appliances, solar water heaters and plumbing components. A research project can be commenced that develops a small-scale, low-cost technology for removal of carbonates. RADG has conducted studies for WAWA which confirm the viability of wastewater reuse from sewage lagoons for revegetation around communities. Demonstration projects need to be established in remote communities for further development. Dry composting toilets have been successfully implemented at communities in the Goldfields and Kimberley. Their introduction needs to be accompanied by further trials of greywater reuse systems for productive use (e.g. revegetation or fruit orchards) which would be supported by the National Guidelines for Domestic Greywater Reuse and the new Australian Standard 1547-1996 currently in draft form.

Electricity Supplies	Renewable energy systems are now cost-effective in remote communities where diesel fuel supplies are expensive. However, other factors such as existing diesel maintenance skills, skilling for a new system, energy use patterns, initial capital costs and replacement parts need to be considered. The demonstration project can include an energy conservation strategy to determine usage patterns to make renewable energy systems practicable. A training, management and maintenance strategy necessary for regional delivery can be developed. Solar/wind water pumping systems can be monitored.
Housing	Thermally comfortable housing is not usually achieved in remote communities and large amounts of energy for heating and cooling are consumed. Low-cost locally-manufactured climate sensible designs can be trialed. Further development and improved practice in the outdoor living environment is necessary (Pholeros, Rainow & Torzillo, 1993): landscaping, fencing, shade structures, cooking facilities, windbreaks, vehicle access.
Food Production	Dryland strategies can be trialed to achieve some level of self-reliance in this area by adapting sector analysis for shade and shelter, and zoning (Mollison, 1988) as follows: Zone 1 - intensive home food garden; Zone 2 - intensive home fruit orchard and poultry system; Zone 3 - community garden and orchard; Zone 4 - forestry, grazing and tree crops.
Land Restoration and Conservation	Design and planning methodologies can be trialed for revegetation and conservation of bushland around the community. Revegetation can be demonstrated using sector analysis (Penberthy, Anda & Kalotas, 1997).
Dissemination	The community will need to be equipped with facilities that allow residential educational programs for Aboriginal people from the region. Educational programs will be action-oriented that contribute to the development of infrastructure, landscape, management and maintenance on the site.

5. Conclusion

RADG has formulated this proposal after a number of years of activities in the Goldfields: collaboration with Kalgoorlie College; research and development of ablutions facilities; training and implementation trials for a water supply test kit; revegetation planning and practice; a feasibility study into the need for technical information services; attendance at conferences in Kalgoorlie; regular visits to communities in the region, and advice from a senior Wongai Aboriginal person on its Advisory Committee. Further consultation with Aboriginal communities and organisations, Kalgoorlie College, the Goldfields-Esperance Development Commission and the Centre for Arid Lands Science will be necessary.

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Challenges for the Future

Papers Not Presented at the Conference

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A New Approach to Cambat Desertification in China — an example of Naimanm

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Desetification is an essential socio-economic and environmental problem that has aroused concern of the Chinese Government for it has seriously affecting sustainable development in part of the regions in China. The expansion of desertified area constitutes an essential factor for the gradual shrink of land resources. With regard to the sandy desertified area in the farming-pastoral region of Northern China, the affected area increased from 30% of the total land area in the 1970 s to 40% in the mid 1980 s. The essence of desertification combating is to improve the degraded land conditions by rehabilitating productivity of the already desertified land, how to revers the degradation process of the ongoing land desertification and how to prevent the development of the potential desertified land; and to make land resources being sustainably utilized and bring even greater benefits. This paper is for example Naimanm Banner of Inner Mongolia — a model for combating desertification in semi-Arid zone.

Naimanm Banner is located in central Horqin Sand Land of Jerim League, Inner Mongolia, a representative of wind erosion dominated desertified land in farming-pastoral area east of semi- arid zone in northern China. Ground surface is composed with 20-120 m thick of sandy deposits, annual average precipitation is 352.1 mm, gales blow 21 days and sandstorm 26 days per year. Primary landscape is sand land sparse steppe on dian (interdune bottomland) crisscross with tuo (dunes). Vegetation coverage varies with intensity of human activities in different places, generally ranging between 5-50 percent. Mobilization of stabilized dunes occurs to differing degrees due to overgrazing, excessive farming and vegetation devastation by fuelwood gathering, resulting in a landscape having moving dune and semi- moving dune with stabilized dune in alternation. Moving dunes roughly accounted for 17.8 percent of the total sand land, semi- moving dunes, 34 percent and stabilized dunes, 25.7 percent. In recent decades, sandy desertification got rapid development. In the late 1950s, the area accounted for 20 percent, developed to 50 percent in the mid 1970s, and 77.6 percent in the mid 1980s. Vegetation was generally in the reverse evolution process of sparse grassland → shrubs + perennial herbs → perennial herbs, wormwood artemisi.. steppe → wormwood artemisia, weeds grassland → psammophytes vegetation, being one of the serious sandy desertified areas in northern China. In light with variations in desertified landscape of different parts on the Horqin Sand Land as well as other land use features, different combating models were adopted.

1. In dian-tuo crisscross area dominated by farming on open pastureland in desertified area, work started from stabilizing shifting sand and closing grazing ground on fixed and semi-fixed dunes; then land use structure dominated by dry farming was adjusted, pastureland (subsurface water table 5-8 m) with better water conditions was taken for farmland capital construction for the aim of environmental protection and rehabilitation and development of land productivity. Now the Yaoledianzi village is taken for demonstration.

Yaoledianzi is situated at western bank of Jiaole River in central Naiman, characterized by a ground landscape alternated by shifting and semi-shifting sand, fixed and semi-fixed dunes with interdune bottomland. It has a farming history of around 100 years. Sandy desertification started in the 1950s, reached climax in the mid 1970s. The chief reason accountablle for this is extensive reclamation of already stabilized sand land guided by the instruction of "taking grain as lead", the peak of cultivated area was 3 times that of the present; then excessive fuelwood gathering along with herbal medicine collection as sideline occupations; and thirdly, overgrazing. Shifting sand and semi-moving dunes made up 72 percent of the village's total land area, annnual soil loss from farmland due to wind erosion reached 150 t/ha during windy season. As a consequence, soil organic matter dropped from 2.27 percent in the 1950s to 1.06 percent in the 1980s. Per ha grain yield was only 675

kg, per capita income, 174 yuan. In light with this situation, the following measures were taken to combat desertification.

(i) Stabilize shifting sand and rehabilitate artificial dune vegetation. *Artemisia halodendron* were planted on moving dunes in rainy season, serve as barrier against sand the following rainy season, and *Caragana microphylla* was planted inside the barrier. After 3 years, *Caragana microphylla* grew up into one-meter-high shrubby belt with different species of herbal plants reproduced here. After 3-5 years, a stabilized shrubby- grass vegetation system can be basically set up.

(ii) Fence stabilized and semi-stabilized dunes to grazing and fuel gathering to facilitate vegetation, and conduct supplementary aerial sowing grass seeds. In management, household contracting system was practiced.

(iii) Adjust land use structure dominated by dry farming. Rate of pre-treatment agriculture, forestry and animal husbandry was 40.2, 11.6 and 48.2 percent respectively, after treatment, the rate was 15.9, 19.3 and 64.8 percent respectively. Dry farmland seriously affected by aeolian and wind erosion was reduced for grass. Farmland capital construction was carried out on flat bottomland with better soil and water conditions. Shelterbelts to protect farmland were established, irrigation facilities were increased and watering area increased, high-yield varieties were increased and melons and fruits were developed.

(vi) Adjust animal population structure, increase ratio of stockyard raising and reduce the number raised on grazing ground.

After 10 years effort, serious sandy desertified dominated by shifting sand in Yaoledianzi dropped only to 13 percent. Comparisons of pre- and post-treatment indicated that dry farmland declined from 78.9 percent to 17.3 percent; irrigated area increased from 21.1 percent to 82.7 percent, per ha grain output increased 6.6 times on an average basis, reaching 5137 kg; and per capita income increased 126.3 percent.

2. In livestock farming dominated dian-tuo crisscross desertified area where fixed and semi-fixed dunes in predomination with shifting sand distribution in spotted patterns, ecological household was taken as unit to combat desertification under contract because of scatteredness of settlements and gradual expansion of shifting sand. Generally, interdune lowland with better water and soil conditions scattered around settlements was taken as a centre for enclosing. Tree- shrubby forests were planted in the peripheries of the enclosed areas, sand binders such as *Artemisia halodendron, Salix gordejevii* and *Caragana microphylla* were planted on shifting sand, after 3 years, the sand can be stabilized for grazing. Meanwhile, land levelling was combined with ground water (generally 3-4 m deep) exploitationand utilization to develop grain crops. In places where conditions were permitted, plastic canopy was used on sand land to cultivate rice, forming a micro eco-economic spheres with areas of 0.15-0.25 km^2. Such kind of micro eco-economic spheres tackled basically the feed and clothing problems of the ecological households. Based upon which, economic crops such as melons and fruits were developed. In the peripheries, natural grassland reservation or supplementary aerial sowing to promote animal husbandry were carried out. After 5 years reservation, vegetation coverage can increased from 5-15 percent ot 60-70 percent, thus enlarging the green micro eco-economic spheres and separating sandy desertified land. This method was applied to combat desertification in areas around Baiyantala. Of which, desertified land dominated by shifting sand dropped from 75-80 percent pre-treatment to below 10-15 percent, and per capita income increased from 400 yuan pre-treatment in 1985 to 1500 yuan post-treatment in 1995, an increase of 375 percent in Xiwutala alone.

3. As for combating undulating sandy desertification, Huanghuata Township in southern part of Naiman Banner can be taken as an example. The township was originally a fertile pastoral land, owing to excessive reclmamtion of sand land, the area of sandy desertified land has reached 83 percent of the land area, serious affecting agricultural and pastoral economy. the following measures were taken to tackle the problem, i.e., change the extensive dry farming economy dominated by grain production

and increased proportions of forestry and animal husbandry by adjusting land use structure of farming, forestry and animal husbandry from original 6:2:2 to 2:4:4. In this connection, large scale farmland and grassland protection system by planting trees, shrubs and grass was developed, putting 4200 ha of farmland and pastureland under protection within over 500 grids in addition to conduct vegetation reservation in marginal areas. Different measures were adopted according to different natural features, turning each grid into a small ecosystem. In grids with flat terrain and better water conditions, irrigation farming was developed; and in grids with sligh undulating stabilized and semi-stabilized sand land, forage base was constructed to develop livestock fasrming. As a result, 85 percent of sandy desertified land was tackled, total output of grain increased 3 folds, grass yield increased 1.5 folds and per capita income increased 5 folds.

4. As to desertified areas adjacent to edges of farmland with apparent undulating dunes and small interdune pastureland but dominated by dense moving dunes, in addition to build shelterbelts of high trees on flat land in front of the forward moving dunes, what is more important is to plant shrubby sand binders such as *Artemisia halodendron, Salix flavida, Caragana microphylla* and *Amorpha fruticosa* in combination with natural reservation. Shifting sand surface was generally fixed after 5 years. *Pinus sylvestris var mongolica* can be planted under protection of shrubby forest. Moving dunes can be stabilized or semi-stabilized after 5-8 years. The moving dunes around Shelihu and south of Shetang where the Sha-Tong railway went through was stabilized in this way in the mid 1970s. The vegetation coverage went up from pre-treatment less than 10 percent to 70-75 percent two dozens of years after treatment. Another example is west to Daliushu Desertification Experimental Station. In the mid 1960s, the area was entirely occupied by dense moving dunes which accounted for 82 percent of the total area. After 3 years treatment, shifting sand dropped to only 8 percent, and original dense shifting sand became stabilized or semi-stabilized dunes with vegetation coverage of 50-70 percent. In some interdune openland, measures of levelling sand land, exploiting ground water and practicing irrigation by diverting canal water were taken. The plastic canopy technique developed then to cultivate rice facilitated per ha grain output being as high as 7,500-9,000 kg.

5. Because of ecologically self-rehabilitation capability, natural enclosed reservation (in combination with artificial supplementary aerial sowing) is, among others, the most fundamental way of combating to desertified land in semi-arid farming-pastoral areas, given no continuous human disturbance. Take Bagapoli township as an example. In the 10 years from 1975 to 1985, vegetation coverage increased from 20 percent to 71 percent, total dry weight biomass increased from 1089 kg/ha to 4675 kg/ha, organic matter content contained in soil horizons of 0-50 cm thick increased from 0.045 percent to 0.537 percent, sandy desertified land declined from 24,000 km^2 in the mid 1970s to 10,000 km^2 in the 1980s, grass yield increased 1.5 folds and per capita income increased 2 folds.

6. Examples concerning desertification combating in Horqin Sand Land of Naiman Banner can represent desertification combating model of semi-arid farming-pastoral areas. Major measures are summarized below:

(i) Adjust land use structure dominated by dry farming and form a model of farming-pastoral integration under forestry protection.

(ii) Carry out farmland capital construction centered around pastureland.

(iii) Stabiliize moving dunes by integrating grass reservation, sand binder plantation on dune surface with interdune woodlots.

(vi) As to dune and sand land stabilization, the principle of moderate use should be followed along with natural grass reservation combined with supplementary aerial sowing, and rational utilization of grassland resources to develop animal husbandry.

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Kalgoorlie-Boulder: The Water Efficient City

Rod BOTICA* and Stuart WHITE**

Abstract - The Kalgoorlie-Boulder Water Efficiency Program aims to reduce the demand for water by 10%, or 700 ML/a, in this Western Australian mining centre which has 11,000 connected water customers. The program is targeted at the domestic, commercial and industrial sector, but has excluded the mining sector. The $3.0m program was developed and implemented jointly by the Water Corporation of W.A., the Water and Rivers Commission and their predecessors and consulting firm Preferred Options. It is a world first, with a unique combination of indoor retrofitting, water auditing, loans, education and outdoor efficiency incentives. The uptake rates for retrofitting and incentives have exceeded estimates, and the program has been well supported by key stakeholders and trade allies. The annual saving documented for 1995/96 in Stuart White's Assessment Report are 350 ML (35 kl average per connection) on the previous eight year average for the Residential Indoor and Publicity Components of the program. This translated to 690 ML (69 kl average per connection) on a climate corrected basis.

Keywords: Kalgoorlie-Boulder, water efficiency, demand management, climate correction

1. Introduction

The demand for water at Kalgoorlie-Boulder is of particular interest for two reasons. Firstly, at 7,000 ML/a, it is the largest single demand on the pipeline, and the number of customers in Kalgoorlie-Boulder has been steadily growing. Secondly, it is at the end of the pipeline and therefore the operating and capital costs associated with supplying this demand are amongst the highest.It was therefore appropriate that Kalgoorlie-Boulder was chosen as the site for a water efficiency project of this kind. This team crossed professional boundaries and included those with skills in water efficiency program design, economic analysis, marketing and advertising, population and demographics and demand modelling. Many people, including Water Authority staff and trade allies, such as plumbers, nursery proprietors and irrigation contractors were consulted and assisted with the study process.

2. The Study

The objectives of the study were to find ways to permanently reduce the demand in Kalgoorlie-Boulder in order to reduce the cost of pumping water through the pipeline, and also to defer the need to increase the capacity of the pipeline and the source in the future. Water use restrictions had been in place over the previous two summers, and surveys had shown that the community in general support them as a means of conserving water. However it is clear that restrictions do not permanently reduce the demand for water, and restrictions on watering times often merely shift the peak of water use, rather than reducing the overall demand. Providing permanent and measurable reductions in demand requires changes to the efficiency of water using equipment, such as the toilets, shower heads, evaporative air conditioners and irrigation systems, as well as changes in the type of landscaping. In addition it requires an education and advisory component to provide information on watering times and patterns, on pool operation and other day to day water using behaviour. The emphasis was on measures that would provide the same or even an improved level of customer service. A community consultation process was also part of the study, and this included information leaflets, media publicity, public workshops and interviews of key stakeholders.

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The study involved a number of stages. Firstly, it was necessary to look closely at the demand for water over the years and at present. How much water do the various customer groups use? The study was targeting all sectors of water use except the large mining sector customers. Therefore the demand was broken down into the domestic and the non-domestic, and then into the various major users in the non-domestic sector, such as schools and colleges, hotels and motels and so on. The raw data for this task comprises the daily bulk water demand for the whole of Kalgoorlie-Boulder, between 1987 and the present, and the metered customer demand, which for most customers involves three readings per year. The next task was to try and determine the end-use of water. In other words, what do customers use water for, and what sort of appliances do they have? To assist with this task a door-to-door survey of domestic customers was conducted, in which they were asked about the types of toilets, showers, watering systems and other appliances they owned and how they were used. From this information it was possible to build up a picture of the potential for improving the efficiency of water use through changing the appliances that use water, and through improvements to landscaping and irrigation practices.

Each of these end-uses were then analysed in turn. The study team needed to answer the following questions:

How could the adoption rate of more efficient appliances be increased?

How could it be ensured that water using equipment, such as evaporative air conditioners, were used properly?

How could a net reduction in the area of irrigated lawn be achieved, while still allowing for resident's needs for a serviceable recreation area in their yard?

How could it be ensured that customers knew about, and planted, waterwise shrubs and trees?

Different approaches were considered, and the costs and benefits estimated. The costs included any incentives or hardware that were provided, as well as the advertising and promotion costs. The benefits were the financial savings that would result from the reduction in demand. In Kalgoorlie-Boulder the benefits can be quite large, because the cost of water exceeds $2/kL and the price is usually around 70¢/kL for the average household.

In summary, the final program involved a comprehensive approach covering all aspects of water use in Kalgoorlie-Boulder and all customers except the mining sector. It included retrofitting appliances, education and advisory services, incentives for lawn replacement, waterwise landscaping and free water audits for non-domestic customers.

3. The Program

The objectives of the program are as follows:

- To achieve reliable and permanent water demand reductions in the community of Kalgoorlie-Boulder in the non-mining sectors by implementing cost effective water efficiency measures.
- To promote a culture of water efficiency in the community with the aim of making Kalgoorlie-Boulder a water efficient city.
- To provide net financial benefits to the Water Corporation and participating customers.
- To trial cost effective water efficiency measures for possible use elsewhere.
- To identify opportunities for progressively extending the program to other areas with a high cost of water supply.

The program has been implemented in the following phases or sub-programs:

3.1 Communication Strategy

Along with extensive media coverage,a Water Efficiency Advisory Committee (WEAC) was established to act as a public and stakeholder forum for community and industry input. WEAC met seven times during the project implementation. A schools kit was developed as part of an implementation strategy for WaterWise schools. Several public addresses were made to public groups and clubs, including at meetings of Rotary, Rostrum, the Master Builders Association and to schools. There were a number of public displays in shopping centres and at fairs.

3.2 Domestic Internal Phase

This phase, operating from May 1995 to February 1996, involved offering free retrofitting of shower heads, air-conditioner bleed valves, basin tap restrictors, aerators and dual flush toilets and the repair of leaking taps. The offer exceeded expectations with 5,200 properties retrofitted.

3.3 Non-Domestic Phase

This phase was designed to improve the water efficiency of the non-domestic sector. The first step involves the offer of free cost water audits of the premises of 150 medium to large water users, providing a report detailing potential water and energy savings. A licensed plumber with water auditing qualifications and experience was engaged to facilitate the implementation of audit reports with proprietors. Loans were offered to participating businesses to implement the recommendations of the water audits.

3.4 Domestic External Phase

This phase involves offering free checking and adjustment of garden reticulation systems and an offer of free advice, reduced price tap timers, free plants and mulch and discounted brick paving for lawn reduction and new garden establishment, available in the period September 1995 to March 1996. It also involves the establishment of demonstration water efficient gardens and display areas and the encouragement of ongoing research at Kalgoorlie College in the area of outdoor water efficiency.

3.5 Evaluation

Of the 8,200 domestic customers in Kalgoorlie/Boulder, around 5,200 houses have taken up the free plumbing and retrofitting of toilets offer and approximately 3,200 houses have taken up the external reticulation and gardens offer. The financial analysis of the program suggests that the financial benefits in reduced operating and capital costs will more than make up for the financial costs. There will also be a major financial benefit to customers in reduced water bills and energy bills due to reduced hot water usage. It has been estimated that annual energy savings of 3,000 MWh will result from reduced water pumping and reduced water heating costs.

Other benefits that accrue from the program include:

- the economic benefits that are generated by the retrofitting and appliance sales work, which was carried out primarily (70%) by local contractors using mostly (95%) Australian-made materials;
- over 2,000 improved and water efficient gardens that enhance the character and beauty of neighbourhoods of Kalgoorlie-Boulder;

- the upgrade in the value of properties due to the new and improved appliances and landscaping;
- potential spin-off into sales of other water and energy efficient appliances, such as washing machines and dishwashers;
- the Water Efficient Primary School's education package providing experiential learning about the value of saving water and energy;
- the development and running of courses for plumbers, irrigation contractors and other trades in the area of water efficiency, adding to the body of knowledge and increasing the skills level.

4. Conclusions

The Kalgoorlie-Boulder Water Efficiency Program has been successfully implemented beyond the original expectations. Kalgoorlie-Boulder is a challenging location to implement such a program, and yet the adoption of measures and the community support have been excellent. Of the 8,200 domestic customers, some 5,200 have taken up the free indoor water efficiency measures, and about 3,200 customers have taken up the outdoor water efficiency measures. Over 150 non-domestic customers with annual demand greater than 1,000 kL/a have taken up the offer of a free water audit, and many have now started to act on the recommendations of the audit reports.

Water demand for the period July 1995 to June 1996 is down 35 kL/connection compared to the average of the previous eight years, which translates to a reduction from anticipated demand of 350 ML/a. Preliminary data comparing monthly demand per connection calculated using weather-related variables ('climate corrected demand') and the actual demand per connection indicate that the results are promising and certainly in the right direction. There has been an average 11% reduction in the climate-corrected monthly demand per connection in the period July 1995 to March 1996, based on the demand in the period July 1987 to August 1994. This saving has been maintained during the twelve month period ended 30th June 1997and people in Kalgoorlie-Boulder are proud to identify with their city being the world's first water efficient city and this goodwill will need to be reinforced in the community with a continuing community based information campaign.

The sort of program that has been implemented in Kalgoorlie-Boulder has been a major advance for the demand-side of the water industry. It has made real the proposition and has provided recognition that it is often cheaper, quicker and better to save a megalitre than it is to supply an extra one.

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Workshop Recommendations

沙漠研究 7S, 351-358 (1998)
Journal of Arid Land Studies

Workshop Sessions

The challenge

Four concurrent evening workshops were held on Thursday 25 September. Delegates were invited to attend one of the workshops, to address one of the following questions:

Workshop 1: Water

What is the role of scientists in ensuring the improvement in potable water supplies to arid areas over the next ten years?

Workshop 2: Land

What changes can scientists make to improve the sustainability of production in arid areas? What topics of research in either agricultural production or land rehabilitation in arid areas are likely to produce the largest sustainable gains?

Workshop 3: Air

What activities in arid areas over the next ten years will most help to improve the long term quality of the atmosphere? What is the scientist's role?

Workshop 4: People

As scientists how can we influence land use controls? How can we assist land users to become more involved in finding and implementing solutions to improving land quality and sustainable production?

What the workshop groups developed

Workshop 1: Water

The participants of Workshop 1 brainstormed a list of possible ways to improve potable water supplies.

The list of possibilities has been grouped by topic.

Water supply at the national or regional level:

Develop the concept of water as an international store of value - 'water standard'
Further develop cloud seeding technology
Pipe sea water to arid areas, and there desalinate it and extract minerals and salt
Freeze excess potable water and export it as ship ballast
Develop the technology to tow icebergs from Antarctica
Explore climate modification technology
Model and predict implications of future climate changes
Develop wind technology to produce and transport water (direct/indirect)
Educate the population on the need to be water efficient
Breed plants which have reduced water requirements

Water supply at the sub-regional or community level:

Develop independent and low maintenance water supply systems for each community
Develop solar technology for independent water systems
Improve solar still technology by including an evaporation accelerator
Recycle water (eg. use waste water for toilet flushing)
Install dual household/community water mains for a) potable water and b) grey water
Use salt lakes to distil potable water on a large scale
Improve reverse osmosis technology and use solar power
Develop a biological filter to purify water with high organic matter
Develop technology to extract water from the transpiration of plants
Develop greenhouse technology to collect water from salty water
Develop technology to gather water from changes in air temperature and humidity
Distil water from permafrost soils to make localised water cycle
Construct earth mounds to accelerate the collection of distilled water
Develop earthworks technology to harvest storm water
Improve dam design to suit arid areas
Cover storage reservoirs to reduce evaporation loss

Water supply at the household level:

Develop a system of water stills for every house
Develop an affordable household micro-filter to purify water
Harvest rainfall from the roofs of buildings

Choosing six of these possibilities the group next considered the positive and negative aspects of these options.

Recycle water (eg. use waste water for toilet flushing)

Positives	*Negatives*
Use waste water as a resource	Limited to communities with toilets and waste water
Saves on high value potable water	Expensive capital costs to install
Stable water resource	Storage of grey water required
	Efficient 'no water' toilet technology is available

Use salt lakes to distil hypersaline/ brackish water to produce potable water

Positives	*Negatives*
No problem disposing of salt waste	Drawdown on the lake may affect related water sources
Lots of salt lakes, which are efficient collectors of water from spasmodic rain events	
Cheap technology	
Produce salts and mineral by-products	

Develop water from transpiration technology

Positives	*Negatives*
Can utilise green materials from forestry operations	Inappropriate for degraded or low vegetation environments
Promotes carbon sequestration	Some plants are poisonous and therefore not suitable for this use
Encourages vegetation	
Improves the microclimate in which to establish plants and reforestation	
Cheap	

Improve solar still technology (eg. by including evaporation accelerators)

Positives	*Negatives*
Immediate results	Costly
Secure source of water	Inappropriate solution for certain communities
High quality and high value water	Needs a source of water to distil
Simple technology	
Low energy requirement	

Improve dam design to suit arid areas (including reservoirs, tanks and storages)

Positives	*Negatives*
High and large impact	Changing climate may change runoff characteristics
Cheap technology	Water cycle - localised implications
Immediate results	
Improvements to human and animal health	
Subsurface storage will reduce losses due to evaporation	

Educate population to conserve water (Be 'Waterwise' aware)

Positives	*Negatives*
Culture to educate for national survival	Lack of trust in foreign concepts and technology
Very high community support is possible	Demonstration of immediate benefits

Workshop 2: Land

Workshop 2 participants developed a number of strategies for improving the sustainability of production in arid areas. The participants identified a number of key issues with the overall objective of maximising sustainable production. In priority order the four most important pursuits were seen to be:

1. Educating more people to support and apply the concepts of sustainability in relation to economically and ecologically viable use of arid areas
2. Preserving the most productive land for agricultural and horticultural production, and discouraging urbanisation of this land
3. Making the best use of land for the global population
4. Educating urban people in the importance of preserving and protecting natural land resources

The workshop participants ranked the other issues they raised with equal fifth priority.

All the issues raised have been re-grouped under appropriate sub-headings. The editors have taken some editorial license in listing research topics from amongst the list of issues which have the potential to lead to large and sustainable gains in land productivity.

Land use planning based on land capability

Reserve the most productive land for agricultural and horticultural production, and discourage urbanisation on such land
Plan land use for the benefit of the global population
Use land judiciously to maintain sustainability and prevent further degradation and deterioration
Use all land according to its capability. Pool resources and wisdom internationally to achieve this.

Optimise production

Increase production but at the same time conserve the land in its present state or better
Develop systems to encourage more sustainable productivity
Encourage the development of low technology inputs

Education

Educate people to support and apply the concepts of sustainability in relation to economically and ecologically viable use of arid areas
Educate urban people in the importance of preserving and protecting natural resources

Research topics with the potential to lead to large and sustainable gains in land productivity

Increase bio-organism productivity
Develop a pest problem warning system.

Develop low technology input farming systems for arid areas
Develop global weather forecasting systems
Develop energy efficient land rehabilitation technology
Develop irrigation systems for arid areas which are sustainable and do not cause salinisation

Mr David Fitzgerald presented the workshop findings at the plenary session, and made some important observations which are recorded here:

He expressed his admiration for scientists at the conference who had presented papers in English although their own language was other than English.

After hearing and talking to many people at the conference from different parts of the world Mr Fitzgerald made the important observation that it is much easier for countries like Australia, which have large areas of land and relatively small populations, to preach and put into practice conservation ethics, compared to some countries that need to coax more and more production from their land to keep their people fed. Even in the face of this those countries are well aware of the dangers, and all the time are looking for better ways to achieve sustainability.

Workshop 3: Air

The participants of Workshop 3 tackled the task in a slightly different way. They listed a number of problems and outlined a solution for each of the problems that affect the quality of the atmosphere. Next the group stated three priorities for action, and, lastly, outlined in general terms the roles that scientists should be playing to achieve the goals and solutions they had listed.

Pre-amble

The quality of the atmosphere is affected by Greenhouse Gases (Carbon dioxide, Methane, Hydrofluoro carbons, Nitrous oxide) and by pollutants (Oxides of Sulphur and Nitrogen, dust and particulates). Controlling the formation of these substances, and finding sinks to remove them from the air will improve the global environment. The vast area of arid lands around the globe make them important sinks for Greenhouse gases. The efficiency with which arid areas act as sinks for greenhouse gases could be greatly increased through the rehabilitation of arid areas, their conservation, and the ways in which they are managed.

Problems	*Solutions*
Prevent dust movement in arid areas	Regenerate vegetation, control sand movement, and stop unwanted human activity as far as possible
Identify whether dust has a net beneficial effect on soil nutrition	Study the soil nutrition properties of dust
Develop ways to 'greenify' arid areas	Use conventional and solar desalination for irrigation in arid lands, and use wind and solar energy for water pumping for irrigation

Stop sand movement	Develop and use 'sand fencing' and greenification
Use arid areas to improve global air quality	Develop technology to grow forests in arid areas to act as 'carbon sinks'
Develop public awareness of the role arid areas can play in carbon sequestration	Provide demonstrations, promote interaction and education programs, and foster people's participation
Develop new technologies for afforestation in arid areas	Improve water and salt management through bio-technology
Achieve consensus on the CO_2 problem between developed and developing countries	Use renewable energy sources as far as possible, and promote public education programs
Develop energy sources in arid areas	Use renewable energy sources as alternatives to solid fuels, including biomass
Establish a relationship between climate and desert formation	Carry out remote sensing and modelling. Establish networks of information on how areas change into desert
Understand how the desert systems have the potential to control the atmospheric environment - locally and globally.	Develop integrated knowledge through scientific activities

Priorities

1. Afforestation using sustainable systems

2. Establish the relationship between climate and desert formation

3. Use renewable energy sources as far as possible

The Scientists' Role

1. Develop and apply new technologies based on scientific principles

2. Establish the methodology to assess environmental changes, gather data, develop an understanding of arid ecosystems, and construct scientific models. Establish networks for information exchange between scientists.

3. Propose clear solutions to the public and to policy makers. Promote the concept of global sustainability

4. Organise the Desert Technology V conference with 1000 participants from many countries.

Workshop 4: People

The group in Workshop 4 dealt with the thorny issue of how to influence land use controls and improve land management by farmers. It was not surprising that a dichotomy of views became evident, reflecting the different roles of 'science' in different countries, and differences in economic and educational circumstances. The group identified five methods to influence land use and considered the merits of each. From these the workshop developed seven priority goals to promote land management and sustainable production.

Influencing land use controls and improved land management

Land use regulation
Farmer persuasion
Extension through providing the education needs of the land user
Improving communication and access to knowledge of land use regulations (eg. increasing literacy)
Demonstrating the economic benefits of changed land use behaviour

Regulation

Land use regulations sensitive to the variability of seasons in arid areas are needed to indicate the standard of practices which are acceptable to government authorities, and to provide the framework for regulatory activity should this be needed. However, it was a majority view that, in most countries, a reliance on land use regulation as the major method to improve land use management indicated a failure on the part of extension agents to bring about change through persuasion and education. Often the land user is the victim of his or her circumstance, and in such situations regulation will not bring about willing and enduring changes in attitude towards land management or methods of land use.

The group felt that scientists should not be too involved in land use regulation

Persuasion

Ideally land use control should become an integral function and part of land management. This raises the question how does the land user become involved in a self 'owned' set of land management objectives and processes? There is a need to emphasise participation in finding and carrying out the solution to land use problems on the part of the land user in partnership with scientists. This sometimes also requires a change in attitude on the part of the scientists!

Extension and education

'Extension' is a term used to describe practical education for farmers, to give the farmers the 'technology tools' through broad access to scientific knowledge. In the area of farmer education commonly the subjects which are most needed are management training and problem solving.

Improving communication

Sometimes 'extension' messages and the communication of government objectives fail to achieve their aim because of the form of language in which they are delivered. Land users can have their own agendas and language. There can be cultural and background differences between scientists and farmers. Certainly the use of specialised 'scientific' language can be a barrier to comprehension by farmers. In 'extension' there is a need for understandable language which is less formal and scientific, and which promotes more inclusive communication and discussion.

Demonstrating benefits

Initiation of demonstrations is generally the responsibility of scientists and 'extension' officers who can bridge the gap between government objectives and farmer needs. An example could be the demonstration of new, high yielding varieties of crops to improve production and rural economies while at the same time incorporating improved land management techniques.

Goals

1. Develop models and pilot schemes to facilitate technology transfer.
2. Recognise specific circumstances of culture, economics and land use objectives, and design assistance and technology transfer accordingly.
3. Improve communications between farmers and scientists.
4. Farmers and scientists need to learn from each other.
5. Involve farmers and other land users in solving land condition problems.
6. Promote partnerships between farmers and scientists
7. Monitor the results of changing attitudes.

Acceptance

The products from the workshops were presented at the Conference Plenary Session, and were accepted by the delegates as a listing of worthwhile goals and challenges to be met by scientists involved in the sustainable use of arid areas around the world.

Edited by Adrian Williams and Brian Fergusson

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（1995年5月12日改訂，10月23日一部追加）

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小川　了（1987）：『サヘルに暮らす－西アフリカ・フルベ民族誌－』NHK ブックス540，日本放送出版協会．

田中　明・長　智男（1987）：土壌の保水性及び透水性と作物根への水分供給力．「九大農学芸誌」41-1/2：63-70．

GROVE, A. T. (1986 a): The scale factor in relation to the processes involved in "desertification" in Europe. *In* FANTECHI, R. and MARGARIS, N. S. eds.,

Desertification in Europe, D. Reidel, Dordrecht, 9–14.

GROVE. A. T. (1986 b): The state of Africa in the 1980s. *Geogr. J.*, 152: 193–203.

LEAN, J. and WARRILOW, D. A. (1989): Simulation of the regional climatic impact of Amazon deforestation. *Nature*, 342: 411–413.

ROGNON, P. (1994): *Biographie d'un Désert: Le Sahara*. L' Harmattan, Paris.

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