Ｇ－１　砂漠化防止対策の適用効果の評価手法の開発

（３）砂漠化防止及び再生技術の検索・評価

②日本における砂漠化防止及び再生技術の検索・評価

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［要旨］砂漠化は，乾燥地や半乾燥地における最も深刻な地球環境問題の一つであり，早急な対応が必要とされる。西オーストラリアは砂漠化の影響を受ける地域の一つであり，政府は多年にわたり砂漠化防止の研究と対策に多大な努力を払い，多くの成果を収めてきた。

最近，砂漠化防止のためのいくつかの新しい技術が日本で開発されている。砂漠化防止に関する研究者に会い，最先端の技術を調査し，西オーストラリアにおける現地実証試験の可能性と適応性を評価した。

［キーワード］砂漠化，脱塩水製造装置，保水剤，西オーストラリア

1. Introduction and objective

Desertification is one of the most serious global environmental problems, especially in the arid and semi-arid area, demanding urgent action. Western Australia is one of the affected region by desertification, it has destroyed the ecological systems and affects sustainable development, for these reasons, Western Australian government has made a lot of efforts for researching and combatting desertification for many years and achieved some success.

Recently, some new technologies for the areas suffered from desertification are developed in Japan, and it is expected that these technologies contribute to the prevention and remedies for desertification.

A collaboration is carrying on between Japan and Western Australia and I visited Japan with the following objects;

1) Introduce the recent research activities of desertification in Western Australia, discuss and exchange information with Japanese researchers.

2) Review the Japanese countermeasure technology for desertification such as seawater desalination equipment and water holding substance, and evaluate the possibility of application of these technologies in the Western Australia.

2. Result and discussion

Key activities and achievements during the course of my fellowship were:

1) Whilst in the laboratory of Prof. S. Matsumoto (Tokyo University) (Oct 23-Nov 11), I wrote a draft paper and note which will be submitted to International Science Journals. These are both related to aspects of desertification and its control (Abstracts attached at Appendix 1-(1)). In addition, I continued

work on a review paper on playas (salt lakes) which will be submitted to the Japanese Journal of Arid Land Studies. These papers derive from my Doctoral Studies with Prof. R. J. Gilkes (The University of Western Australia). In each paper I acknowledge the Japanese Environment Agency funding for my Fellowship.

I presented a seminar on my desertification research, and commenced Preparing an application for research funds to the Research Institute on Innovative Technology for the Earth (RITE), with Professor Matsumoto.

I attended the Desert Technology 3 Conference at Lake Motosu-ko (Fuji), where I presented an oral paper on my research on wind erosion (Abstract attached at Appendix l-(2)) and a poster structural decline in semi-arid soils (Abstract attached at Appendix l-(3)) (Oct 16-20). The paper wind erosion will be Published in the Japanese Journal of Arid Land Studies. I also had the opportunity to interact with many scientists who share similar research interests, and several Japanese scientists who propose to work in Western Australia. The next Desert Technology Conference will be held in Australia.

2) I visited the National Institute of Agro-Environmental Sciences (Oct. 26-27), with Mr. Tanigawa (Kubota Corp), inspected facilities and had meetings with Dr. Fukuhara and Mr. Taniyama in particular. I also presented an outline of my research into desertification to a small group. One of my specific research interests is in pedology/geomorphology, and Mr. Taniyama was exceptionally co-operative in providing information relevant to this area.

I visited Tsukuba University (Prof. Abe, and colleagues (Oct 14-15)). Here I accompanied an Australian Delegation led by Prof. L.A.G. Aylmore (The University of Western Australia) and Mr. R. Walster (Goldfields-Esperance Development Authority). Prof. Abe proposes to undertake research in Australia, and I met some of his team.

I met with various staff members of Kubota Corporation at various times and discussed proposed desertification research activities in Australia.

In above research institute, university and companies I inspected the latest researches and technologies for combatting desertification, and evaluated their possibility and adaptability for the experiment demonstrates in Western Australia, These promising technologies are summarized in Appendix 2.

3. Comments on EF Fellowship Program

Australian scientists undertake research in a variety of areas related to the environment and in particular sustainable development and the solution of various forms of desertification. Australia is in the unique position of having problems which commonly occur in the developing countries (i.e. erosion, salinization) but with a developed country infrastructure (i.e. research facilities, scientists). Hence the strong interest shown by Prof. Matsumoto's team in solving these environmental Problems provides substantial opportunities for future co-operative research, as Australia can provide a large number of problems which require solutions, scientific facilities and scientists from an array of backgrounds.

A possible suggestion for future EF Fellowships is thus to continue to develop these cooperative links, by both inviting Australian scientists to visit Japan, and Providing funding for Japanese scientists to work in Australian research institutes. Similarly, implementation of joint-research projects will offer many opportunities for the solution of the very real problems that desertification poses. From my own experience, it has only been through visiting Japan that I have been able to better appreciate the context of the research proposed by Prof. Matsumoto and this team.

I also used the Fellowship as an opportunity to further my understanding of the Japanese people and society. This was enhanced by the exceptional hospitality extended to me by many people, particularly as I do not speak Japanese.

I found that this was a very enlightening study and hence would like to thank the Environment Agency for the opportunity to participate in this program. In particular I would like to thank Prof. Matsumoto (Tokyo University), Mr. Kubota (Kubota Corp), Mrs. Watanabe (Tube Inc.) and Mr. Hori and staff at the Mitsubishi Research Institute for their diligent efforts in making my visit run very smoothly.

Appendix 1

(l) Aeolian influences on the soils and landforms in the Yilgarn Block of semi-arid, south-western Australia

R.J. Harper and R.J. Gilkes

Paper (6000 words) to be submitted to Geoderma

Keywords: Desertification, wind erosion, aeolian geomorphology, desert loess, soil survey, landscape evolution

A strong aeolian influence on the soils and geomorphology of a semi-arid environment (mean annual rainfall 350 mm), near Jerramungup, Western Australia is apparent. Within a landscape developed on deeply weathered, granitic rocks, several soils have formed on aeolian sediments. Arrays of clayey saltation deposits occur dunes (lunettes) extending for up to 5 km to the south-east of the playas, whereas quartzose sand dunes and sheets occur in a 2 km wide band which extends 10 km south-east of an ephemeral creek line. Parabolic blowout dunes occur within the lunettes. The orientation of these features, and the elliptical shape of the playas suggests that the geomorphologically most effective winds have been from the north-west. Moreover, the lunette arrays are chronosequences, and their consistent orientation suggests uniformity of winds over a long period. A more widespread, but subtle, aeolian influence on the soils is likely. Desert loess deposits are inferred to be coeval with the clayey saltation deposits; evidence includes a plume of calcareous and illitic soils south-east of the magor playa.

Similarly, deep sandy soils on many slopes with a south-easterly aspect may represent the interference of topography on the transport of saltating sands. Severe and recurrent, contemporary

wind erosion represents a hazard to sustainable land use.

(2) The incidence of wind erosion in relation to the properties of some sandy surfaced soils from south-western Australia

R.J. Harper and R.J. Gilkes

In Proceedings 'Desert Technology 3.'Lake Motosu-ko, Japan, October 16-20, 1995 and to be published in the Journal of Arid Land Studies
Keywords: wind erosion, soil management

The incidence of wind erosion, near Jerramungup, Western Australia, was related to an array of soil attributes, Wind erosion only occurred on sandy surfaced soils. with <5% clay and <2.5% silt. All soils with <1% clay were eroded, with the proportion of soils eroded in successive 1-2. 2-3, 3-4 and 4-5% clay classes being 63, 35, 12 and 14% respectively. Wind erosion increased in incidence with sandy surface horizon depth, 2% of soils with surface horizons <10 cm deep were eroded, and 80% of those>100cm deep. Wind erodibility is explained in terms of the strength of the soils (which is related to clay content), and mount of plant cover (related to soil management, chemical fertility and water storage).

(3) Parabolic blowouts in clayey lunettes: a new aeolian landform?

R.J. Harper. And R.J. Gilkes

Note (1800 words) to be submitted to Earth Surface Processes and Landforms
Keywords: clay dunes, aeolian geomorphology, lunettes, palaeoclimates

Clay dunes are aeolian saltation deposits that have been used to determine past environmental history, and provide insights into the outcome of contemporary desertification and future environmental change. Those derived from elliptical playas often have a crescentic shape and are termed lunettes. These features are common in south-western Australia, with lunettes occurring on the south-eastern shore of playas either as single dunes or multiple arrays.

Clay dunes are generally regarded as being immobile once deposited, and are hence used to indicate the location of former source shorelines. Some clay dunes, however, have been remobilised by the wind. Parabolic blow-outs occur in a multiple array of clayey lunettes near Jerramungup, Western Australia. These have paired arms -500 m long, which terminate in low lobate dunes. They are thus akin to the hair-pin, or blow-out, dunes described in sandy dune-fields. Their NW-SE orientation indicates formation by wind from a direction similar to that inferred from other aeolian features in this landscape, such as linear sand dunes and multiple lunette arrays and playa shapes. Not only are these features evidence of infrequent, high magnitude events, but they suggest that the use of clay dunes to determine the location of former shorelines should be undertaken with care.

Appendix 2

(1) FERTILIZERS CONTRIBUTING TO THE GREENING OF THE DESERT

OUTLINT OF THE TECHNOLOGY

The following are some of the problems associated with plant growth in desert soil.

1) Lack organic matter with the result that the soil has a lower buffering capacity.

2) High salinity of the soil arising from 1) directly leading to damage to plant life.

3) Phosphate deficiency arising from low phosphate availability.

4) Difficulty in managing crop nutrients (fertilization) due to the low buffering capacity of soil.

In view of the above, a new fertilizer was developed which introduces both organic matter and phosphates to the soil

The subject fertilizer is composed of two important ingredients, both of which are expected to have a significant effect in improving desert soil. One ingredient is humic acid, the main effective ingredient among soil organic substances having the capacity to absorb, sustain and exchange positive ions including plant nutrients as well as buffering acids and alkalis. The other is fused phosphate fertilizer, which does not dissolve by itself and carries no risk of raising the salt concentration in the soil solution.

PROSPECTS FOR THE FUTURE

The product is already being utilized and is expected to become one of the key materials to assist in the greening of the desert due to the fertilization and soil improvement qualities which make it ideal for desert soil.

(2) APPLICAT1ON OF VA MYCORHTZAL FUNGI TO DESERT AGRICULTURE

OUTLINE OF TECHNOLOGY

VA (vesicular-arbuscular) mycorhizal fungi are symbiotic microorganisms which enter the plant roots and live together with the host plant.

Once VA mycorhizal fungi invade plant roots, they provide an adequate level of phosphates and micronutrients to the plant and can activate the roots. The plant acquires resistance to environmental stresses and it is probable that growth will be accelerated in cultivated land and even in such environmentally stressed situations as desert soil

PRSPECTS FOR THE FUTURE

First of all, it is thought that VA mycorhizal fungi will improve the quality and increase the yield of crops. In view of increasing environmental stresses in agriculture, I think that VA mycorhizal fungi will become established as a means of ensuring excellent quality and yield increases through the raising of sound seedlings and promoting the healthy growth of plants. Because the technology, from the outset, was aimed at a type of resource conserving agriculture and to protect the environment, significant benefits are expected in countries having economic problems or in those seeking to Prevent environmental pollution, especially those countries having desert soils.

(3) APPLICATION OF A COMPOSITE (WATER HOLDING SUBSTANCE) FOR GREENING IN THE DESERT

OUTLINE OF THE TECHNOLOGY

This technology is composed of plant designs and methods for producing a water holding substance (the "composite") by mixing super absorbent polymer with base materials and to manufacture and use it for water-saving cultivation in arid areas.

PROSPECTS FOR THE FUTURE

The water saving effect of the Composite was 58.8% on average (weighted mean of 66% for leaf vegetables and 43% for fruit vegetables) at a model farm in Egypt. However, it will be difficult to use the Composite until the price of irrigation water can cover the composite price because the main material, SAP, is expensive.

The marketability of the composite is limited to regions where water conservation is vital, when planning the enlargement of farming areas or in regions where the costs of irrigation water is high. There is room for active use of the Composite, for example, by incorporating it from the planning stage of water resources development or other projects in desert areas where such resources are scarce.

(4) SEAWATER DESALINATION BY SOLAR HEAT

OUTLINE OF THE TECHNOLOGY

It is developed that closed system seawater desalination equipment using polyethylene film which is highly resistant to ultraviolet rays. Surfactants insoluble in water are painted inside the polyethylene film on which the seawater vapor adheres. This greatly promotes desalination efficiency by limiting condensation and the dripping of water which often occurs inside the film.

PROSPECTS FOR THE FUTURE

The near-term objective is 10 liter/day m^2, which would allow the practical application of seawater desalination equipment using solar heat. Although there seems to be no problem in finding installation sites in arid areas, there are certain limiting factors with respect to location taking into consideration installation, maintenance and management. How to raise the fresh water recovery efficiency is main objective as long as this method is to be utilized. The efficiency can be raised by using it in conjunction with a solar thermal water heater. Water can also be recovered from the highly humid dead air at night by laying ceramic pipes around the evaporation plates. These pipes have been conventionally used in negative pressure differential irrigation. In these ways, the desalination of seawater processed with solar heat can be maximized.

(5) CULTIVATION OF VEGETABLES AND DESALINATION ON A SMALL SCALE USING SEAWATER OR BRACKISH WATER

OUTLINE OF THE TECHNOLOGY

It was developed and established fresh vegetable cultivation technology in a greenhouse in the desert using saline water. With this technology, condensed water is produced through heating seawater or other water which cannot be used for irrigation, bringing it below the sand culture bed and condensing the vapor evaporated from it with cooling water pipes buried at the bottom of the sand culture bed or the surrounding soil. The condensed water infiltrates the soil very quickly via capillary action providing the planted crops (vegetables) with welter. Thus an Advanced Sand Culture System (SCS) has been developed. At the same time, greenhouse cultivation management technology has been developed to control the temperature inside the greenhouse which is subject to high daytime temperatures and intense insolation under desert conditions.

PROSPECTS FOR THE FUTURE

I think that a basic part of vegetable cultivation technology for a desert greenhouse can be actualized using this system. We hope that the technology will be developed further to allow the close control of the water supply and fertilization management to achieve better quality and higher yields.

(6) RESEARCH INTOTHE POSSIBILTY OF USING PHOTOVOLTAIC POWER GENERATION TECHNOLOGY FOR DEVELOPMENT IN THE DESERT

OUTLINT OF THE TECHNOLOGY

The utilization of solar batteries in arid areas solves such traditional problems peculiar to solar batteries as limited output arising from low levels of insolation and the need for large areas due to sparse energy. 1f we are to consider utilizing

solar batteries as power sources for pumping systems, desalination equipment or compressors the storage function could be substituted for by employing a water tank or otherwise. Photovoltaic power generation in the desert has many great advantages such as no necessity for fuels, ease in maintenance and management, constant power generation efficiency independent of the size of the system, modularizing capability by which power generation capacity may be added anytime and no necessity for long distance power transmission due to the feasibility of installing power stations close to consumption areas.

PROSPECTS FOR THE FUTURE

There is an estimate that "if we try to supply worldwide energy demands by photovoltaic power generation, an area representing 4 % of the deserts throughout the world would suffice." The desert is an ideal place for utilizing photovoltaic power generation because of the high insolation level and low rainfall. What we envisage towards the future are hybrid systems combining photovoltaic power generation and solar thermal electric power generation by using the high insolation as well as solar battery production bases utilizing the self-multiplying ability of solar batteries.

(7) COMPOSTING TECHNOLOGY TO PRODUCE A SOIL AMENDMENT

OUTLINE OF THE TECHNOLOGY

Desert soil is greatly deficient in organic matter and therefore not satisfactory in terms of soil physics, water holding capacity, and biochemical reactions with soil organisms, which are basic conditions for plants to grow. However, it contains abundant inorganic elements necessary for plants. This technology is intended to utilize effectively, as the energy, the digester gas (methane gas) produced in the course of the treatment of high-concentration waste water or organic wastes while utilizing the digested wastes and sludge as fertilizer for greening the desert. The effluent from this system can be reused for irrigation after the advanced waste water treatment.

PROSPECTS FOR FUTURE

Needless to say, organic wastes are useful resources by themselves. Lots of attempts have been made to find out how such resources can be converted into a readily utilizable form and what is the most feasible method for such a transformation using the least amount of energy. These problems could be overcome at a stroke if this system can offer fertilizer and irrigation water as the final value-added products for use in deserts, areas that have a high development priority.

(8) DEVELOPMENT OF A NEW AGRICULTURAL SYSTEM FOR ARID LAND USING NEGATIVE PRESSURE DIFFERENTIAL IRRIGATION

OUILINE OF THE TECHNOLOGY

The principle of negative pressure differential irrigation had already been introduced in 1934. However, it was a long time before the principle could be applied because the porous ceramics, key to this process, had not reached a sufficient performance standard. The recent development of technology to manufacture the ceramics inexpensively and apply them to irrigation has allowed the regulation of a high efficiency water- and resource-saving cultivation method.

PROSPTECS FOR THE FUTURE

Development of desert agriculture must be based on thoroughly effective utilization of irrigation water. Though only now being put into practice, this irrigation method is considered to have considerable promise since the development of the key ceramics tubes and is expected to demonstrate its effectiveness in the field.

(9) SOLAR THERMAL DESALINATION TECHNOLOGY IN JAPAN

OUTLINE OF THE TECHNOLOGY

Technology using solar energy for the desalination of brine is introduced here. The most significant technical requirement in this case is that the solar energy supply is sufficient in terms of heat to meet the energy requirements of the desalination system. Two promising technologies developed in

Japan are introduced. They are (1) a type using solar energy directly and (2) types using solar energy indirectly. Types (2) include solar thermal electrodialysis in which a solar collector is used to evaporate and condensate seawater in a thin firm state, electrodialysis with photovoltaic cells, reverse osmosis with photovoltaic cells, and distillation with a porous membrane while using both photovoltaic cells and a solar collector.

PROSPECTS FOR THE FUTURE

When assuming that the desalination cost is determined from the (energy + system maintenance costs)/desalination amount, accommodation of the solar energy for energy supply is highly significant. In addition, it is expected that technical development should be made in terms of system maintenance so as to achieve further savings of labor and cost.

(10) UNDERGROUND DAM CONSTRUCTTON TECHNOLOGY

OUTLINE OF THE TECHNOLOGY

The underground dam is a new water resource development technology. A waterproof wall is constructed below the ground to control the groundwater flow, storing it in the water retaining layer and thereby securing the amount of water needed to meet requirements throughout the year.

PROSPECT FOR THE FUTURE

Underground dams currently constructed in Japan use an alluvial gravel bed and porous limestone originating from coral reefs as the aquifer. The aquifer concerned is mostly in the form of ordinary rivers or special buried fault valleys (underground valley). With the geological and hydrological conditions in Japan there are still technical subjects to be solved, but it may be said that underground dam construction technology is being established.

In arid districts on the other hand, the hydraulic characteristics of the tropical weathered soil, hydraulic and geological characteristics of fossil valleys, handling of the large amount of evapotranspiration in terms of water balance, and water quality are not known well. What is required in the future for the establishment of the underground dam construction technology is the accumulation of hydraulic and hydrogeological data as well as construction data.