日本沙漠学会誌 ISSN 0917-6985

VOL.10 S March 2000

沙漠研究

JOURNAL OF ARID LAND STUDIES

目　　次

特集号：第５回国際沙漠技術会議論文集

DESERT TECHNOLOGY V

1999年10月3-8日、リノ、米国

日本沙漠学会

Proceedings of the International Conference on **DESERT TECHNOLOGY V**

October 3 - 8, 1999, Reno Hilton Hotel, Reno, Nevada 89595, USA

Contents

Session IV

Session V

DESERT TECHNOLOGY V

DESERTS IN CHANGING TIMES

RENO, NEVADA, USA
James A. Young Chair

Lack of financial support reduced the number of delegates attending the conference, but those that were in attendance enjoyed excellent scientific paper presentations, discussions, and field trips to the deserts of the Great Basin. The Great Basin is a temperate desert environment where most precipitation occurs during the winter months as snow. During an all day field trip to the Black Rock Desert, the symposium participants experienced a very unusual cold rain storm which limited visibility and left the vast playa surface glistening with moisture. We had the opportunity to tour an industrial farming complex that produces its own energy requirements from geothermal wells. We toured onion and garlic dehydration facilities than left most participants with burning eyes. Other tours features state of the art water treatment facilities and the scientific laboratories of the Desert Research Institute.

A manuscripts were reviewed by at least two anonymous peer reviewers.

沙漠研究 10S, 3-4 (2000)
Journal of Arid Land Studies

−Special Issue− "Desert Technology V"
Refereed Paper

Plant Geography and Physiography of Great Basin Deserts

Paul T. Tueller*

Abstract - The Great Basin of the United States is a semi-arid to arid region from which there is no drainage to the ocean. It is not one continuous basin, but consist of some 180 mountain ranges with interspersed basins. Precipitation largely occurs in the winter as snow. During the Pleistocene the basins were largely filled pluvial lakes. The near total evaporation of these has left vast areas of salt influenced soils.

Key Words: climate, physiography, soils, vegetation.

1. Introduction

I will describe the general floristic and synecology of the area along with insight as to relations between the natural vegetation and landforms, soils, and climate.

2. Climate

The Great Basin generally supports a temperate or cold desert environment. Moisture comes to the basin from either the Pacific Ocean or the Gulf of Mexico. The Pacific Ocean is by far the most important and provides virtual all of the moisture from October to June. The Gulf of Mexico acts as a source of summer precipitation. As you proceed from south to north, the summer precipitation decreases in amount and frequency. The Sierra Nevada and Cascade Mountain ranges cast a rain shadow across the Great Basin.

3. Physiography

The Great Basin is part of the Basin and Range physiographic province. Isolated mountain ranges rise abruptly from broad, alluvium-filled basins. Nearly all these mountain ranges trend north to south. Elevations range from a few hundred meters along the Colorado River in the south to over 4000 meters. Moderate to extremely steep slopes are common on the mountain ranges, leading to a highly dissected topography representing a wide variety of environments.

4. Soils

The concept of soil-vegetation relations, considered in the context of the synecology of the Great Basin landscapes is the basis for natural resource management. The soils of the Great Basin are derived from a variety of parent materials. Soils of the lake plains in the basin bottoms are characterized by deep

* Department of Environmental and Resource Sciences, University Nevada, Reno, NV 89507, USA.

water, fine textured sediments and high levels of salts left by evaporation. These soils support salt desert plant communities. In the foothills of the mountains the soils have well developed profiles and often a meter or more in depth. On the higher mountains the surface soils are mollisols.

5. Vegetation

5.1 Artemisia Woody species of *Artemisia* are the landscape characterizing plants of much of the Great Basin. Exceptions are the lower elevation sites where the combination of salt influenced soils and atmospheric drought inhibit the growth of most *Artemisia* species. The lower elevation or salt desert sites are dominated by various species of chenopod shrubs. Because of the extremes in elevation and the highly dissected topography, almost every aspect has a different assemblage of plants. These represent homogeneous groupings of flora which constitute discrete plant communities.

5.2 Perennial Grasses Before domestic livestock were introduced, late in the 19th century, the interspaces among shrubs supported stands of perennial bunch grasses. The dominant shrubs are not browsed by domestic and increase under heavy grasses. The native perennial grasses are very susceptible to damage from heavy grazing, especially grazing in the early spring with no chance to restore carbohydrate reserves. The net result of the introduction of large numbers of domestic large herbivores was the virtual loss of native perennial grasses and an increase in shrub density.

5.3 Bromus tectorum The annual grass *Bromus tectorum* was accidentally introduced to the Great Basin early in the 20th century. In spread in the ecological void left by the destruction of the native perennial grasses. It produces abundant, early maturing herbage that greatly increases the chance of ignition and the rate of spread of wildfires. Such fires destroy the dominant species of *Artemisia* converting the sites to annual grasslands.

5.4 Woodlands Much of the Great Basin is treeless. The exception is *Pinus monophylla/Juniperus osteosperma* woodlands that occur in bands around the higher mountain ranges. These dwarf conifers spread into the western Great Basin during the Holocene.

6. Land Use

The principle use of the Great Basin has been as range and habitat for livestock and wildlife. Most of the land (87%) is owned by the American Federal government. Only about 5% of the landscape is devoted to irrigated, intensive agriculture.

沙漠研究 10S, 5-8 (2000)
Journal of Arid Land Studies

—Special Issue— "Desert Technology V"
Refereed Paper

Influences of Holocene Climate and Vegetation Changes on Present and Future Community Dynamics

Robin J. TAUSCH* and Cheryl L. NOWAK**

Abstract - Plant community and ecosystem function, particularly in deserts and semi-deserts, is strongly dependent on their history of development over the last 4,000 years of the Holocene.

Key Words: Holocene, Vegetation, Community, Great Basin, Woodlands.

1. Introduction

Managing desert and semi-desert ecosystems requires understanding how they function. This requires knowledge of the history of their development over most of the last half of the Holocene, or at least the last 4,000 years. Four thousand years can be a single lifetime for a bristlecone pine, or only six to ten lifetimes for pinyon and juniper, common dominants in the Great Basin. Also important is knowledge of the influences and patterns of both natural and anthropogenic disturbance and their changes through time. The vegetation history of the Great Basin provides an example to illustrate the importance of these patterns. The Great Basin, an area of about 370,000 square kilometers with internal drainage, is found primarily in Nevada and western Utah. This area contains high north-south trending mountains that are commonly over 2,000 m, and can reach 3,000 m, above the adjacent valleys.

The majority of the plant species found in the Great Basin today were present during the late Pleistocene. Throughout the Holocene, these species have occurred at different elevations and abundances, and in different community associations that are all dissimilar, and unlike those in which they were found during the late Pleistocene (Nowak et al., 1994a,b). A limited number of plant species were not found in the Great Basin during the Pleistocene. They migrated in during the Holocene and often brought substantial changes to the communities into which they became established.

To illustrate how relationships between vegetation and climate have changed over time we have divided the last half of the Holocene into time periods of similar environmental conditions (Tausch, 1999a). These divisions are based primarily on paleo-vegetation information from pollen cores and woodrat middens provided by Wigand et al. (1995), as well as supplemental information from geomorphological changes (Chambers et al., 1998), and from woodrat midden macro-fossils (Nowak et al., 1994a,b; Chambers et al., 1998). Many of these changes continue to have significant effects on the dynamics of modern communities.

2. Holocene Climate and Vegetation History

2.1 Mid Holocene (8,000 to 5,500 years BP) This was the warmest part of the Holocene and many species were found 300 to 500 meters higher in elevation than where they occur today, and as much as 1,500 meters higher than where they were found at the beginning of the Holocene. The northward migration of species that were new but influential into the Great Basin, such as pinyon, occurred throughout this period (Nowak et al., 1994a,b; Wigand et al., 1995). Lake Tahoe, on the Nevada/California border, was 10 to 15 m below its geologic rim (Lindstrom, 1990). Trees and grasses preferring more mesic conditions declined in abundance and desert species increased in abundance, driving considerable changes in plant community

2.2 The Neoglacial (4,500 to 2,500 years BP) This period was cooler and wetter (Wigand, 1987; Woolfenden, 1996), resembling the early Holocene. Pinyon and juniper reached their current range in the Great Basin and their abundances potentially reached levels equal to what are present today, particularly at mid to low elevations (Wigand et al., 1995). Pinyon abundance also increased relative to that of juniper (Thompson and Kautz, 1983). Increases in herbaceous vegetation are also evident (Chambers et al., 1998; Tausch and Nowak, unpublished data). Parts of the Great Salt Lake Desert apparently flooded in the latter part of this period (Thompson and Kautz, 1983) and Mono Lake reached its highest level since the early Holocene (Stine, 1990).

2.3 Post Neoglacial Drought (2,500 to 1,300 years BP) In the Great Basin a significant drop in precipitation followed the Neoglacial (Chambers et al., 1998). The abundance of herbaceous vegetation strongly decreased, as did all woodlands, particularly those dominated by pinyon (Thompson and Kautz, 1983; Chambers et al., 1998). Desert shrub vegetation dominated by chenopods and greasewood increased (Wigand et al., 1995). Major geomorphic changes occurred in many mountain drainages in both the Great Basin and the eastern Columbia River Basin (Chambers et al., 1998) with the agradation or buildup of floodplains coinciding with rapid alluvial fan development. The resulting geomorphic structures are still present and continue to have a major influence on the distribution of plant communities, particularly those along riparian corridors (Chambers et al. 1998).

2.4 Medieval Warm Period (1,300 to 800 years BP) Temperatures warmed and some increase in precipitation occurred. This was accompanied by a seasonal shift in which late spring and early summer precipitation levels possibly equaled those for winter, again resulting in major vegetation changes (Nowak et al., 1994a,b; Woolfenden, 1996). Snow pack and stream levels were lower than in the Neoglacial period (Wigand et al., 1995; Woolfenden, 1996). Grass increased in abundance (Wigand and Nowak, 1992), and the presence of buffalo increased in northern and eastern areas of the basin (Butler, 1978). Both pinyon and juniper began to increase following the low levels of abundance reached by the end of the previous drought (Wigand et al 1995). A transition to the Little Ice Age followed.

2.5 Little Ice Age (550 to 150 years BP) This cooler, wetter period was similar to the Neoglacial and had possibly the largest glacial advances of the Holocene (Woolfenden, 1996). Upper tree lines in the Sierra Nevada were the lowest of the last 7,000 years (Stine, 1996). Pinyon and juniper continued their increase in abundance (Nowak et al., 1994a,b; Wigand et al., 1995). Plant communities changed in both composition and location compared to the Medieval Warm Period (Woolfenden, 1996). The plant communities that developed during the Little Ice Age are what was present when the first European explorers passed through the Great Basin region.

Despite a similarity in their range, dominance patterns of pinyon and juniper differed considerably compared to today. Evidence for this includes relict woodlands, tree age-class ratios, fire scars, and historic documents (Gruell, 1999) These indicate that the woodlands were more open with the trees often found in savannas or confined to fire protected sites (Wigand et al., 1995; Miller and Wigand, 1994). These differences resulted from a higher fire frequency (Swetnam and Betancourt, 1998; Gruell, 1999). Communities with a matrix of non tree-dominated regions containing pockets of woodlands and individual pinyon or juniper scattered through them were common. The higher fires frequencies, however, were not uniform across the landscape, but strongly controlled by topography, soils, and available moisture. For many areas, often dominated by old-growth woodlands, the fire return intervals were separated by centuries even though adjacent areas would burn several times a century.

2.6 Recent (the last 150+ years) Many important environmental changes have occurred during the last 150 years. These included: a climate change with rising temperatures (Woolfenden, 1996); the cessation of hunting, gathering and burning by indigenous peoples (Creque, 1996); the period of heaviest livestock use with its effects on plant communities including the reductions of herbaceous vegetation that contributed to the much reduced fire frequency now present in the region (Swetnam and Betancourt, 1999); increasing CO_2 levels that are both changing plant competitive interactions (Farquhar, 1997) and favoring the dominance of woody perennials (Polley et al., 1996); increasing nitrogen levels from input do to air pollution (Fenn et al., 1998); and finally, the continued introduction of exotic species that are substantially changing many communities. In combination, these many factors have contributed to the rapid ongoing vegetation changes. Woodlands of the Great Basin, for example, now cover over three times the area within their range than they did in the Little Ice Age. Within these woodlands the trees have also increased in dominance as fire became less common to where they now equal or exceed their abundance levels during the Neoglacial (Miller and Wigand 1994). These changes are greatly increasing the risk of crown fires replacing entire stands over large areas (Tausch, 1999b).

3. Conclusions

Many of the changes occurring since the end of the Little Ice Age are creating vegetation thresholds that, when crossed, result in additional dramatic irreversible vegetation change (Tausch, 1999b). Introduced exotic annuals, for example, can create a threshold where the community that follows disturbance by fire changes from one dominated by perennials, to one dominated by annuals. Many desert and semi-desert communities are now burning where they did not do so in the past. How and where changes are occurring, the rates at which they are occurring, and where they will occur in the future is largely determined by how and where major changes occurred in the past, and by the community composition that followed those changes. The type, pattern, and frequency of past disturbance has a strong influence on the type, pattern and frequency of disturbances that are now occurring, and that will occur in the future, particularly for the outcomes of anthropogenic disturbances.

4. Literature Cited

Butler, R.R. 1978. Bison hunting in the Desert West before 1800: the paleoecological potential and the archaeological reality. Plains Anthropologist. 23:106-112.

Chambers, J.C., K. Farleigh, R.J. Tausch, J.R. Miller, D.Germanoski, D.Martin, and C. Nowak. 1998. Understanding long- and short-term changes in vegetation and geomorphic processes: The key to riparian restoration. In: D. Potts (ed.) Procedings of AWRA specialty conference, *Rangeland Management and Water Resources.* American Water Resources Association, Herndon, Virginia, TPS-98-1.

Creque, J.A. 1996. An ecological history of Tintic Valley (Juab County) Utah. Logan, UT: Utah State Univ., Ph.D. Dissertation.

Farquhar, G.D. 1997. Carbon dioxide and vegetation. Science. 278:1411.

Fenn, M.E., M.A. Poth, J.D. Aber, J.S. Baron, B.T. Bormann, D.W. Johnson, A.D. Lemly, S.G. McNulty, D.F. Ryan, and R. Stottlemyer. 1998. Nitrogen excess in North American ecosystems: Predisposing factors, ecosystem responses, and management strategies. Ecological Applications 8:706-733.

Gruell, G.E. 1999. Historical and modern roles of fire in pinyon-juniper. in press In: Monsen, S.B., R. Stevens, R.J. Tausch, R. Miller and S. Goodrich comps. Proceedings: ecology and management of pinyon-juniper communities within the interior west. USDA Forest Service, Rocky Mountain Research Station, Provo, UT.

Lindstrom, S. 1990. Submerged tree stumps as indicators of mid-Holocene aridity in the Lake Tahoe Basin. Journal of Calif. and Great Basin anthropology. 12:146-175.

Miller, R.F., and P.E. Wigand. 1994. Holocene changes in semiarid pinyon-juniper woodlands. Bioscience 44:465-474.

Nowak, C.L., R.S. Nowak, R.J. Tausch, and P.E. Wigand. 1994a. Tree and shrub dynamics in northwestern Great Basin woodland and shrub steppe during the late-Pleistocene and Holocene. Amer. J. Bot. 81:265-277.

Nowak, C.L., R.S. Nowak, R.J. Tausch, and P.E. Wigand. 1994b. A 30,000 year record of vegetation dynamics at a semi-arid locale in the Great Basin. J Vegetation Sci. 5:579-590.

Polley, H.W., H.B. Johnson, H.S. Mayeux, C.R. Tischler. 1996. Impacts of rising CO_2 concentration on water use eficiency of woody grassland invaders. In: Barrow, J.R., E.D. McArthur, R.E. Sosebee, R.J. Tausch, comps. Proceedings: shrubland ecosystem dynamics ina changing environment. U.S. Department of Agriculture, Forest Service, Intermountain Research Station INT-GTR-338: 189-194.

Stine, S. 1996. Climate, 1650-1850. In: Sierra Nevada ecosystem project: final report to congress, Vol. II, Chap 2. Davis, CA: University of California, Centers for Water and Wildland Resources: 25-30.

Swetnam, T.W. and J.L. Betancourt. 1998. Mesoscale disturbance and ecological response to decadal climatic variability in the American southwest. J. of Climate 11:3128-3147.

Tausch, R.J. 1999a. Historic pinyon and juniper woodland development. in press In: Monsen, S.B., R. Stevens, R.J. Tausch, R. Miller and S. Goodrich comps. Proceedings: ecology and management of pinyon-juniper communities within the interior west. USDA Forest Service, Rocky Mountain Research Station, Provo, UT.

Tausch, R.J. 1999b. Transitions and thresholds: Influences and implications for management in pinyon and juniper woodlands. in press In: Monsen, S.B., R. Stevens, R.J. Tausch, R. Miller and S. Goodrich comps. Proceedings: ecology and management of pinyon-juniper communities within the interior west. USDA Forest Service, Rocky Mountain Research Station, Provo, UT.

Thompson, R.S., R.R. Kautz. 1983. Chapter 7. Paleobotany of Gatecliff Shelter: Pollen analysis. In: Thomas, D.H. Ed. The archaiology of Monitor Valley: 2. Gatecliff Shelter. Anthropological Papers of the American Museum of natural History. Vol. 59:136-157.

Wigand, P.E. 1987. Diamond Pond, Harney County, Oregon: vegetation history and water table in the eastern Oregon desert. Great Basin Naturalist, 47:427-458.

Wigand, P.E., and C.L. Nowak. 1992. Dynamics of northwest Nevada communities during the last 30,000 years. In: Hall, C.A., V. Doyle-Jones, B. Widawski, eds. The history of water: eastern Sierra Nevada, Owens Valley, White-Inyo Mountains. White Mountain Research Station Symposium Volume 4:40-62.

Wigand, P.E., M.L. Hemphill, S. Sharp, S. Patra. 1995. Great Basin semi-arid woodland dynamics during the late Quaternary. In: Waugh, W.J. ed. Proceedings: Climate change in the four corners and adjacent regions: implications for environmental restoration and land-use planning: Mesa State College, Grand Junction CO: U.S. Depart of Energy: 51-70.

Woolfenden, W.B. 1996. Quaternary vegetation history. In: Sierra Nevada ecosystem project: final report to congress, Vol II, Chap 5. Davis, CA: Univ. of Calif., Centers for Water and Wildland Resources: 47-70.

沙漠研究 10S, 9-12 (2000)
Journal of Arid Land Studies

—Special Issue— "Desert Technology V"
Refereed Paper

Recent Climatic Change and Micro-climatic Alleviation by Windbreaks in Arid Land of Northwestern China

Taichi MAKI* and Mingyuan DU**

Abstract – The climatic differences of desert and oasis are explained in this paper. The meteorological improvement by windbreaks was recognized at Turpan in arid land of China. The climatic changes at oases and deserts in China were recognized in recent years. The degradation area by desertification is increasing in China. At some part around the Taklimakan Desert, precipitation is increasing and air temperature is decreasing in these 40 years due to the increase of development for agricultural field. However, it is not a wide area and just near the oases that is based on the meteorological observatory located in those area.

Key Words: Climatic change, Climatic improvement, Desert, Oasis, Windbreak

1. Introduction

The cultivation area of northern China has increased recently. On the other hand, desertification is also increasing. Although the cultivation area has increased 3.4 times, the population has increased 3.7 times from 1949 to 1990 in Xinjiang, China. The increase of arable land is significantly smaller than that of population in these 10 years. The reasons are the increase of desertification, increase of land used for another object, decrease of suitable land for agriculture.

The author investigated in this paper impact of climatic change on the air temperature and precipitation. Differences of cultivated area, oasis and desert area, desert, and microclimatic improvement by usage of windbreaks in arid land were also studied.

2. Observations and Analyses

2.1 Meteorological observation of windbreak Windbreaks are made of four rows of trees and the average heights are 8.0 m. The first windbreak is *Ulmus pumila* L. and *Elaeagnus angustifolia* L. with a density of 70 %, with 60 % upper, 80 % middle and 70 % lower densities. The second is both trees of mentioned above, and *Populus euphratica* Oliv. and *Lycium barbarum* L. for 70 % densities with 60, 70 and 80 %, respectively. The third and fourth are both trees for 70 % densities with 60, 70 and 80 %, respectively.

2.2 Meteorological observations at desert and oasis The observation of climatic elements of air temperature and relative humidity were carried out by the mobile observation from a car at Turpan, Xinjiang on September 2 to 4, 1997. The air temperature and humidity were observed at the height of 1.6 m above the ground surface.

2.3 Meteorological data analysis The meteorological data of monthly air temperature and precipitation are from Kashi, Hotan, Qiemo, Ruoqiang and Kuqa in western Xinjiang, Turpan, Hami and Dunhuang in eastern Xinjiang and Guansu, and

*, ** Division of Agrometeorology, National Institute of Agro-Environmental Sciences, 3-1-1, Kannondai, Tsukuba, Ibaraki 305-8604, Japan (+81-298-38-8204)
* Present Address: College of Agriculture, Ehime University, 3-5-7, Tarumi, Matsuyama, Ehime 790-8566, Japan (+81-89-946-9895)

Altay, Tacheng, Yining, Usu and Urumqi with 1951 to 1993 (Fig. 1). Meteorological data in western China is from 12 points in Xinjiang except Dunhuang and eastern China is 6 points in Inner Mongolia (Du *et al.*, 1996, 1998).

3. Climatic Improvement by Forest Windbreaks

3.1 Observation result at 12:00 June 16 (Fig. 2A) The wind speed decreased to 39 % by the first windbreak, and 33 % by the second, and recovered to 82 % and 63 %, respectively. An accumulation of decreasing wind speed is recognized. The soil surface temperature decreased inside the windbreaks by shade, but increased a little in windward side near the windbreak and increased more at 2 to 5 H (the numerals are indicated the multiple distances of windbreak height from the windbreak, positive is leeward side and negative windward side) in leeward side by the decrease of heat transfer based on decrease of wind speed (Maki *et al.*, 1995).

The difference of soil surface temperature was 20℃ at 0 H and 5 H. The air temperature increased a little in the leeward side by the 1st and 2nd windbreaks. If the wind speed is low, the air temperature increased in leeward side. It is not good for crops particularly at daytime in summer.

The relative humidity was increased 2 % by 1st windbreak and increased additional 1 % by the 2nd windbreak based on the evaporation from the soil surface and transpiration from the windbreak tree and *Gssyium spp.* or cotton plant leaves. This is also found that the accumulation of relative humidity increased by the 1st to 2nd windbreaks. The absolute humidity is higher than relative humidity at 2 to 15 H.

3.2 Observation result at 15:00 June 16 (Fig. 2B) The changes of meteorological elements at 15:00 is a little smaller than that at 12:00, June 16. The decreasing of wind speed was accumulated from 1st to 2nd windbreaks. Soil surface temperature is a little high in front of windbreaks, and was higher from 5 to 15 H in the leeward of the 1st windbreak, but is lower in the leeward of the 2nd. The relative humidity increased 1 to 2 % from 1st to 2nd with the accumulation of humidity. Absolute humidity also increased from 1st to 2nd, however, it is decreased at 15 to 25 H in the leeward side of 2nd windbreak at 12:00 and 15:00 because of lack of cotton plants. It was good for the cotton plants that air temperature in the leeward side of 2nd decreased because of decrease of soil surface temperature and increase of humidity (Maki *et al.*, 1995).

The windbreaks at Turpan are suitable for poplar, elm, and tamarisk. Tamarisk is best particularly adapted for very severe environmental condition. However, poplar is best under the irrigation, because it grows fast and very tall, and it is useful for timber.

4. Climatic Differences from Desert to Oasis

The difference of air temperature from desert to oasis was 4 to 5℃ by windbreaks and for relative humidity 10 to 17 % based on the windbreaks at Turpan on September 2 and 4, 1997 (Fig. 3). There are significantly different (Kurose *et al.*, 1998). Another additional data also showed that the differences of air temperature and relative humidity are 3℃ and 6 %, respectively on September 2 (Kurose *et al.*, 1998).

5. Relation among the meteorological data, climatic change and development of desert

The annual mean air temperature and annual precipitation has increased at Taklimakan of western Xinjiang. Air temperature increased in January and decreased in July, and precipitation increased on July and does not change on January (Du *et al.*, 1993).

The results are similar in the eastern Xinjiang. However, in western Xinjiang the air temperature in winter increased, but does not change in summer, and precipitation does not change in summer. At western Xinjiang, annual air temperature increased 3.0℃ at the range of 2.0 to 9.0℃ and decreased 1.0℃ in summer and precipitation increased

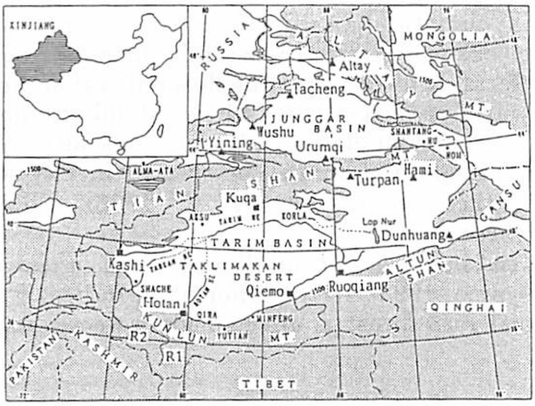


Fig. 1. Map of meteorological observatory in Xinjiang, China.

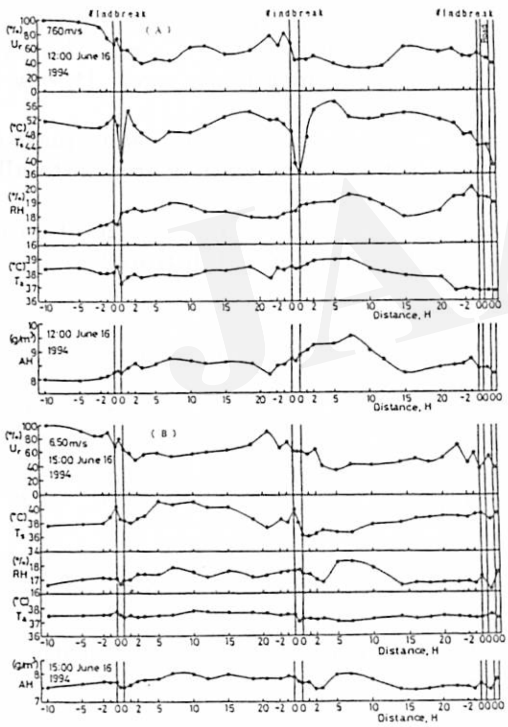


Fig. 2. Horizontal variations of five meteorological elements caused by four row windbreaks made of four mixed trees at Turpan (Maki *et al.*, 1995).

(A) 12:00 June 16 and (B) 15:00 June 16, 1994. Ur; relative wind speed (%), Ts; soil surface temperature (℃), RH; relative humidity (%), Ta; air temperature (℃) and AH; absolute humidity (g/m^3).

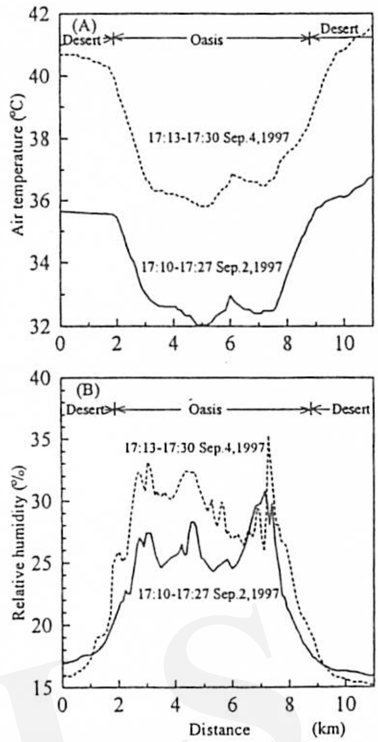


Fig. 3. Horizontal variations of (A) air temperature and (B) relative humidity at the desert and oasis of Turpan (Kurose *et al.*, 1998).

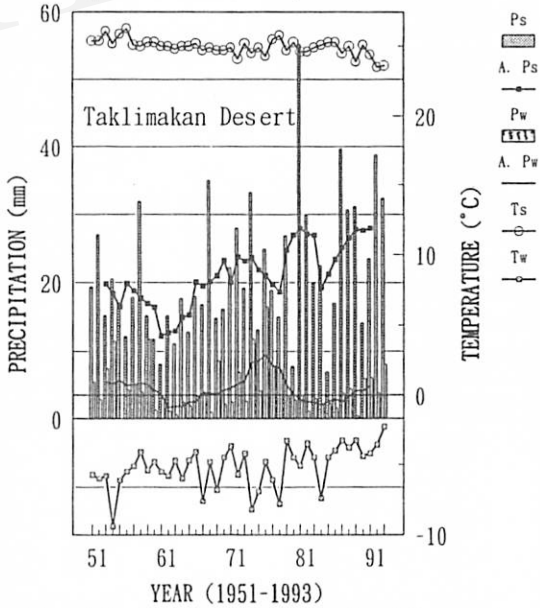


Fig. 4. Variations of precipitation (P) and air temperature (T) for summer (s; mean or sum of June, July and Aug.) and winter (w; mean or sum of Dec., Jan. and Feb.) in the western part of China. Notation (A.) is five year running average (Du *et al.*, 1996, 1998).

50 % in summer, even though large differences of 5 % at Ruoqiang and 100 % at Hotan (Fig. 4, Du *et al.*, 1996, 1998).

The air temperatures are increasing and precipitation are decreasing in winter, and summer and annually. It is recognized that climatic change is due to the desertification because of mainly artificial effects in eastern area. In winter, increase of air temperature is due to mainly artificial effects. It is based on the desertification, but in winter, the heating is based on a global warming, large scale of heat island or climatic change. City and town are expanding by development of desert, that is, making oases or cultivation area. Oases have agricultural fields and irrigation system in city area. Martonn's arid index is increasing in these years (Du *et al.*, 1996). Climatic improvement or alleviation was found in these area.

It is interesting in the simulation that the increase of rainfall was found in the area order of 100×100 km^2 in Australia (Komiyama, 1998). In the other hand in Brazil, it is said that cutting off large scale of tropical rain forest is effected for a decreasing of rainfall.

6. Conclusions

(1) The meteorological improvement by windbreaks was recognized in arid land, Turpan.
(2) The difference of local climate at a desert and oasis were numerically obtained.
(3) Climatic change at oases around Taklimakan Desert was found recently that the increase and decrease of precipitation in winter and summer, respectively. However, it is not wide area just around oases like Hotan.
(4) Climatic change was also found that the increase of air temperature and decrease of precipitation in eastern China. The degradation by desertification area is totally increasing recently in China.
(5) It was introduced that the increase of rainfall based on increase of vegetation in Australia and decrease of rainfall based on cutting off rain forest in Brazil.

References

Du, M. (1993): Variations in air temperature and precipitation in arid area of China in recent 40 years. Abstracts of the 1993 Meeting of the Japanese Association for Arid Land Studies, 4: 5-6.

Du, M., Yoshino, M., Fujita., Y., Arizono, S., Maki, T. and Lei, J. (1996): Climate change and agricultural activities in the Taklimakan Desert, China, in recent years. J. of Arid Land Studies, 5(2): 173-183.

Du, M. and Maki, T. (1998): Climate change and its relationship with oases development in Xinjiang, China in recent years. Proc. the Japan-China Joint Research Conference on Environmental Conservation, JRCAS:14-20.

Komiyama, H. (1998): System approach: Does it rain in a desert? The 6th Meeting of Commission of Agricultural Development for Arid Lands: 1-6.

Kurose, Y., Tang, L., Ohba, K., Maruyama, A. and Maki, T. (1998): Variations of air temperature and relative humidity from a desert to an oasis in Turpan, China. J. Agric. Meteorol., 54(4):337-343.

Maki, T., Pan, B., Sameshima, R., Du, M. and Kawakata, T. (1995): Microclimatic improvement of agricultural fields by multiple row windbreaks made of mixed tree species in the arid Turpan region of China. J. Agric. Meteorol. 51(3): 229-238.

沙漠研究 10S, 13-16 (2000)
Journal of Arid Land Studies

– Special Issue – "Desert Technology V"
Refereed Paper

The Impact of Desert Afforestation on Weather Modification in Western Australia in Summer

Dayin LI*, Hiroshi KOMIYAMA*, Kazuo KURIHARA** and Yasuo SATO**

ABSTRACT - The impact of desert afforestation on weather modification in western Australia in summer was evaluated. A three-dimensional spectral model was used to simulate limited-area weather modification by changing surface conditions. Using global analysis data sets as the initial and boundary conditions, comparative simulations were done for original and modified surface conditions in the selected region in several typical days in January 1990. The simulation results show that significant additional precipitation in the modified region (i.e., the increase of precipitation exceeded the increase of evaporation in the modified region) occurred when we changed surface conditions from bare soil to forests.

Key Words: Local weather modification, Surface characteristics, Desert forestation

1. Introduction

In recent years, much attention has been paid to the impact of landscape changes on weather and climate, especially changes caused by human activities. The Rajputan Desert is believed to be a man-made desert formed by cutting down and burning forests (Hora, 1952). Stebbing (1935) and Aubreville (1949) concluded that cutting down trees on the desert border and then using the wood for energy might have caused the increase in the size of the Sahara Desert. Charney (1975) proposed a mechanism of desertification over northern Africa in which the removal of vegetation increased the albedo of the land. In his study, when the albedo changed from 14% to 35% the precipitation decreased about 40% during the rainy season. Studies show that the ongoing Amazonian deforestation has caused a decrease in precipitation in the deforested area (Nobre et al. 1991). From the above studies we can know decrease of vegetation coverage of the Earth will induce the decrease of local precipitation. Therefore, we may hypothesize that the increase of vegetation coverage may enhance the local precipitation. Enger and Tjernström (1991) studied the effects of an artificial lake made in a semiarid region on the regional precipitation. Their results showed that the lake significantly increased precipitation.

In a nearly 500 x 500 km area of arid or semi-arid land between the coast and desert adjacent to Perth, we simulated weather modification in summer caused by changing the albedo, evapotranspiration efficiency ß, and surface roughness Zo from the arid land to forest. A two-step simulation was used to make the result close to the real conditions. (1). Calculations were done for a surrounding region 1920 x 1920 km using a coarse grid and initial and boundary conditions from global analysis data set; (2). The results from Step 1 were used to provide the initial and boundary conditions for the simulations in a small domain using a fine grid. This procedure yields boundary and initial conditions corresponding to the surrounding area for five days in January 1990. Also, local circulations induced by the dynamic response of land and ocean to solar radiation were calculated. For the simulations, we used a three-dimensional spectral meso-scale model called the Japan Spectral Model (JSM) developed by the Japan Meteorological Agency for areas strongly controlled by the Earth 's surface conditions.

2. Structure of the JSM model

The JSM uses advection forms of the fundamental equations for momentum, mass, specific humidity, and virtual temperature. Detailed descriptions of the model are given elsewhere (Segami et al. 1989), and therefore only the major points are summarized here.

The JSM uses a rectangular grid of 129 x 129 grid points, in which horizontally the equations

* Faculty of Engineering, University of Tokyo, Japan (Fax: +81-3-5689-7352)
** Applied Meteorology Research Dept., Meteorological Research Institute, Japan

are cast on an x-y grid transformed with appropriate map projections of the Earth to account for the spherical shape of the Earth. The number of vertical levels is 23 above the ground. Furthermore, a four-layer model can be used to calculate ground temperature by inducing heat flux exchange with the subsurface. The simulation of precipitation involves three processes: large-scale condensation, moist convective adjustment, and evaporation of raindrops. Evaporation of raindrops was calculated using the formula by Ogura and Takahashi (1971). Details were previously described by Segami et al. (1989).

3. Two-step simulation

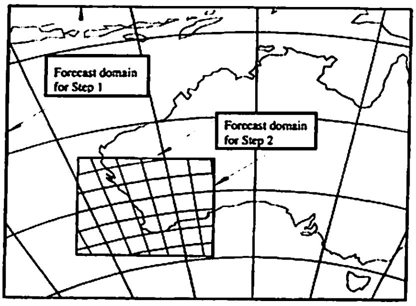


Figure 1. Forecast domains for the two-step simulation

Table 1. Surface conditions in the modified region

	β	Zo(m)	Albedo
Original case [from the global data base (mean values)]	0.1	0.11	0.20
Modified case	0.6	1.00	0.15

(Modified domain: latitude: S 28° ~ S 33°
longitude: E 116° ~ E 121°)

For the two-step simulation shown in Figure 1 in this study, in Step 1, simulation was carried out for a period of two days with a coarse grid size of 15 km, using global analysis data set of the resolution of 1.875° x 1.875° and 15 vertical levels as the boundary and initial conditions. Using the calculation results on the second day as the boundary and initial conditions, in Step 2 simulation was carried out for the respective area with a finer grid size of 15 km. There were three reasons for this two-step simulation. The first was to create initial and boundary conditions that are justified physically to make the results close to the real condition. The second was that it takes time for the near-surface conditions, such as temperature, moisture, and wind, to reach equilibrium with the surface changes. Generally, the cycle period was about one day. The atmosphere was expected to follow the surface change on the second day. The third was to resolve local circulations, which influence meso-scale weather.

4. Cases Studies

4.1 Description of the case studies

In each case we made a pair of simulations for the original surface conditions where the surface coverage of the simulated area was taken from NASA 1 deg. data, and the modified surface conditions listed in Table 1. We assumed relatively large-scale surface modification (about 500 x 500 km) from Australian original conditions to wetter surfaces.

Generally, the values of ß, roughness, and albedo for calm water were set at 1.0, 0.05, and 0.1, respectively. Strictly speaking, such parameters should not be constant, but should change with time. For our simulations, we used the values recommended for forests of 0.6, 1.0 m, and 0.15 for ß, roughness, and albedo.

4.2 Results

Table 2 and Figure 2 showed the simulation results of those days for averaged precipitation and evaporation in the modified region, and examples (Jan. 2 and 14, 1990) of distributions of 24 hrs accumulated precipitation.

Table 2. Simulation results of averaged precipitation and evaporation in the modified region (mm/d)

		Mean precip.	Mean evap.	Precip. increase	Evap. increase
Jan. 02	original	0.3	2.6	0.2	3.2
	modifed	0.5	5.8		
Jan. 04	original	0.0	3.1	0.3	3.6
	modifed	0.3	6.7		
Jan. 12	original	0.0	2.8	0.9	3.4
	modifed	0.9	6.2		
Jan. 14	original	8.5	3.1	5.0	3.1
	modifed	13.5	6.2		
Jan. 19	original	2.4	2.6	1.1	1.9
	modifed	3.5	4.5		
Jan. 22	original	4.2	2.1	4.0	2.2
	modifed	8.2	4.3		

From Table 2 we can find that changes of surface conditions caused significant changes of evaporation. The evaporation for the modified cases was about 2 times higher than that for the original case. Figure 2 showed that in original condition, natural rainfall occurred on Jan 14 and distributed in and surrounding the modified region. The precipitation increased significantly for the modified cases, compared with the original cases. This increase occurred not only in the modified area but also in the outsite region. The increase of evaporation was in same order but smaller (about half) than the increase of precipitation, as well as the case on Jan. 22 (in Table 2). It means that the additional water vapor, more than the increased amount of evaporated water vapor, in the atmosphere precipitated due to the surface changes.

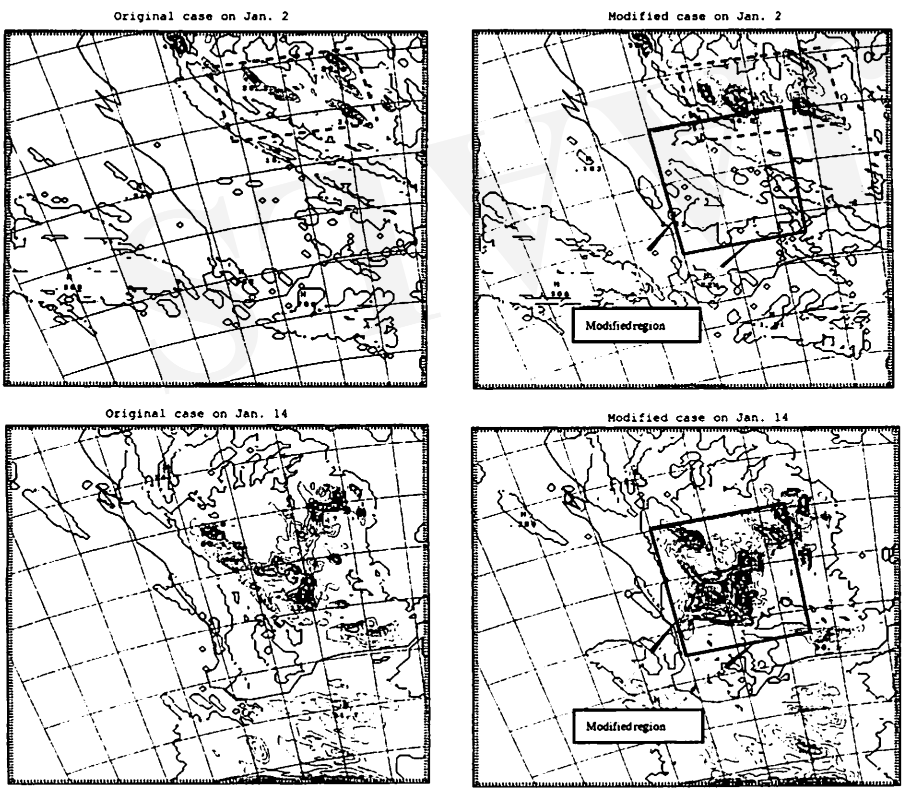


Figure 2. Accumulated precipitation (interval: 5 mm) over 24 hrs for two typical days in Jan. 1990, under the original and the modified surface conditions

In original cases, from sectional profiles of RH at 8:00 p.m. not shown here, we can find clouds locating from 870 to 310 mb over the region of interest on Jan 14. These clouds induced precipitation naturally (with out changes of surface conditions). However, the modified cases had a broader cloud depth, extending from lower to higher altitudes (930 - 230 mb) than that for the original case. Detailed analyses showed that the additional precipitation occurred in the afternoon and evening (2:00 p.m. to 8:00 p.m. LST) and the precipitation peak occurred earlier in the modified case than that in the original case. The cross-sectional profiles of RH at 6:00 p.m. indicated that precipitation occurred in the modified cases, but no rain fell in the original cases at that time. Precipitation occurred at low levels due to more water vapor evaporated from surface in the modified case and released a large amount of latent heat. This heat warmed the surrounding air, which then moved upward. The maximum upward speed was about 1.5 m/s, which was stronger than that induced by the landscape discontinuity at about 0.1 to 0.2 m/s in the afternoon. This strong uplift intensified the vertical circulation of clouds in the upper atmosphere, therefore activating precipitation at high altitude. Precipitation enhanced by this uplift exceeded the precipitation seen in the original case. This is the postulated mechanism for the extra precipitation exceeding evaporation.

Figure 2 also showed that in the original condition, natural rainfall almost did not occur on Jan 2 in the region of interest, but precipitation distributed in the area marked with dash line near the modified region. The increase of precipitation in the marked area was significantly intensive. Results on Jan. 4, 12 and 19 in Table 2, indicated that even evaporation in the modified cases was about 2 times of that in the original case, the precipitation increase was less than that of evaporation.

5. Summary and Conclusion

In this study, we simulated weather changes for arid land after forestation in an area of about 500 x 500 km between the coast and desert in western Australia. The results of case studies showed that local convective circulations induced by changing surface conditions will cause local changes in evaporation and precipitation. These effects on the local weather, especially on precipitation, are different from different atmospheric conditions of selected days. For example on Jan. 14 and 22, the extra precipitation (the increase of precipitation exceeded the increase of evaporation in the modified region) can be induced by surface modifications from dry soil to wet. In the case of Jan. 2, additional precipitation occurred in the region adjacent to the modified area. In the cases of other days, the increase of precipitation was seen. However it was not of significance to influence the local weather intensively.

The significance of our simulations is that the comparison results between the original and modified cases indicate obvious changes in precipitation, evaporation and local weather. It is necessary to classify the seasonal weather into several types, and then evaluate the impact of surface modification in each group. Then, we can correctly evaluate the impact of desert afforestation on weather modification in western Australia seasonally and annually.

References

Aubreville, A., (1949): Climates, Forests, et Desertification de l'Afrique Tropical. *Societé d'Editions Geographiques, Maritimes et Coloniales*, 351 pp.

Charney, J. G., (1975): Dynamics of desert and drought in the Sahel. *Quart. J. Roy. Meteor. Soc.*, **101**, 193-202.

Enger, L. and Tjernström, M. (1991): Estimating of the effects on the regional precipitation climate in a semiarid region caused by an artificial lake using a mesoscale model. *J. Climate Appl. Meteor.*, **30**, 227-250.

Gadd, A. J. and J. F. Keers, (1970): Surface exchanges of sensible and latent heat in a 10-level model atmosphere. *Quart. J. Roy. Meteor. Soc.*, **96**, 297-308.

Hora, S. L., (1952): Hora's Satpura hypothesis: An aspect of Indian biogeography. *Current Science (Bangalore)*, **19**, 364-370.

Nobre, C. A., Sellers, P. J., and Shukla, J., (1991): Amazonian deforestation and regional climate change. *J. Climate*, **4**, 364-370.

Ogura, Y., T. Takahashi, (1971): Numerical simulation of the life cycle of a thunderstorm cell. Mon. *Wea. Rev.*, **99**, 895-911.

Segami, A., K. Kurihara, H. Nakamura, M. Ueno, I. Takano, and Y. Tatsumi, (1989): Operational mesoscale weather prediction with Japan Spectral Model. *J. Meteor. Soc. Japan*, **67**, 907-923.

沙漠研究 10S, 17-20 (2000)
Journal of Arid Land Studies

—Special Issue— "Desert Technology V"
Refereed Paper

Water Supply for Arid and Semiarid Regions

Gary W. FRASIER*

Abstract - Water is a key component for man to survive and live. In many semiarid regions over 80% of the precipitation that falls returns to the atmosphere by evapotranspiration processes. Water harvesting is an old technique that is still useful in collecting this water for man's beneficial use. A relatively small area that is impermeable to water infiltration such as a house roof can collect sufficient water for domestic family use. In addition to the collection area there must be provisions for preventing seepage and evaporation losses of the collected water.

Key words: Water harvesting, precipitation collection, water supply

1. Introduction

Water can be both a problem and a solution. With few exceptions, there is usually some type of water problem everywhere in the world. There may be too much water (floods), or too little water (drought). The water may not be of suitable quality. Without water man can not live and land has no value. In arid and semiarid regions, surface water is frequently a scarce commodity. Yet, in most areas, on an annual basis there is sufficient water for man to survive and live. The problem is; the water (precipitation) may come too soon or too late. Precipitation may come all at once in a single event and be lost from the land as flood runoff. It may come as many small events which only wet the soil surface and evaporate directly back into the atmosphere. In many places, water shortage is not the problem, water distribution is the problem; both spatially and temporally.

2. Water sources

The earth's supply of water remains relatively constant but always on the move from the oceans to the atmosphere (evaporation) and back to the surface (precipitation). The water that falls back into the ocean is of no direct benefit to man. Precipitation falling onto the land masses can be intercepted by the vegetation or soil surface and evaporate back into the atmosphere. Water which reaches the soil surface can run off or be infiltrated into the soil and potentially end up in the groundwater. Surface runoff and groundwater are the major water sources which can be exploited by man.

The amount of water from the total water balance which is available for man's use varies from region to region (ie. arid vs. humid). In semiarid regions receiving about 320 mm of annual precipitation, it is estimated that 96% (305 mm) will return to the atmosphere via evapotranspiration. About 4% (12 mm) will run off the soil surface, and less than 1% (3 mm) will infiltrate into the soil and may recharge groundwater supplies (Branson 1976). In southern Arizona, at the USDA-ARS Walnut Gulch Watershed which receives about 300 mm of precipitation, there is an estimated 250 mm (83%) in surface detention and infiltration, most of which is returned to the atmosphere by evaporation and transpiration processes. Of the 50 mm (17%) of on-site runoff, 44 mm (15%) are lost to transmission losses in the normally dry stream channels and returns to the atmosphere by evaporation from the soil. Less than 1 mm of water ever reaches the groundwater. A total of 6 mm (2%) passes the outlet of the watershed as surface outflow (Frasier and Renard 1987, Renard 1970) (Figure 1). While absolute values may change, the relative proportions are probably representative of many arid and semiarid regions.

*Research Engineer, USDA-ARS, 1701 Center Ave., Ft. Collins, Colorado 80526 (FAX 970-482-2909)

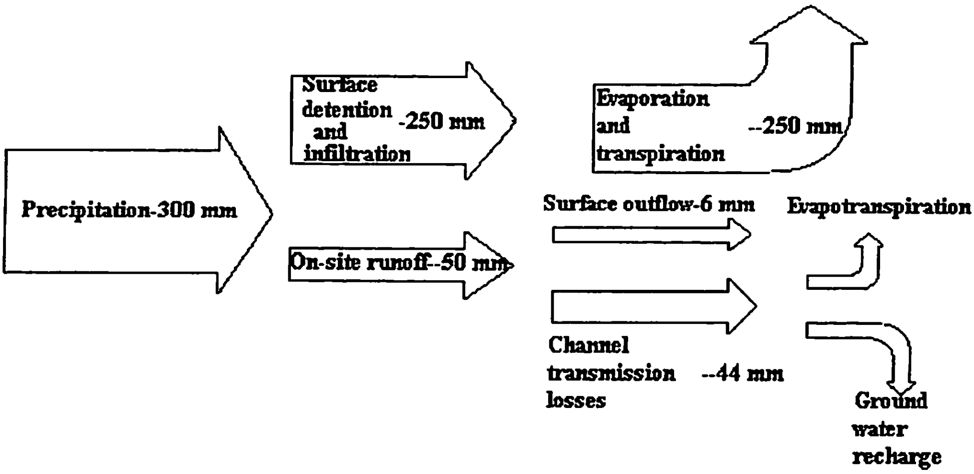


Fig. 1. Hydrologic water balance at Walnut Gulch Experimental Watershed, Tombstone, Arizona (adapted from Frasier and Renard 1987).

3. Water needs:

The major purposes of man's water needs are for drinking supplies (domestic and livestock) and for growing crops. Drinking water must be available from a steady, dependable source on almost a daily interval. A continual supply of water is not as critical for growing crops. Most crops can withstand short periods without water and still survive. If precipitation occurs at some set interval during the crop growing season, much of the water previously described as lost by evapotranspiration processes can be beneficially utilized in plant production. Problems arise if the precipitation comes during a period of time when the crops are not growing. Then the water is effectively lost.

4. Water supply:

4.1 Groundwater: One of the earliest means for obtaining water at places where streams and rivers were non-existent or unreliable has been by drilling wells or bore holes into the underlying groundwater aquifers. With pumping equipment, these can be a dependable means of water supply. There are many places where the groundwater is of marginal quantity or of unsuitable quality because of dissolved minerals and/or salts. There are many other places where the depth to groundwater makes it an impractical water supply.

4.2 Surface water: In most arid and semiarid regions there is very little surface water. The few streams that cross these areas usually originate in the highland areas where there is greater precipitation. These water sources are generally only useful for a strip of land near the streams. In many instances these streams are intermittent and go dry during the summer months. In some areas there are small depressions that collect water during the rainy season but go dry as the water is lost by seepage or evaporation.

One source of surface water that has potential for both drinking water and growing crops is the collection of precipitation on site, as it falls. This technique known as water harvesting or precipitation collection is one of the oldest methods of water supply in areas where groundwater and surface streams are not available or unreliable.

5. Water harvesting:

Water harvesting is defined as, "the process of collecting and storing precipitation (rain or snow) for beneficial use from an area that has been treated to increase precipitation runoff" (Frasier 1998). Basic water harvesting concepts are not new. There is evidence in the Edom mountains of southern Jordan of water harvesting structures used over 9,000 years ago (Bruins et al. 1986). Water harvesting was practiced as early as 4500 B.C. by the people of Ur and later by the Nabateans and other people of the Middle East. Many of the principles of water harvesting are still being used today but in a slightly different context.

It is probable that the first water harvesting system was simply a depression that filled with water that had run off from an uphill area. Many desert areas have small rain-filled depressions at the bottom of rock outcroppings that provide wildlife drinking water. It was only a small step in water harvesting technology to create depressions for water storage at the outfall of a rocky ledge to collect runoff from rainstorms that would otherwise be lost.

Water harvesting has the potential to collect a significant portion of the 80% of the water in semiarid regions that is otherwise lost to the atmosphere by evapotranspiration processes (Fig. 1). Table 1 presents some estimates of the annual quantities of water than can be collected at selected locations around the world.

Table 1. Annual precipitation potentially available for collection at selected locations (adapted from Myers 1964).

location	average precipitation liter/m^2
Cipolleti, Argentina	148
Oran, Algeria	366
Alice Springs, Australia	312
Arica, Chile	0.6
Alexandria, Egypt	207
Helwan, Egypt	39
Gibraltar	677
Jask, Iran	118
Bagdad, Iraq	121
Jerusalem, Israel	550
Idris, Libya	310
Chihuahua, Mexico	368
Bahrain, Saudia Arabia	60

If we assume that 40 liters of water is required per day per person for cooking, drinking and washing (Frasier and Myers 1983), it is easy to see that a relatively small impermeable area, for example, (100 m^2), can potentially provide significant quantities of water (10,000 to 50,000 liters) on an annual basis in many areas. In some places a sufficient size catchment area may be the roof of a house. If larger quantities of water are needed there are various techniques that can be used to seal the soil surface and increase precipitation runoff (Frasier and Myers 1983).

Collecting the precipitation is just the first step. The collected water must be stored until it is needed. In many places the water storage facility is the most difficult to construct. It must be both water tight, to prevent seepage losses, and covered, to prevent water loss by evaporation.

Runoff farming is a technique of water harvesting utilized for growing crops. In most runoff farming systems, a portion of the land is dedicated to water collection. The collected water is diverted onto the crop area where it infiltrates into the soil for use by the plants. The runoff area is frequently smoothed and maybe compacted to increase the quantity of water that runs off. Runoff farming is an effective technique in areas where the precipitation occurs prior to, or during, the crop growing season. Runoff farming is less effective where the precipitation does not occur during the growing season. In these instances the collected water is usually lost by evaporation.

6.Conclusion

Most places in the world have some type of a water problem. In many semiarid and arid regions the problem is inadequate supplies for drinking, both animal and man, or for growing crops. Water harvesting is an ancient technique of water supply that is receiving renewed interest as a means of water supply.

References:

Branson, Farrel A. (1976): Water use on rangelands. In Heady, H.F., Falkenborg, D.H. and Riley, J.P., eds Watershed Management on Range and Forest Lands. Proc. 5th Workshop of the United State/Australia Rangeland Panel, Boise, Idaho, June 15-22, 1975. Publisher Utah Water Research Laboratory, Utah State University, Logan, Utah 193-209.

Bruins, H.M., Evenari, M., and Nessler, U. (1986): Rainwater-harvesting agriculture for food production in arid zones: the challenges of the African famine. Applied Geography 6:13-32.

Frasier, G.W. (1998): Water harvesting for rangeland water supplies: a historic perspective. In: Proc. A Symposium on Environmental, Economic, and Legal Issues Related to Rangeland Water Development. November 13-15, 1997, Tempe, Arizona. Published by: The Center for the Study of Law, Science and Technology, Arizona State University, Tempe, Arizona 17-24.

Frasier, Gary W., and Myers Lloyd E., (1983): Handbook of water harvesting. Agriculture Handbook No. 600, Agriculture Research Service, United States Department of Agriculture. 45 pgs.

Frasier, Gary W., and Renard, Kenneth G. (1987): Erosion and runoff measurements from semi-arid rangeland in southwestern USA: an overview. In: Pathak, P., El Swaify, S.A., Singh, S., Raghavan and Beckerman, S.R. eds. Alfisols in the Semi-Arid Tropics. Proc. Consultants' Workshop on the State of the Art and Management Alternatives for optimizing the Productivity of SAT Alfisols and Related Soils. 1-3 December 1983. ICRISAT Center, Patancheru, Andhra Pradesh India. 145-154.

Myers, Lloyd E., (1964): Harvesting precipitation. Publication 65 of the I.A.S.H. 343-351.

Renard, Kenneth G. (1970): The hydrology of semiarid rangeland watersheds. ARS 41-162. Agricultural Research Service, United States Department of Agriculture. 26 pgs.

沙漠研究 10S, 21-24 (2000)
Journal of Arid Land Studies

—Special Issue— "Desert Technology V"
Refereed Paper

Disposal of Salt Water on the Evaporation Drainage Method

Tetsuo OGAWA*, Daiji NAITO* and Yukuo ABE**

Abstract - Excess salt-laden water in soils is a serious problem in arid to semi-arid climates. We have proposed the usage of an evaporation drainage method which utilizes an evaporation accelerator and resident strong evaporation forces prevalent in the climate of arid lands. Evaporation accelerators evaporate excess water by radiating it into the atmosphere. An accelerator could perform effectively even under a high water potential condition in soil surface. Water was evaporated from the accelerators' surface and resultingly only KCl remained in crystal form. The amount of KCl in the upper sections of the accelerators increased markedly, and blocked evaporation. However the KCl in the mid and low sections of the accelerators did not crystallize and as a result, these sections of the accelerators accelerated cumulative evaporation. The evaporation accelerators could function divided into an area of salt accumulation and an area of evaporation according to the height of accelerators.

Key Words: Evaporation, Drainage, Excess water, Salt accumulation, Evaporation accelerator

1. Introduction

In arid to semi-arid climates, proper disposal of water is necessary to cope with waterlogging, poor drainage and ponding of saline drainage water. However in some cases this is not always possible because of either technological difficulties, unsuitable geographical conditions or financial implications concerning the construction of underdrainage systems, etc. Thus, a different approach to solving this problem is deemed necessary.

We have proposed the usage of an "Evaporation Drainage Method," (Ii *et al.*, 1995, Abe *et al.*, 1995, Ogawa *et al.*, 1998) which utilizes an "Evaporation Accelerator" as well as existent strong evaporation forces which are prevalent in arid regions. The evaporation accelerator consists of three sections that perform such functions as absorption of soil solution, solution transportation, and water evaporation. Methodologically, excess soil moisture is evaporated and radiated into nature and salt is removed. This report investigated how effective evaporation accelerators would perform in enhancing the evaporation drainage of salt-laden water.

2. Materials and Methods

An Evaporation Accelerator is a stick type instrument made of highly-absorbent paper (Cooking Paper marketed in Japan by Lion Co., LTD.) coiled around a nylon thread.

Experiment A (as shown in Fig. 1 - (a)) used a pot with an inner diameter of 9 cm and a height of 12 cm. It was filled with sand (Toyoura standard sand) saturated with pure water and placed in an air-conditioned enclosed chamber and kept at a temperature of 40 ℃ with a relative humidity of 50% and a wind velocity of 1-2 m/s. The accelerator was inserted into the pot extending a height of 20 cm above the sand surface. A cover was installed on the sand surface for protection against evaporation. The weight of the pot was measured for estimating evaporation rates.

Experiment B (as shown in Fig. 1 - (b)) used a pot with an inner diameter of 25 cm and a height of 30 cm, and it was filled with solution with a concentration of 0.7% KCl and placed in an air-con-

*Doctoral Program in Agricultural Sciences, University of Tsukuba, 1-1-1 Tennodai, Tsukuba, Ibaraki 305-8572, Japan

**Institute of Agricultural and Forest Engineering, University of Tsukuba, 1-1-1 Tennodai, Tsukuba, Ibaraki 305-8572, Japan

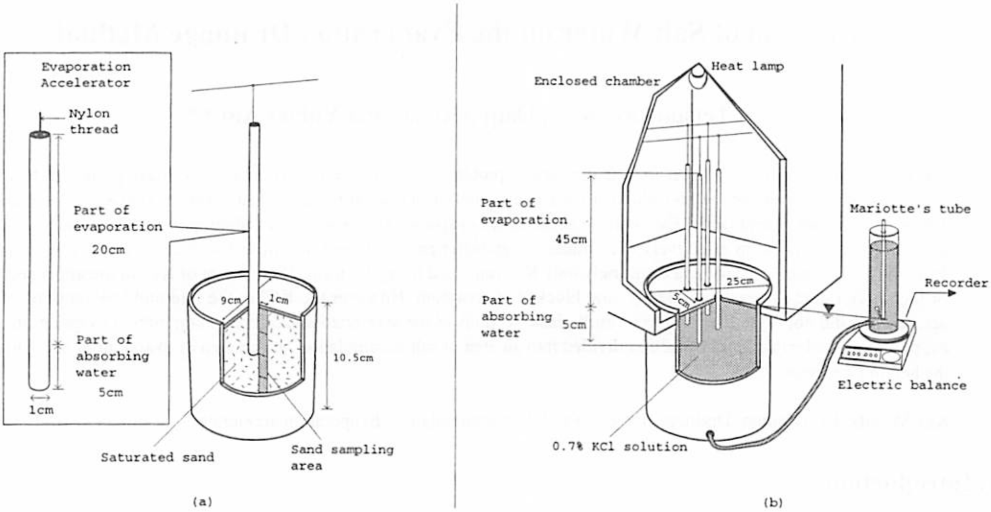


Fig. 1. Test apparatus.

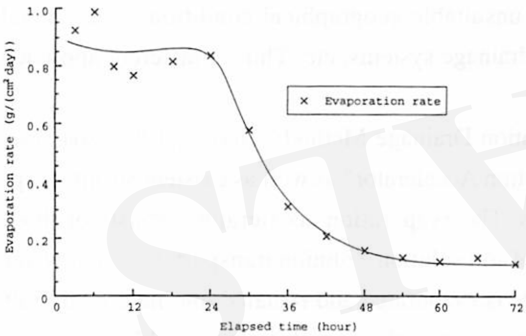


Fig. 2. Changes in Evaporation rate for the test apparatus (a).

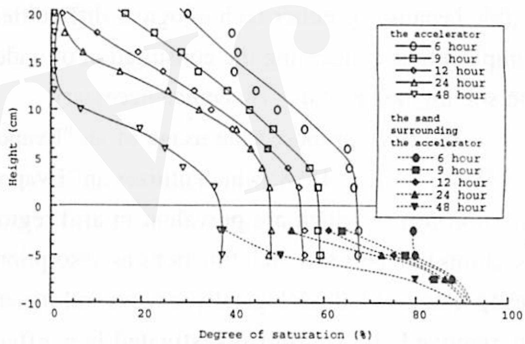


Fig. 3. Changes in degree of saturation for the test apparatus (a).

ditioned enclosed chamber and kept at an average temperature of 35 ℃ with a relative humidity of 45% and a wind velocity of 1-2 m/s. Four evaporation 50 cm accelerators were installed into the pot. The accelerators were inserted into the pot extending a height of 45 cm above the water surface. A cover was installed over the water surface for protection against evaporation. The bottom of the pot was connected to a mariotte's tube for maintaining a constant water level. During the experiment, the weight of the mariotte's tube was measured for estimating evaporation rates.

3. Experimental results and discussion

3.1 Accelerator assisted drainage from saturated sand

Water present in the sand was absorbed into the accelerators and raised in a vertical direction by the accelerators' capillary forces as well as evaporated from the accelerators' surface. Fig. 2 shows the changes in the evaporation rate of the accelerator for the test apparatus (a). The evaporation rate was nearly constant for 24 hours. This was ascribed to constant water transport from the sand to the surface of the accelerator. However, the evaporation rate dropped considerably from 24 to 48 hours. This indicated that the accelerator was unable to extract enough water from the sand to meet evaporation potential.

Fig. 3 shows the changes in the degree of saturation for the test apparatus (a). The degree of saturation in the accelerator decreased according to the amount of time elapsed. Then, the degree of saturation in the sand surrounding the accelerators decreased too. As the degree of saturation in the sand surrounding the accelerators decreased by less than about 60%, water did not rise to the upper section in the accelerator. Consequently, the accelerator could perform effectively under a high water potential condition in soil surface.

3.2 The accelerators in salt water

Water in the solution evaporated from the accelerators' surface and KCl accumulated on the accelerators' surface. Fig. 4 shows the relationships between KCl and the degree of water saturation concentration over a period of 50 days at varying heights for the test apparatus (b). The KCl in the most upper section of the accelerators increased markedly according to the elapsed time. The KCl formed crystals in the upper section of the accelerator as the concentration in the accelerator exceeded saturation concentration. However the KCl in the mid and lower sections of the accelerators did not form crystals for 50 days.

The degree of water saturation decreased in accordance with the height of accelerators, but no change occured according to elapsed time. As a result, salt accumulation on the accelerators did not impede the transport of salt water from the water table to the upper section of the accelerators.

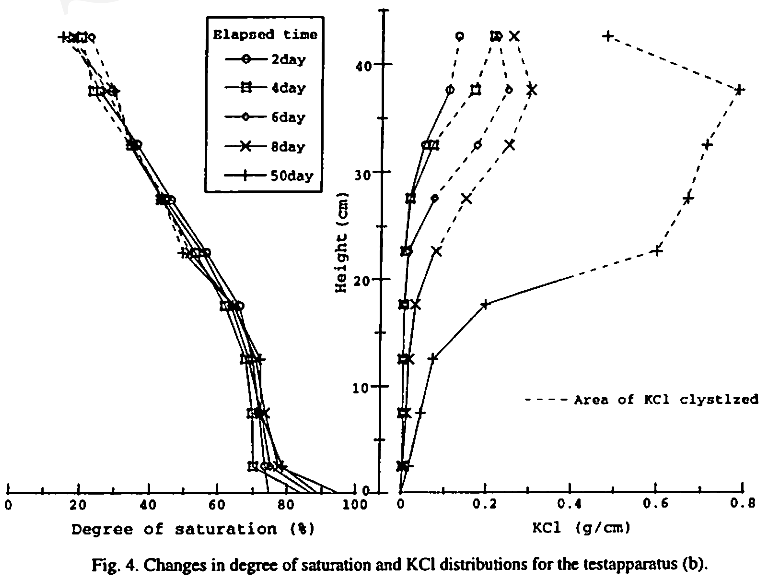


Fig. 4. Changes in degree of saturation and KCl distributions for the testapparatus (b).

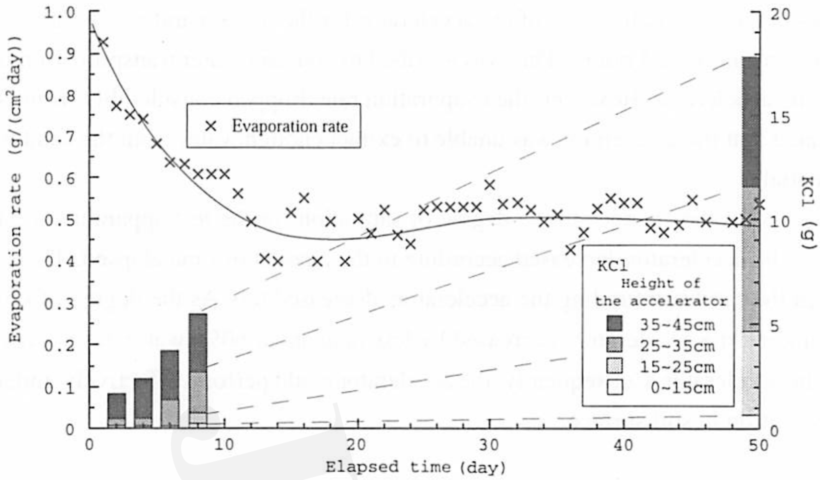


Fig. 5. Changes in evaporation rate and amount of KCl for the test apparatus (b).

3.3 Effective salt water elimination using the accelerators

Fig. 5 shows the change in the evaporation rate of the accelerators and the amount of salt captured in the accelerators according to the elapsed time for the test apparatus (b). While the amount of KCl increased according to the amount of time elapsed, the evaporation rate of the accelerators dropped by 60% for approximately 10 days. The main reason for this was that the KCl in the upper section of the accelerators blocked evaporation by KCl crystals. Thus, evaporation rates depended on the area of salt accumulation. The evaporation rate was, however, nearly constant from 10 to 50 days. Consequently, the mid and lower sections of the accelerators did not impede evaporation. The evaporation accelerators could function divided into an area of salt accumulation and an area of evaporation according to the height of accelerators. As a result, 4 Evaporation accelerators of height 45 cm could continue salt accumulation for more than 50 days, accelerating approximately 2 times the amount of evaporation in proportion to the surface water of the pot.

4. Conclusion

According to this study, we can conclude that the evaporative drainage method using the evaporation accelerator has a great potential for a drainage management in case of need the disposal of excess water and saline. Therefore we feel that it could possibly be used as a new drainage method differing from former methods which used drainage equipment.

References

Ii, H., Ohtsuka, Y., Ogawa, T., Abe, Y. and Yamaguchi, T. (1995): *Journal of Arid Land Studies*, 5: 33-42

Abe, Y., Tsurui, J., Yamaguchi, T., Ohtsuka, Y. and Ii, H. (1995): *Journal of Arid Land Studies*, 5: 43-54

Ogawa, T., Abe, Y., Yamaguchi, T., Ozaki, M. and Yabashi, S. (1998): *Journal of Arid Land Studies*, 7S: 261-264

Ogawa, T., Abe, Y. (1998): *Journal of Arid Land Studies*, 8-1: 19-25

沙漠研究 10S, 25-28 (2000)
Journal of Arid Land Studies

—Special Issue— "Desert Technology V"
Refereed Paper

NUMERICAL PREDICTION OF WATER MOVEMENT IN WESTERN AUSTRALIAN SOIL FOR LARGE SCALE AFFORESTATION

Hiroyuki HAMANO*, Yasuyuki EGASHIRA** and Toshinori KOJIMA*

Abstract - Large-scale afforestation of arid lands is thought to be one of the most promising countermeasure technologies against the CO_2 problem. It is said that the primary problem in arid land usage is water shortage. We think that it is necessary for afforestation in arid land to consider effective use of limited water systematically. The Leonora site in Western Australia was chosen as a research site known for its poor soil permeability. Our first step is to estimate the infiltration behavior of water after rain by simulation. We first discuss properties of Australian soils then the point at issue from the results of the simulation studies. Second, we discuss various possible ways to enhance water infiltration into the soil in Australia.

Key Words: Afforestation, CO_2, Simulation

1. Introduction

The anthropogenic global warming is thought to be an emergent international problem. Carbon dioxide is the substance mainly responsible for global warming. Large-scale afforestation of arid lands is thought to be one of the most promising countermeasure technologies available. In the course of the afforestation of arid lands, how to effectively use the limited amount of available water needs to be addressed in terms of water and heat balance.

In the present study, Leonora in Western Australia was selected as a research subject area because of the convenience, cooperation and having a problem soil. Although the mean annual rainfall is about 222 mm, possible annual evaporation is about 3 m (Law and Williams, 1996). There is a hardpan layer with slow permeability at 20-100 cm deep from the soil surface. Relatively good vegetation exists in limited regions of the area (Yamada et al., 1999). The existence of the hardpan limits the growth of trees because of the poor permeation of the water and also restricts root growth. It has been reported that the deeper the hardpan layer, the larger the tree growth observed. It is thought that the difference in the vegetation may be caused by the difference in the available water in the soil.

Thus, it is important to know how the water moves in the soil during and after a rainfall event. In the present study, the water movement in such soil was predicted by using simulation software. The necessity and expected effect of various countermeasures were evaluated. Furthermore, the possibility of adaptation of new techniques is suggested.

2. A method of analysis and soil properties

2.1 A model for simulating one-dimensional water flow

The one-dimensional water movement in unsaturated soil under isothermal conditions can be described with the following modified form of the Richards' equation (Richards, 1931)

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial z}\left(K\frac{\partial h}{\partial z} - K\right) \qquad (1)$$

where θ is the volumetric water content [cm^3/cm^3], h is the pressure head [cm], K [cm/h] is the unsaturated hydraulic conductivity function, z [cm] is the position and t [h] is time.

It is impossible for us to solve equation (1) because it contains two unknown variables, h and θ. Thus we need a relationship between the water retention curve θ (h) and hydraulic conductivity K(h). These two unsaturated soil hydraulic properties (Mualem, 1976, van Genuchtern, 1980) are given by

*Department of Industrial Chemistry, Seikei Univ., Musashino-shi Tokyo 180-8633, Japan
**Division of Chemical Engineering, Graduate School of Engineering Science, Osaka University,
(Fax: +81-422-37-3871, E-mail: kojima@chgw.ch.seikei.ac.jp)

$$\theta(h)=\begin{cases}\theta_r+\dfrac{\theta_s-\theta_r}{\left(1+|\alpha h|^n\right)^m} & (h<0)\\ \theta_s & (h\geq 0)\end{cases}\qquad (\text{m}=1-1/\text{n})$$

$$K(S_e)=K_sS_e^{1/2}[1-(1-S_e^{1/m})^m]^2,\qquad S_e=\frac{\theta-\theta_r}{\theta_s-\theta_r}$$

where θ_r and θ_s [cm^3/cm^3] denote the residual and saturated water content respectively, K_s [cm/h] is the saturated hydraulic conductivity, n [-] is a pore-size distribution index, α [1/cm] is the inverse of the air-entry value and S_e [-] is the effective water content.

Table 1. summarizes the initial and boundary conditions. The soil of the Leonora region in Western Australia is very dry. It was assumed that initial soil water content is the same as the residual water content. We also assumed that soil surface was saturated completely during and after rain. So, volumetric water content of the soil surface after rain is the saturated water content. In the research site, we can see places with a hardpan layer with slow permeability at the 30 cm deep from the soil surface. In this study, we assumed that the hardpan layer is at 30 cm deep and has zero permeability.

Table 1. Analytical condition

Initial condition	t=0 [h], $\theta=\theta_r$
Boundary condition	
Surface of soil (z=0 [cm])	h=0 [cm], $\theta=\theta_s$ [cm^3/cm^3]
Bottom of soil (z=30 [cm])	q(flux)=0 [cm/h]

2.2 Soil properties of Leonora area

In the report of Leonora area in Western Australia (Law and Williams, 1996), two typical soil types were reported: gravel and loam. The gravel soil is classified into sandy clay loam and clay loam by using the U.S. Department of Agriculture (USDA) classification. On the other hand, the loam is classified into clay loam. The bulk density for these two types of soil is about 1.56~1.72 [g/cm^3].

In this section, comparisons are given between measured and calculated conductivity curves for these two types of soils, shown in Figs.1 and 2. The calculated results of the moisture characteristic curve and saturated hydraulic conductivity are also shown in these figures. The values of four independent parameters (θ_r, θ_s, n, α) were selected to best fit the measured pF moisture characteristic curve data. A hydraulic conductivity curve was calculated by using saturated hydraulic conductivity and the values of three parameters (θ_r, θ_s, n). Table 2. summarizes the typical soil-physical properties of the two soils.

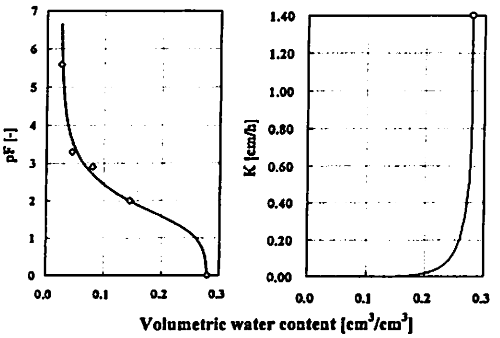


Fig.1 Measured (open circles) and calculated curves of the soil hydraulic properties of Gravel

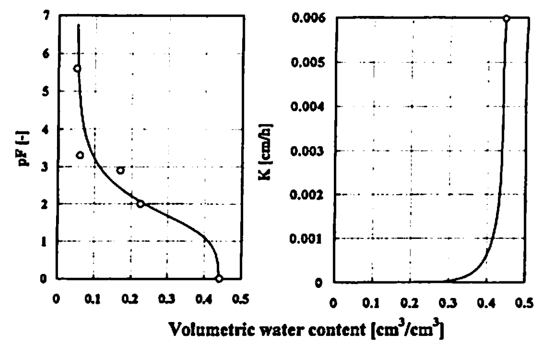


Fig.2 Measured (open circles) and calculated curves of the soil hydraulic properties of Loam

Table 2. Physical properties of the two soils

Soil name	θ_s [cm³/cm³]	θ_r [cm³/cm³]	n [-]	α [1/cm]	K_s [cm/h]
Gravel	0.025	0.278	1.49	0.044	1.400
Loam	0.050	0.441	1.48	0.044	0.006

Water infiltration into the two soils were calculated using the software "HYDRUS ver.5 (supplied from U. S. Department of Agriculture Riverside, California)", which was developed at the U.S. Salinity Laboratory, for simulating one-dimensional water flow, solute transport, and heat movement in variably-saturated media. In this study, the surface condition of soil was assumed to be saturated completely when it rained for 24 hours. Moreover, the bottom layer is a hardpan that has no permeability.

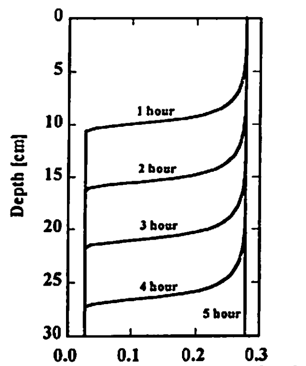


Fig.3 Infiltration in Gravel Soil

3. Results and Discussion

3.1 Infiltration

Results of gravel and loam are shown in Figs. 3 and 4. It took 5 hours for saturation of the gravel soil layer to 30 cm depth. On the other hand, it became clear that wetting front (penetration depth) for the loam soil after 24 hours of rain was only about 2 cm from the surface of soil. The Leonora region, selected as a research site, has a soil similar to loam. Therefore, it is predicted that the permeability at the research site is very low based on soil hydraulic properties. The saturated hydraulic conductivity of loam is smaller than that of gravel by 200 times.

3.2 Runoff

From the numerical results of infiltration, it is possible to know what is the problem at the research site. We could know the depth of the wetting front in the loam soil after one day. By using the water content profile after one day, it can be predicted that overflow will occur for daily rainfall larger than 7 mm. If it rained 7 mm or more daily, rainwater would runoff on the surface of the soil. The most serious problem of loam soil is considered to be its poor permeation. Gravel soil has a good permeability, but runoff will start after 5 hours due to the existence of hardpan.

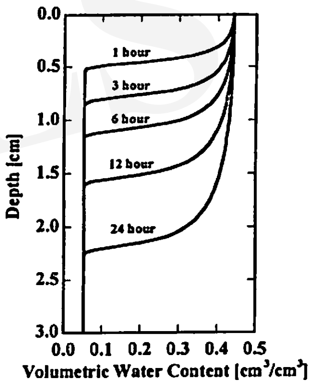


Fig.4 Infiltration in Loam Soil

3.3 Improvement in infiltration rate

From the results of the loam soil infiltration, it becomes clear that the point at issue at this site in Australia is poor permeability of the soil. Recently, many countermeasures have been suggested. Here, we discuss one countermeasure of a soil conditioner that improves the permeability of the soil. Our purpose is to increase water storage ability in the soil after a rainfall event, and reduce runoffs at the site. If these two goals are achieved, the amounts of water that a plant can use for growth will increase after rain.

Super Absorbent Polymer (SAP) has been used frequently as a soil conditioner and has shown to give excellent results for plant growth by reason of its good water retentivity. But it was reported that the glass beads mixed with SAP had only half the permeability of the original glass beads (Tahara et al., 1994). Even in actual soil, it may be possible that SAP can prevent the rainfall water from penetrating into the soil, though there are differences in properties of glass beads and actual soils. In this section, the required water permeability of soil to fill the soil is estimated. Infiltration after rain for 24 hours was calculated in each case of saturated hydraulic conductivity using HYDRUS. The results are shown in Fig.5. From the results, it was observed that 0.45

cm/h of saturated hydraulic conductivity is required for the wetting front to reach 30 cm in depth after a rain lasting 24 hours. It was found that a permeability 75 times larger than that of reported value is necessary for the above condition and the amount of water storage would increase from 7.8 at present to 109 kg/m^2. The present estimation suggests that the permeability is a more essential factor than the water retentivity of the soil layer.

In the subject area, it is considered that the following two countermeasures are promising. One is to drill a soil layer and break the hardpan. This would compel rainwater to infiltrate into the deep soil layer directly. The other is to fill the drilled hole with particles with small pores inside of the particles for water retention, while keeping the permeability developed by the former.

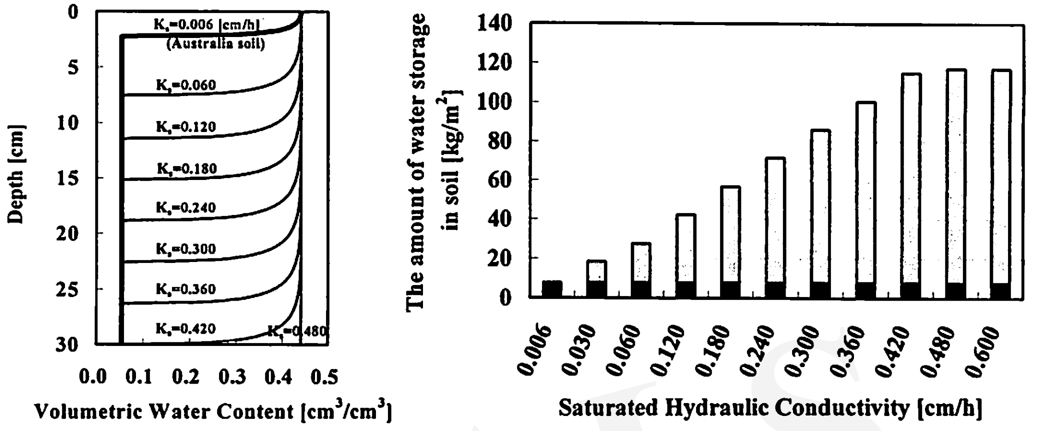


Fig.5 Influence of Saturated Hydraulic Conductivity on Infiltration Depth in Loam Soil after 24h

4. Conclusion

It is said that the soil in Leonora in Western Australia is mostly loam having poor soil permeability. From the numerical results, it became clear that the wetting front after 24 hours of rainfall is only about 2 cm from the surface of soil. And it was expected overflow would occur at rates over 7 mm of daily rainfall. So a soil conditioner to improve permeability of loam is desirable. It was observed that 0.45 cm/h of saturated hydraulic conductivity is required for complete saturation of the 30 cm layer after rain of 24 hours. When the permeability is increased by 75 times, it was expected that the amount of water storage would increase from 7.8 to 109 kg/m^2.

In the subject area, it is considered that the following two countermeasures are promising; to drill a soil layer and break the hardpan and to fill the drilled hole with particles with large size for high permeability and with small intraparticle pores for water retention.

Acknowledgments

This work was financially supported by the Japan Science and Technology Agency. Authors are grateful to Prof. Yamada, Univ. of Shinshu and Prof. Abe, Univ. of Tsukuba, for their useful comments.

References

John Law and Adrian Willams (1996), Resource Information for Research Sites in the Leonora Area, Western Australia, Report for Soc. Chem. Eng. Jpn.

Mualem, Y. (1976), Water Resour. Res., 12: 513-522.

Richards L. A. (1931), Physics, 1: 318-333

Tahara K., K. Horiuchi, S. Uemiya, T. Kojima and T. Mori (1994), Journal of Arid Land Studies, 4: 15-19.

Van Genuchten, M. Th. (1980), Soil Sci. Soc. Am. J., 44: 892-898.

Yamada K., T. Kojima, Y. Abe, A. Williams, J. Law (1999), Species Biomass and Carbon Sequestration in an Arid Environment near Leonora, Western Australia, accepted for publication in J. Arid Land Studies

沙漠研究 10S, 29-32 (2000)
Journal of Arid Land Studies

－Special Issue－ "Desert Technology V"
Refereed Paper

METEOROLOGICAL DATA ANALYSIS AND IRRIGATION PLANNING IN MAURITANIA

KANE Yacouba*, Dr. NISHIO Kunihiko**, Dr. TAKAHASHI Satoru**, WATANABE Fumio **

Abstract . Meteorological data from stations in Mauritania was analyzed to aid in planning agricultural development . Based on annual precipitation received at the reporting stations (13), Mauritania was divided into sub-humid (type A) and desert (type B) zones . For both groups the rainfall was inversely related to the altitude of the recording stations . the disparity between the two groups is indicated by climographs which are elongated for group A and restricted for group B .

Key words : Precipitation, Stations, Sub-humid, Altitude, Climograph .

1. Introduction

Mauritania is a nation located partly in the great Sahara desert and the other part in the Sahelian zone which made it a severely desert-affected nation . In such a region, desert greening and irrigation are of limitless importance for they help decrease the progress of the desert, manage the water resources because of their scarcity, increase food production . Mauritania is located in the northwest of Africa bordered to the west by the Atlantic, to the east by Mali, to the north by Algeria and Morocco and to the south by Senegal . With a population of around 3 million -among which 10% are farmers- and an area of around 1 million km^2 . More than ½ of its land is severely affected by desert which advances on yearly basis, the remaining part of the nation is a sub-humid zone located in the extreme south along the Senegal river where one can find rain forests and it is where agriculture is based . In addition to society and economy-related agricultural problems the dislocation of population to urban centers increased the shortages of agriculture labor, high costs and poor economic viability of the irrigation planning, over-exploitation of forests and vegetative cover in absence of effective check works, there still are wide gaps in the data base related to soils and water and the lack of systematic analysis to determine the probabilities of occurrence is still constraint for crop management relative to rain patterns .

2.Method and data

Meteorological data for Mauritania were collected from FAO world meteorological data book, these data consist of average temperatures, sunshine, vapor pressure, rainfall, humidity, wind speed and total radiation measured at thirteen (13) meteorological stations . Starting with plotting the relation between the altitude and annual rainfall, the relation led to the division of the study area into two separate zones, the same relation was tried for each zone . The disparity between the two groups is indicated by climographs . Relations between evapo-transpiration (ET) and humidity and ET with average temperature were drawn . For greening purposes the total annual evapo-transpiration and rainfall for each recording station was used to calculate of CCR, and for irrigation purposes the relation between average ET and rainfall for each station was drawn to determine the humid period during the year . This process led to the calculation of crop water requirements by means of CROPWAT - a FAO computer software program for irrigation planning - for each station and for *Zea mays* L. (Maize) as an example for a growing season which extends from August to October .

3. Results and discussion

The relation between annual rainfall and altitude was drawn first to get a general idea of the rainfall pattern in Mauritania, it resulted in an unusual phenomenon, the rainfall is invrsely related to the altitude, which led to the division of the study area into zones, sub-humid zone (type A) and desert zone (type B). The same previous relation was tried for each zone (Fig. 1) .

*Grad. Stud. Fac. Agr. Eng. , Tokyo Univ. of Agriculture, 1-1-1 Sakuragaoka, Setagaya, Tokyo 156 Japan (Fax:+81-484-42-6085) .
** Fac. Agr. Eng. , Tokyo Univ. of Agriculture, 1-1-1 Sakuragaoka, Setagaya, Tokyo 156 Japan .

This controversy is due to many facts among which the relatively low altitude (the highest is 400m), the climatic fluctuation and the erratic rainfall pattern throughout Mauritania.

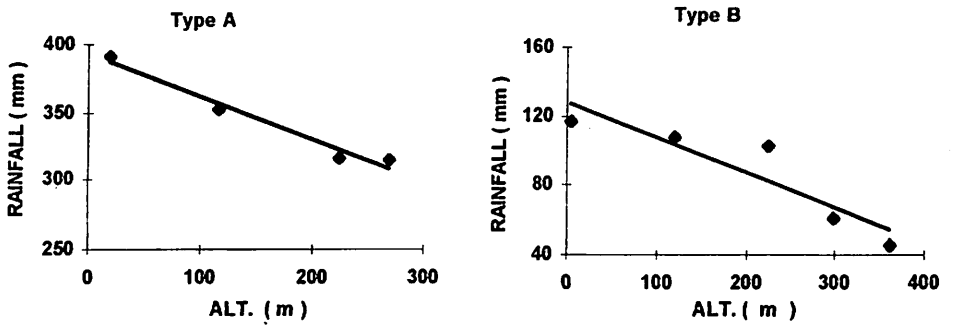


Fig. 1 Relation between annual rainfall and altitude(Alt.) for type A and type B zones .

To assess the disparity between the two zones, climographs were drawn for each recording station they revealed that for type A zone (sub-humid zone) the climographs are elongated which means the amount of rainfall is widely different from one month to another, for instance 2mm in may and 120 mm in Aug., while for type B zone (desert) they are restricted, the rainfall pattern in this zone is not so variable (Fig. 2).

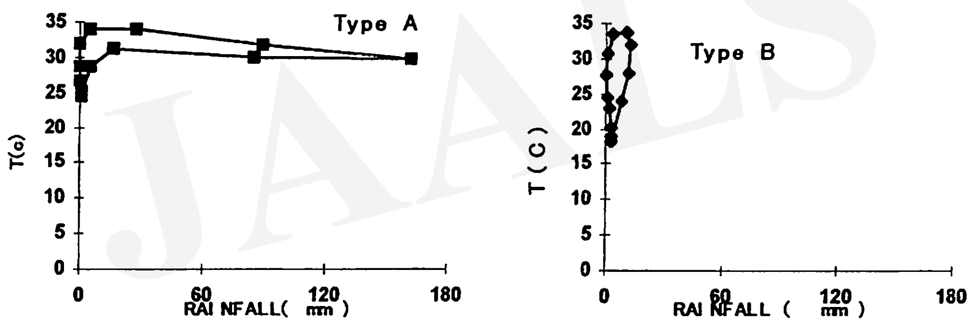


Fig. 2 Climographs for type A zone (station No.4) and type B zone (station No.11).

The evapo-transpiration (ET) is amongst the main irrigation-influencing factors alongside the rainfall . Relations between ET and monthly average temperatures (T) and ET with monthly average humidity (H), the farmer relation reveals that the higher the temperature the higher the ET, while the opposite is true of the latter relation, the higher the H (%) the lower the ET because the Humidity is higher along the coast and during the rainy period, and temperatures are slightly different from area to another depending on time in the year (Fig. 3) . For greening purposes the CCR values were calculated for each recording station to get a rough idea of how much water is needed for a given area according to the following equation .

CCR= Annual ET / annual rain

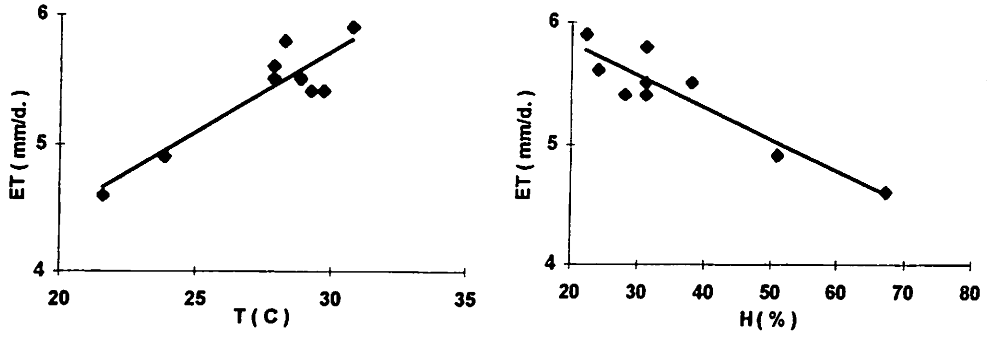


Fig. 3 Relation between ET and monthly average temperature(T), ET and monthly average humidity(H).

Table . 1 Showing CCR values calculated for each recording station .

Station	1	2	3	4	5	6	7	8	9	10	11	12	13
Zone	B	B	A	A	B	A	B	A	B	A	B	B	B
CCR	50	19	6	5	10	4	18	6	20	6	37	39	11

According to the results, the lowest values represent the type A zone where annual rainfall is higher which made the CCR lower and accordingly the amount of water required for greening is less than that of type B zone where CCR is as much high as 50 . Relations between ET and rainfall were plotted to determine at which time in the year the average monthly rain is higher than ET or in short the humid period for each station . It appears that all the stations where average monthly rainfall is greater than average ET belong to type A zone, furthermore, the humid period extends from July through September for this category . By contrast none of the stations in type B zone has a humid period, that is to say ET overweighs rainfall all year round (Fig. 4) .

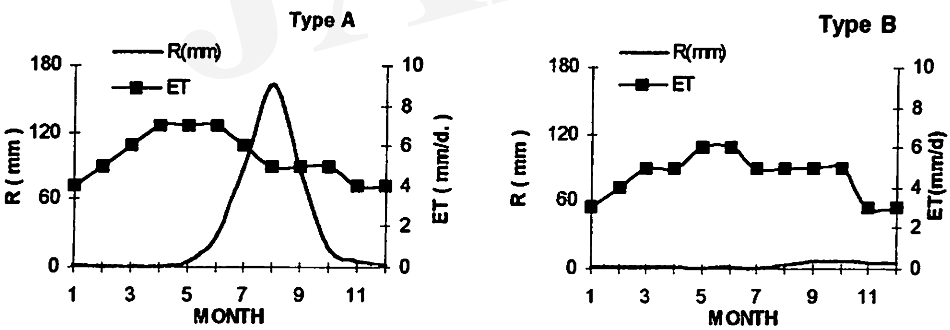


Fig. 4 Relation between monthly average ET and rainfall (R) for type A and type B zones stations 4 and 11 respectively.

The relations ET and rainfall revealed that there is humid period for some locations, but the issue whether irrigation is needed or not (in this period and at least for some crops) remains unknown . To find it out the irrigation water requirements (Irreq.) was calculated using a computer program for irrigation planning (FAO computer program for irrigation planning) as follows, input of monthly ET

and rain data, input of crop data, calculation and output of Crop Water Requirements (CWR), Calculation of ETcrop (equation 1 (Eq.1)), and irrigation requirements (Irreq.) (equation 2 (Eq. 2)) .

ETcrop = Kc.ET , where Kc is crop factor . (Eq. 1)

Irreq. = ETcrop - Peff. (Eq. 2)

Calculation of Effective rainfall by USDA method (equation 3 (Eq. 3) .

Peff = P_{tot}(125 - 0.2 P) / 125 For P< 250 mm

Where P, Monthly rainfall (mm) . Peff. , Effective rainfall . P_{tot}., Total annual rainfall . In this calculation Maize was selected for simplicity and as an example, the period of growth was chosen between August and October . The output revealed that under normal growth conditions, the irrigation process is not needed for this crop whole the month of August in type A zone, but irrigation is indispensable for the remaining time of the period and during whole period of growth in zone B .

4.CONCLUSION

Climatic fluctuation, erratic rainfall pattern and severe drought are reported to be among the main reasons for the "unusual" relation between the altitude and the rainfall for the study area . CCR values are higher for type B zone which means that the water required for the greening process is higher than that needed for type A zone where CCR is much lower . In this study it appeared that rainfed agriculture is not suitable for locations in type B zone since-in this case- ET is higher than rainfall year round . Even though in this study the humid period extends from July to September, August is the only month when irrigation is not needed for Maize, and it remains a necessity for the rest of the growth period even for semi-arid zone (type A) while no rainfed period was noted for the same crop during its growth for type B zone .

5. References

P. M. Driessen and N.T. Konijn (1992), Land-use systems analysis . Wageningen Agricultural Univ., The Netherlands .
Martin Smith (1992) , Cropwat a computer program for irrigation planning and management . Water resources, Development and Management Service . FAO Land and Water development Division . Rome.
FAO Plant Production and Protection series No. 22 , 1984, Agroclimatological data (Africa), Countries north of the equator . rome .
Maire-Helene Birindelli, Nov. - Dec. 1990 . The Courier, AFRICA-CARIBBEAN-PACIFIC-EUROPEAN COMMUNITY. General Secretariat of the ACP Group of States , Avenue Goerge , 451, 1200 Brussels, Belgium . No 124: 64-92 .
Noguchi Yoochiki, Kanata Shintaro, (1987), Noogaku Daijiten (The big dictionary of agriculture)(in Japanese) , second edition ,published by Yookendo .
S. TAKAHASHI, F. WATANABE, T.M. ISMAEL, H. TAKAHASHI, K. FUKUNAGA , Journal of Agricultural Development Studies Vol. 8 No. 2 March 1998: 9-17.
S. TAKAHASHI, F.WATANABE, T.M. ISMAEL and K. SAKURADA(1998), Journal of Arid Land Studies : 47-50 .

沙漠研究 10S, 33-36 (2000)
Journal of Arid Land Studies

－Special Issue－ "Desert Technology V"
Refereed Paper

Development of Solar Desalination System

－Basic performance of basin-type solar stills equipped with evaporation stimulators－

Tomoharu YAMAGUCHI*, Genta KANAI**, Makoto YOKOTA**and Yoshinori KAWAI**

Abstract －There are many ways of desalination by solar energy. The simplest and most popular type is a basin-type solar still, which uses solar energy directly to distill fresh water from saline water or seawater. Our objectives of this study are to develop the effective solar stills equipped with evaporation stimulator. Experiments were performed to evaluate the effect of ultrasonic oscillator attached to the bottom of the basin of still and the absorbers of solar radiation set on the surface of basin water. The ultrasonic oscillator and radiation absorber seem to be working effectively as evaporation stimulator.

Keywords: basin-solar still, evaporation stimulator, ultrasonic oscillator, radiation absorber

1. Introduction

In this study we introduced some experiments evaluating the effects of evaporation stimulators on basin-type solar stills. Experimental factors are as follows,

- ultrasonic oscillator attached to the bottom of the basin as evaporation stimulator,
- solar radiation absorber in a water basin,
- additional evaporative surface.

Furthermore, we made some numerical calculation for performance of solar stills by using heat balance equation, and compared the results of calculation with those of experiments.

2. Method

A. Experiments

①Experiments on the ultrasonic oscillator and radiation absorbers as the evaporation stimulator

The experiments consisted of following three steps.

i. Basic experiment using a ultrasonic bath in a constant temperature and humidity chamber

To examine the evaporation stimulating effect of ultrasonic oscillation, we compared the evaporation losses from the ultrasonic washer's bath(157mm × 157mm × 77mm) in a constant temperature and humidity chamber of 30℃ and 80%RH when the ultrasonic oscillation was on and off.

ii. Laboratory experiment

To examine the evaporation stimulating effect of ultrasonic, we measured the output of desalinated water from the solar still of which the water basin was ultrasonic-oscillated. In the laboratory, we set up the double-slope solar still model which had a 460mm × 970mm basin equipped with a ultrasonic oscillator(40W, 38kHz) and lightened by five 200W electric bulbs and measured output of desalinated water and temperatures of basin water, inside and ambient air of still.

*Inst. of Agric. &Forest Eng., Univ. of Tsukuba, Ibaraki 305, Japan (Fax: +81-298-55-2203)
**Master's Program in Bio-system Studies, Univ. of Tsukuba, Ibaraki 305, Japan

Simultaneously we examined three types of black materials as solar radiation absorber in the basin. One of the absorbent materials was a black plastic sheet set on the bottom of the basin, the 2nd one was a black plastic net set in the basin and the last one was a black perforated plastic sheet set on water surface.

iii. Outdoor experiment

The same type of solar still was set up in the natural weather condition, and we measured the output of desalinated water, and environmental and apparatus conditions, which were solar radiation intensity, wind speed and temperatures of basin water, covering film, inside and ambient air of stills. The data logging system were set up using an auto-weighing balance and a computer. All signals were taken every 10 minutes and recorded on floppy disk in the data logger.

②Experiment on additional evaporation surface of water basin

To examine the effect of wet cloth standing vertically on the basin as additional evaporative surface on the productivity of desalinated water in solar stills, we set up new experimental models which were single-slope solar still models with a 300mm×400mm basin. One is covered by rigid plastic film and the other by flourine containing film. Both models were set in the natural weather conditions, and the same factors were measured with the same method as the former experiment.

B. Calculations

The heat balance on basin water in the solar still can be expressed as following Eq.(1), assuming no ventilation and neglecting temperature gradients in covering film and water.

$$\frac{C_w dT_w}{A_w d\tau} = \eta_o I - U_t(T_w - T_s) - U_b(T_w - T_a) \qquad (1)$$

Heat-transfer calculations for the solar still were carried out over regular time intervals of one hour. The temperature of water in the basin at the end of an hour is obtained by integrating Eq.(1), assuming that the values of the heat-transfer coefficients remain constant over the interval.

$$T_{wf} = \left[\frac{\eta_o \bar{I} + U_t \bar{T}_s + U_b \bar{T}_a}{(U_t + U_b)}\right] + \left[T_{wi} - \frac{\eta_o \bar{I} + U_t \bar{T}_s + U_b \bar{T}_a}{(U_t + U_b)}\right] \times \left[\exp - \left(\frac{U_t + U_b}{C_w}\right)\tau\right] \qquad (2)$$

where T_{wi} and T_{wf} are the initial and final temperatures of water, $\overline{T_a}$ and $\bar{I}$ are respectively the average ambient temperature and the average solar radiation for the interval.

The calculations were made on following steps.

a. Ambient temperature and solar radiation were inputted as weather conditions.

b. The convective heat transfer coefficient outside of the still was assumed to be constant.

c. Temperature of water in the basin at the end of an hour is obtained by Eq.(2).

d. Heat losses through base and sides of the still were assumed to be constant, and the ventilation heat loss was neglected.

3. Results and Discussion

A. Experiments

① Results on the ultrasonic oscillator and radiation absorbers as the evaporation stimulator

Table 1 shows the evaporation losses and average water temperatures of ultrasonic bath which was set in the constant temperature-humidity chamber. The water temperature of bath loaded with ultrasonic oscillation was 5～6℃ higher than that without ultrasonic oscillation. The evaporation loss with ultrasonic oscillation was 15.7kg/㎡·day and that without oscillation was 3.60kg/㎡·day. In such an open system within the chamber, the evaporation loss from ultrasonic oscillated basin was 4.4 times higher than that from the non-oscillated one. Evaporation stimulating effect of ultrasonic oscillation was apparently demonstrated in this condition.

Table 1 Differences between the evaporation losses with and without the ultrasonic oscillation

	Ultrasonic Oscillator On	Ultrasonic Oscillator Off
Evaporation Loss	15.7 kg/㎡·day	3.60 kg/㎡·day.
Water Temperature	32.2℃	26.6℃

Table 2 shows the effects of radiation absorber and ultrasonic oscillation on water productivity of stills. Productivities increased by about 20% when ultrasonic oscillation was loaded for every three types of radiation absorber in the basin. Effect of ultrasonic oscillation on productivity of desalinated water was clearly demonstrated at the indoor condition.

Table 2 Effects of radiation absorber and ultrasonic oscillation on productivity of fresh water

	Productivity of fresh water (kg/㎡·day)			
	No absorber	Black plastic sheet on the bottom of basin	Black plastic net in the basin	Black plastic perforated sheet on water surface
Ultrasonic Oscillator Off	1.80	1.91	2.21	2.23
Ultrasonic Oscillator On	2.07	2.29	2.60	2.74

Table 2 also shows the effect of solar radiation absorber. In comparison with no absorber condition, productivity of pure water using black plastic perforated sheet on water surface increased by about 20% without ultrasonic oscillation, and increased by about 50% with the ultrasonic oscillation. Effect of black materials in a basin as solar radiation absorber on productivity of fresh water was clearly demonstrated at the indoor condition.

Fig.2 shows the results of outdoor experiment. Productivies increased by about 10% when ultrasonic oscillation was loaded to the basin. But this result is not so clear and not steady compared with the results of the indoor experiments.

②Results of the experiments on additional evaporation surface of basin

Fig.3 shows the effect of wet cloth standing vertically on the basin as an additional evaporative surface. Productivies increased by about 35% when the wet cloth was added to the basins of stills using both types of covering materials, rigid plastic film and flourine containing film.

B. Calculations

Fig.4 shows the temperatures and water outputs of the still calculated and measured. Measured ambient temperature and solar radiation data were used for calculation. And we assumed the solar still's optical efficiency $\eta_o = 0.84$, wind heat-transfer coefficient $h_w = 18 W/m^2 \cdot K$ and heat-transfer coefficient through base and sides $U_b = 6 W/m^2 \cdot K$.

As shown in Fig.4, calculated values fairly fit the result of measurement. This calculation method seems to be useful for estimating the temperature of basin water and output of water. But some differences between calculated and measured value were partly due to the assumed constant h_w and neglected temperature gradients in covering material and basin water.

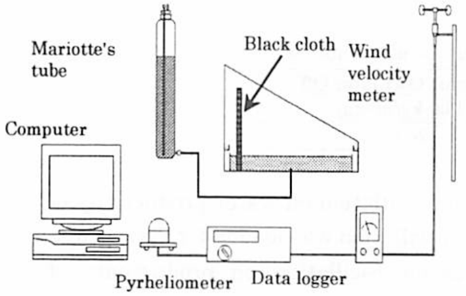


Fig. 1 Experimental apparatus of a single-slope model with additional evaporative surface

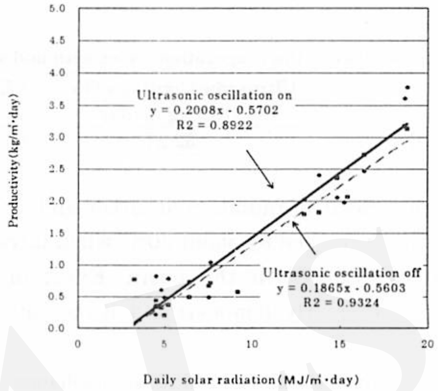


Fig.2 Effect on productivity of ultrasonic oscillation

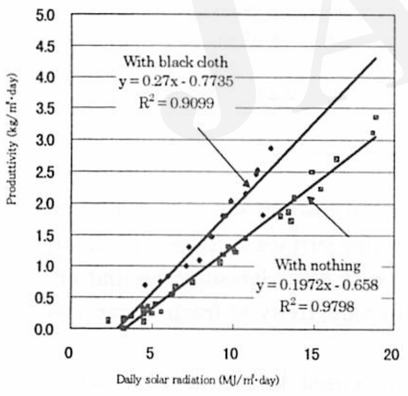


Fig.3 Effect on productivity of additional evaporative surface with a rigid plastic film covered still

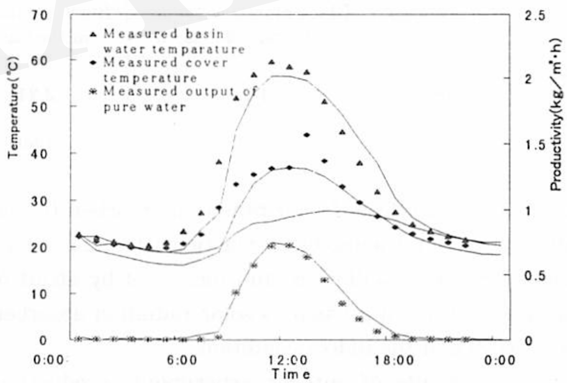


Fig.4 Calculated results and measured values (98/6/30)

References

1) YAMAGUCHI, T., YOKOTA, M., ABE, Y. and YOKOTA ,S. (1997) : *Abst. of 1997 meeting, Jap. Asso. Arid Land Studies*, 4-5.

2) YAMAGUCHI, T., YOKOTA, M., ABE, Y. and YOKOTA ,S. (1998) : *Journal of Arid Land Studies*, 7s, 85-88.

3) SHARMA, V.B. and MULICK, S.C. (1993) : *Journal of Solar Energy Engineering*, 115, 231-236

沙漠研究 10S, 37-40 (2000)
Journal of Arid Land Studies

—Special Issue— "Desert Technology V"
Refereed Paper

Amelioration of Natric Soil Horizons by *Lepidium latifolium*

Robert R. BLANK* and James A. YOUNG*

Abstract: - *Lepidium latifolium* (perennial pepperweed) is a crucifer native to Eurasia. Presently, the weed is aggressively invading wetland and riparian habitats across the western United States. *L. latifolium* readily invades saline and sodic soils and has caused hard and compact natric soil horizons (sodium affected) to become less distinct and more friable. This amelioration is accomplished through differential plant elemental cycling. Compared to plant communities being replaced, *L. latifolium* has decreased soil sodium content and increased the soil calcium content (reduced sodium adsorption ratio) of the natric horizons. This positive aspect of *L. latifolium* invasion is offset by loss of species diversity, wildlife habitat, and economic losses to farmers and ranchers.

Key Words: sodic soils, sodium, calcium, SAR.

1. Introduction

Lepidium latifolium L. (perennial pepperweed, also called tall whitetop) is a crucifer native to southeastern Europe and Asia that has become widely distributed in western North America and in coastal New England. During the past two decades, the species has spread rapidly in the Pacific coastal and intermountain states (Young et al., 1995). Perennial pepperweed plants are from 0.4 to 1.0 m tall, with a multitude of stems forming dense thickets (Young et al., 1997). The plants have extensive underground rhizomes that radiate in all directions from a newly established plant. Aerial shoots emerge from buds along these spreading rhizomes. In two seasons, a single established plant becomes a small colony, up to several meters in diameter. Tillage results in multiple sprouts from cut rhizomes. In the Honey Lake Valley of northeastern California, seed production from stands of 200 stems m^{-2} was calculated to be 16 billion seeds ha^{-1}. Field infestations of perennial pepperweed form almost pure colonies with virtually no species diversity. Its height and density suppresses light reaching the soil surface, which may be a factor in its competitive potential. Although the weed dies back annually, old stems remain to shade the soil surface. In habitats where perennial pepperweed invades, it generally replaces perennial grasses including highly competitive species such as quackgrass (*Elytrigia repens* [L.] Nevski). This project was begun to understand the autecology of this highly invasive species to facilitate long-term control strategies (Blank and Young, 1997). This report summarizes information which indicates that *L. latifolium* invasion ameliorates sodic soil properties.

*USDA-Agricultural Research Service, Exotic and Invasive Weeds Research Unit, 920 Valley Road, Reno, NV 89512, U.S.A. blank@scs.unr.edu.

2. The Study Area

Research was largely done at the Honey Lake Wildlife Refuge, California, approximately 74 km north-northwest of Reno, Nevada. Honey Lake, at an elevation of 1234 m, is a remnant of an immense Pleistocene lake which covered much of northwestern Nevada and adjacent California. Parent materials are largely fine-textured, saline, lacustrine sediments with local influence by aeolian deposits and reworked, coarse-textured, beach and offshore deposits. The topography is nearly level to very gently undulating and interrupted by low swales associated with the distributary system of the Susan River. Honey Lake is arid averaging 23-30 cm of precipitation per year. The area is frequently flooded from spring snowmelt off the Sierra-Cascade mountains to the west via the Susan River. The principle soils include the Standish series (fine, smectitic, mesic, Xeric Natrargids), the Honiak series (fine-loamy, mixed, mesic, Aquic Natrargids), the Bobert series (fine-loamy mixed, mesic, Durinodic Xeric Natrargid), and the Humboldt series (fine, smectitic, calcareous, mesic, Fluvaquentic Endoaquolls). Native vegetation includes black greasewood (*Sarcobatus vermiculatus* [Hook.] Torrey), inland saltgrass (*Distichlis spicata* [L.] Greene), basin wildrye (*Leymus cinereus* Schribner & Merr.), and rushes (*Juncus* sps.). Land use includes pasture, hayland, and cropland.

3. Natric Horizon Amelioration

Our first hint that *L. latifolium* invasion had altered soil properties was when we compared adjacent invaded and non-invaded pedons (Table 1). Sites occupied by *L. latifolium* for more than five years had greater surface accumulation of plant litter, darker, more organic-rich surface mineral horizons, and generally lower pH values than sites occupied by native vegetation. Most interestingly, the hard and compact natric subsurface soil horizons (Btn) characteristic of this environment (natric horizons have greater than 15% exchangeable sodium on the clay complex) had become softer and less distinct in *L. latifolium* invaded soils.

Table 1. Pedon descriptions of *L. latifolium* invaded and paired non-invaded sites.

Horizon	Depth (cm)	pH	Structure	Consistence	EC (dS m^{-1})	% N	% C	C:N
				Invaded area				
O	0+5	7.37			1.3	2.45	32.7	13.3
A	0-15	7.78	granular	soft	5.8	1.55	14.2	9.2
Bty	15-28	7.63	prismatic	hard	8.0	0.33	3.8	11.1
Bt	28-56	7.49	prismatic	hard	12.0	0.03	0.4	15.1
BC	56-76	7.37	blocky	slightly hard	11.8	0.02	0.3	12.8
C	76-107+	7.04	blocky	slightly hard	22.0	0.03	0.3	10.4
				Adjacent non-invaded area				
A	0-6	8.01	granular	slightly hard	5.4	0.99	14.0	14.2
Btn	6-18	7.85	columnar	very hard	3.4	0.27	3.5	12.9
Bt1	18-33	7.83	prismatic	very hard	2.5	0.03	0.5	18.8
Bt2	33-48	7.95	prismatic	hard	2.4	0.01	0.4	11.0
BC	48-69	7.90	blocky	slightly. hard	3.6	0.01	0.4	59.7

To deduce mechanisms involved with natric horizon amelioration we compared soil-solution solutes, by depth, between paired invaded and non-invaded areas occupied largely by *Elytrigia elongata*. Invasion by *L. latifolium* significantly reduces soluble sodium content (Fig. 1) and significantly increases soluble calcium content (Fig. 2) for most soil depths. Lowered sodium and elevated calcium combine to significantly reduce the sodium adsorption ratio (SAR) especially of the 15 to 30 cm depth which encompasses the hard and compact natric horizon (Fig. 3). Reduction of the SAR has been shown to decrease soil dispersion resulting in more favorable soil physical characteristics.

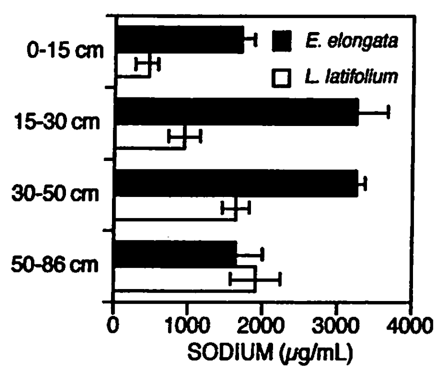


Fig. 1. Aqueous-soluble sodium by plant microsite and soil depth. Error bars are one standard error.

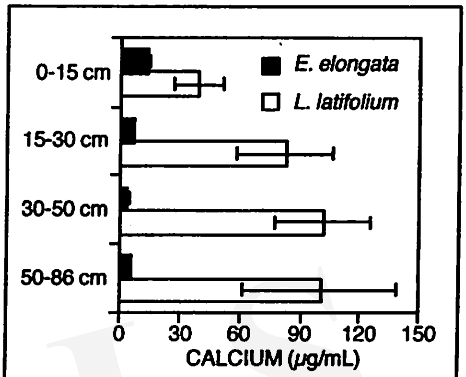


Fig. 2. Aqueous-soluble calcium by plant microsite and soil depth. Error bars are one standard error.

To further clarify the mechanisms of natric horizon amelioration we compared *L. latifolium* root-sap solutes with solutes in the surrounding soil (paste extract) by soil horizon (Fig. 4). Except for the A and C horizons, the Na/Ca ratio of root sap is far below that of the surrounding soil. Combine this information with the visual observation that perennial pepperweed has fine roots and extensive root coverage of the soil matrix in Btn horizons and a picture emerges. With continual root turnover, the chemistry of the Btn horizon will converge toward that of root sap; the natric horizon will have a lower Na/Ca ratio, thereby improving its physical properties.

4. Discussion

Soil, the climate it is exposed to, and the flora and fauna it supports are inexorably linked (Jenny 1941). Plant invasions are occurring at an unprecedented rate (Vitousek et al., 1996). Can invasion of an area by exotic plant species such as *L. latifolium* change soil evolution? Our data indicate that *L. latifolium* ameliorates natric soil horizons. It appears to accomplish this feat by increasing the ratio of Ca/Na within the natric horizon either through leaching from decomposing litter or possibly from root exudation directly into the Btn horizon. Other plants have been shown to ameliorate sodic soils in relatively short time. For example, plantations of the leguminous trees *Prosopis juliflora* and *Acacia nilotica* used for fuelwood in India, significantly reduced soil pH and exchangeable sodium in less than five years (Garg and Jain, 1992). It would appear that amelioration of natric horizons would be a positive aspect of perennial pepperweed invasion, although unquestionably there are many negative effects, including loss of species diversity, loss of wildlife habitat, and economic losses for agricultural crops. Nonetheless, perennial pepperweed is an example of how changes in the vegetation factor in soil genesis can radically alter soil evolution with perhaps lasting consequences.

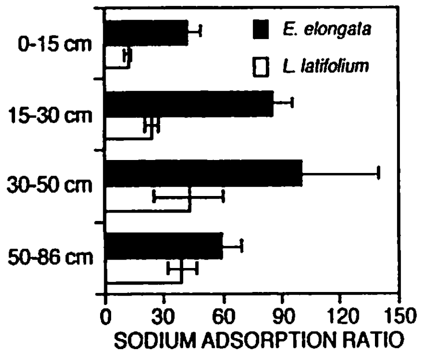


Fig. 3. SAR by plant microsite and soil depth. Error bars are one standard error.

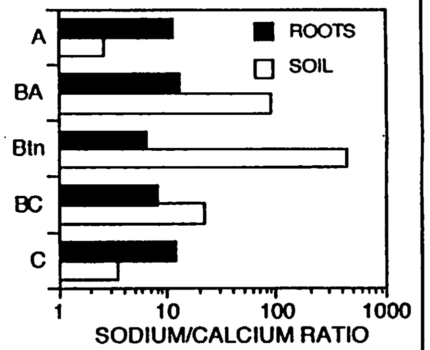


Fig. 4. Aqueous-soluble ratio of sodium to calcium, by soil horizon, in *L latifolium* root sap and soil.

References

Blank, R.R. and Young, J.A. (1997): Plant Invasions: Studies from North America and Europe, Backhuys Publishers, Leiden, The Netherlands, 69-80.

Garg, V.K. and Jain, R.K. (1992): Canadian Journal of Forest Research, 22: 729-735.

Jenny, H. (1941): Factors of Soil Formation. McGraw-Hill, New York.

Young, J.A., Turner, C. E., and James, L.F. (1995): Rangelands, 17:121-123.

Young, J.A., Palmquist, D.E., and Wotring, S.O. (1997): Plant Invasions: Studies from North America and Europe, Backhuys Publishers, Leiden, The Netherlands, 59-68.

Vitousek, P.M., D'Antonio, C.M, Loope, L.L. and Westbrooks, R. (1996): American Scientist, 84: 468-478.

沙漠研究 10S, 41-44 (2000)
Journal of Arid Land Studies

–Special Issue– "Desert Technology V"
Refereed Paper

Study of Salt and Water Movement in Saturated Soil with New Method of Irrigation of Halophytes

Tsuyoshi MATSUMOTO*, S.SINHA*, Toshinori KOJIMA*[1],
Shigeru KATOH* and Hiroaki WAKABAYASHI**

Abstract - In the present paper, a new method of underground saline water irrigation to grow halophytes is advanced as an effective way of afforesting inland deserts. Vertical infiltration behavior of water as well as salt through saturated soil is presented for an effective designing of such systems. Variation of water content in the root zone area shows that water content goes down with increase in salinity of underground irrigation. However, the salinity in the root zone area is always found to be less than the salinity of irrigated water. Results show that underground irrigation would be more efficient and less salt is likely to accumulate in the root zone as compared to surface irrigation.

Key words: Desert greening, Halophytes, Salt accumulation, Water movement

1. Introduction

The rise in population pressure over the years has grossly offset the rise in irrigated area. While there has been a five fold increase in irrigated area since 1900, its distribution per capita has decreased by approximately 10%. Even, average grain production per capita has declined since 1984. These facts indicate that waste lands may need to be used for carbon sequestration in the future. For example, deserts constitute 22% of world's land area (World Resources, 1990), where growing crops can be conceived as a last priority due to economic considerations and efforts required.

Several adverse environmental and climatic changes have been attributed to greenhouse gas emissions by the scientific community. Efforts are now directed to reverse the trend for the welfare of future generations. Desert greening is being perceived as one of the major counter measure which has many other associated positive aspects. It has the potential for more energy food and water. One of the most important peripheral benefits of desert greening will be development of fresh water resources. Afforestation is likely to change the micro-climate of the region attracting rainfall. In particular, afforestation-induced mountain rainfall is likely to encourage water evaporation on the alluvial slopes of desert ranges. Such a phenomenon would fulfill the basic aspiration to bring fresh water to desert zones. A great deal of effort has been expended on its development, but so far there has been little evidence of significant progress for large-scale implementation. Lack of technique to initially secure adequate fresh water at the plantation site is the major reason for this failure. However, nature has provided potential solutions to all such problems. In this present paper, cultivation of halophytes on a large scale using sea water and underground reserves of brackish water is advanced to green both coastal and inland deserts.

Halophytes are salt tolerant plants and can only be grown in saline water irrigation and/or saline soils. They can be used as a new food and forage crop for biomass production, improving soil fertility as well as carbon sequestration (Reimold and Queen, 1974). Natural productive halophyte habitats are wetlands and mangrove swamps which receive saline tidal irrigation, occupying less than 10,000km^2. It has been established that when halophytes are provided with supplemental brackish/sea water irrigation, the same species that are unproductive in a natural setting often yield as high as any agronomic crop. Several species of halophytes have been

[1] Author to whom all correspondence should to be made
*Dept. of Industrial Chemistry, Faculty of Engg, Seikei Univ., 3 Kichijoji Kitamachi, Musahino-shi, Tokyo180-8633 JAPAN, Tel: 0422-37-3758, Fax: 0422-37-3871, E-mail: Kojima@chgw.ch.seikei.ac.jp
**Dept. of Environmental Engg., .Kanazawa Institute of Technology, Ishikawa 921,JAPAN

investigated for their production and utility by different authors (Douglas 1993; Glenn et al. 1994; Sqires 1994, Ayoub and Malcolm 1993). However, the amount of carbon fixed by halophyte communities is low compared to other major world ecosystems because the coastal and salt deserts, while occupying vast areas of the world, have very low rates of biomass production per unit of land area. Nevertheless, experiments on halophyte plantation have shown that the carbon fixation can be achieved up to 5 t/ha/yr with sea water irrigation and even higher removal rates can be achieved at lower saline water irrigation. Pilot scale, sea water-irrigated plantings of halophytes have been undertaken in Kalba, United Arab Emirates and Kino Bay, Mexico. From the available data it appears that large scale plantation does not have technological and economical difficulties. The effect of such plantations on the environment is currently under evaluation.

Excessive and inappropriate irrigation have always been the major cause of rising salinity in the arable land and the same can be in the case of desert plantation where even brackish water availability is limited. Underground subsurface irrigation to grow halophytes using saline water and/or sea water for inland deserts has been proposed in the present communication and vertical infiltration behavior through saturated soils essential for designing of halophyte plantation is suggested. The variation of salt and water content in the plantation area during irrigation is also presented to show that this method of irrigation is better than surface irrigation.

2. Experimental set up

The proposed design of irrigation for halophyte is shown in the Fig. 1. In this design, it is considered that the underground water will maintain the water content of the soil by capillary action and evaporation mechanism. Salinity in the root zone is expected to be less than the salinity of the sea water or saline water applied for underground irrigation because there will not be evaporation of saline water on the surface as in the case of surface irrigation. These factors would enhance the productivity of the halophytes.

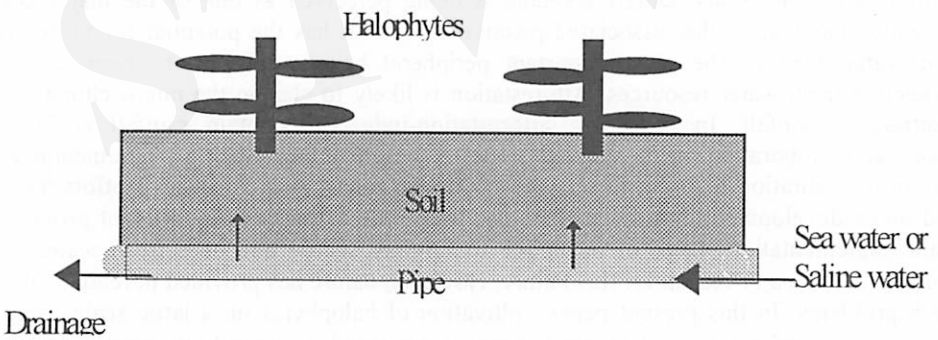


Fig. 1: Underground irrigation

To observe the effect of underground irrigation on the salt and water movement four one dimensional columns have been set up for different salinity as shown in Fig. 2. The column is of 39cm height and of 5cm diameter. Thirteen small cells of acrylic resin of 3cm height and 5cm diameter are joined to make one column. Toyoura standard sand is used for the experiment and the experiments were carried out in controlled laboratory conditions. Room temperature was kept constant at 25°C and relative humidity at 25% throughout the experimental duration. The top surface temperature of the sand was kept at approximately 40°C by infrared radiation. The behavior of vertical water movement in saturated Toyoura sand have been studied for the salt concentration of 1.5%, 2%, 3%, 4% of underground irrigation water.

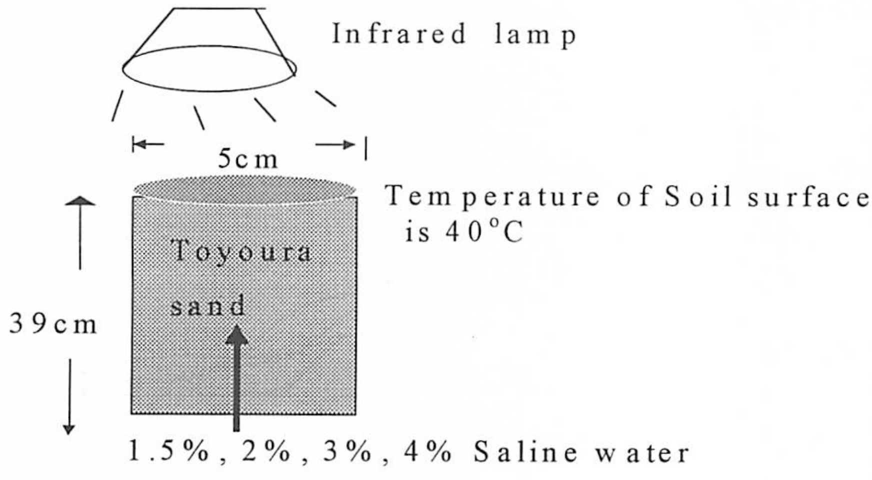
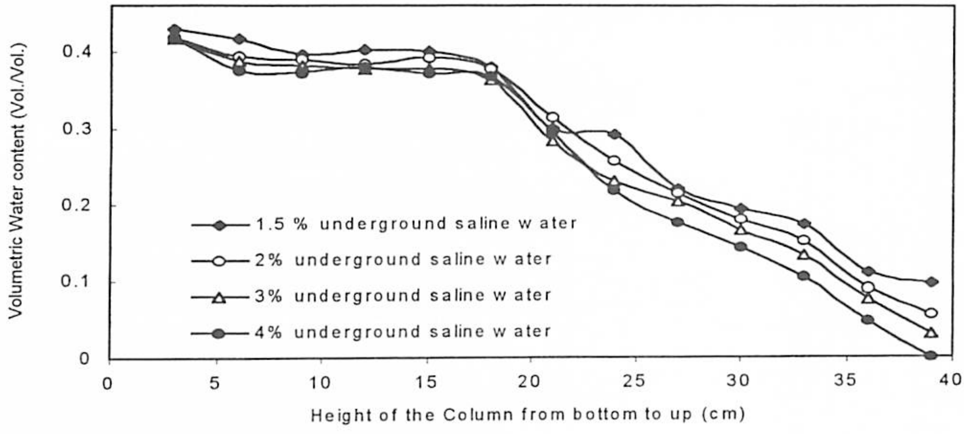


Fig. 2 Irrigation experiments of indoors

3. Results and Discussion

The volumetric water content (cm^3/cm^3) and electrical conductivity, (EC in mS/cm) at different height of the column after ten days of irradiation under infrared lamp are shown in Figs. 3 and 4, respectively. Experimental results show that in general, water content decreases with increase in height i.e., from bottom cell to the top cell. This emphasizes that the placement depth of underground irrigation is the most important factor for controlling the water content in the soil. However, a close look at Fig.3 shows that decrease in water content in the upper part cells are quite sharp, which is due to higher evaporation from this layer of soil. However, overall water content is maximum in the case of 1.5% underground saline water irrigation.



Low salinity of underground water may give rise to higher evaporation and thereby, higher water content in the upper level of soil.

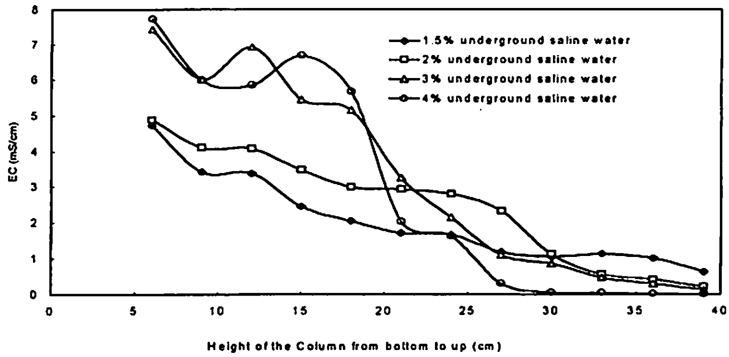


Fig.3: Variation of Volumetric Water Content with Height

Fig. 4: Variation in EC with the Height of the Column

Figure 4 shows the variation of salinity in terms of electrical conductivity (EC). EC increases with the depth of the column. EC of the topsoil is maximum in case of 1.5% saline water underground irrigation and minimum in case of 4% salinity. This is because higher evaporation gives rise to higher salt transportation in the upper layer. In case of higher saline water irrigation, evaporation remains lower and the salt transportation remains confined to the deeper cells and in turn, accumulation of high salt in the deeper layers further obstruct water movement to the upper layer. However, the salinity in all the cases is well within the limits to grow halophytes. Water content in the upper level soil layer is more important. Therefore, underground irrigation with less saline water is likely to have more positive effect. The salt accumulation and EC on the soil surface in case of underground irrigation is lower compared to surface irrigation to halophytes. Thus salinity in the root zone is also less than that of surface irrigation by saline water to halophyte. It may be concluded that underground irrigation with water of lowest possible salinity is likely to result in higher productivity of halophytes.

Acknowledgment

The investigations described in this article have been financially support by the Japanese Society for Promotion of Science to whom we are greatly indebted. Without their support, our work could not have been accomplished.

References

Ayoub, A.T. and Malcolm, C.V. (1993): Rehabilitation of degraded land and sequestering atmospheric carbon, UNEP Environmental Guidelines for halophytes for livestock.

Douglas, J.(1993): A rich harvest from halophytes, EPRI, Oct/Nov. 16-23.

Glenn, E.P., Olsen, M., Frye, R. and Moore, D. (1994): Use of halophytes to remove carbon from the atmosphere- results of a demontration experiment, EPRI TR-103310, Project 801103.

Reimold, R.J. and Queen, W. H. (1974): Ecology of Halophytes, Academic Press, INC.

Sqires, V. (1994): Overcoming salinity with salt water, Search, 25-1:9-12.

World Resources (1990): Oxford Press.

沙漠研究 10S, 45-48 (2000)
Journal of Arid Land Studies

—Special Issue— "Desert Technology V"
Refereed Paper

Cause of Oasis Desertification on the Southern Fringe of the Taklimakan Desert

QIAN Yibing* and WU Zhaoning**

Abstract: Grain size distribution, quartz oxygen isotope nature, mineralogy and chemistry were used to deduce provenance of sand materials responsible for desertification. The results indicates the mud and sand carried by the present rivers, and sandy component of oasis' ground surface with loose texture and poor cohesion serve as material condition for the occurrence and development of desertification. However, the sand sources for oasis' desertification origin from not only "the spot", but also "foreign" place of long-distance transported by wind in the process of homogenization of the Taklimakan Desert's sand materials. Finally, excessive human activities resulting in desertification of oasis are discussed.

Key Words: Cause of Desertification Oases The Taklimakan Desert

1. Introduction

The oases on the southern fringe of the Taklimakan Desert lie to the frontland of the mountains, where water systems are well developed, in the Hotian prefecture. There are several hundreds of large and small oases, which are distributed on a narrow zone over 600 km long. The peripheries of the oases are largely desert and sandy gobi. For several thousands of years, people have been suffering from desertification so that they were compelled to move away. Examples include the Niya ancient town abandoned (A. D. 4~5 century), Mazatag ancient castle becoming desert land (A. D. 25~938 years or after 11 century), as well as a vast of land desertified and the house ruins buried by sand from Song to Qing Dynasty (being seen in Cele, Luopu, Hotian and so on).

Since the last 40 years, the desert vegetation in the periphery is continuously destroyed. There is almost no herbage-bush vegetation belt between a considerable part of the oasis' periphery and the northern desert. The expansion and spread of mobile dunes result in land desertification of 167 km^2 in the margin of oases, among them, the area of cultivated land affected by desertification is 58.7 km^2 [1].

2. Environment

Since the south of the oases is separated by the Kunlun Mountains and the north has the Tianshan Mountain barrier, the oases are in a geographic environment of closed inland. Thus, the humid air currents from the south and north as well as the southeastern monsoon are difficult to reach here. In addition, the latitude of the oases is slightly low, so, the oases have higher temperature, less precipitation (30.2~48.2 mm), dry air, frequent strong winds and sand-dust storms.

The oases survive mainly from seasonal rivers, originating from the Kunlun Mountains, parallel each other, with running direction from south to north. The landscape of the upper reaches is cliff mountain land, the basement rock mainly consists of the Archaeozoic and Proterozoic schist and gneiss, Palaezoic and Mesozoic sandstone, conglomerate, as well as magmatic rocks of different ages. The erosion action in this section is strong. With the relief tending to flat, the great amount of clastic material deposit form many small river deltas, which at last join together constituting the Quaternary alluvial plain. The ground surface's material component of the oases developed on this plain is sandy sediment with loose texture, poor cohesion, thus, as soon as the wind blows, the loose sands will move. At the same time, the present water system has continuously been carrying sand material into the oases.

3. Study on Sand Material of Desertified Land

In this study, the range of collecting sample is large, in order to compare in a wide area, from not only the interior and margin of the oases, but also the northern desert of the oases and the windward area of the oases' peripheries.

* Xinjiang Institute of Ecology and Geography, CAS, Urumqi, 830011, China (Fax: +86-991-3835459)
** Xinjiang Institute of Technology, Urumqi, 830008,China

3.1. Features of Sand Material's Grain Size The results of grain size analysis (Fig.1) show that the dunes in the interior oases with large mobility take extreme fine sand as main composition. The sands of megadunes are evidently coarser, consisting of fine sand mainly, because frequent winds have brought finer sand materials to the leeward. The sands of bush vegetated dunes are finer, consisting of extreme fine sand and silt mainly, which shows that the sand is stabilized by plants. The grain size features of the dune sand near the rivers and the river sands are similar because of both relationship of the same source[2].

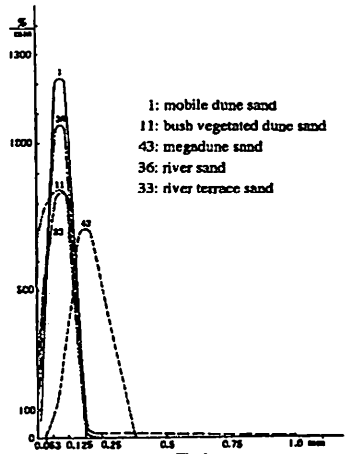


Fig.1.
The frequency distributions of sand grain size from different types of samples

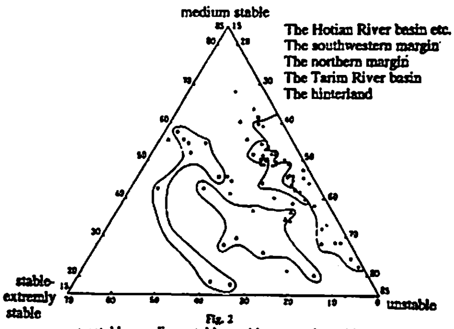


Fig.2
unstable, medium stable, stable-extremly stable mineral content diagram of sand materials

3.2. Mineral Composition of Sand Material The samples, according to different sources, can be divided into river sand, dune sand and stratum sand which are collected from the Quaternary sandy sediment underground 1 m along the river basin. The heavy minerals are: unstable minerals—amphibole, biotite; medium stable ones—epidote families, muscovite, chlorite, apatite, titanite; stable-extremely stable ones—garnet, tourmaline, zircon, rulite and so on. By comparison, it can be seen that most of river sands take amphibole, biotite and epidote families as dominant heavy minerals, belonging to unstable—medium stable series. The mineral assemblages of dune sands have difference. Generally, the heavy mineral assemblage of dune sand along the river banks are still unstable—medium stable series, then, that far from the oases are most medium stable—unstable mineral series (epidote increases and amphibole decreases). Stratum sands have two kinds of series above-mentioned [3][4]. On the other hand, the heavy mineral assemblage of dune sands in the oases on the southern fringe of the desert is similar to that of the desert hinterland and the middle-lower reaches of the Tarim River (Fig.2), and, the later two sections lie to the windward[5].

The ratio between quartz and feldspar is related to the light mineral's assemblage characteristic. The ratio of the river sands in the oases is 1.45 (average value); the dune sand along the river banks 1.38; the stratum sand 1.31; the dune sand in the oasis' periphery 1.17; the dune sand in the middle-lower reaches of the Tarim River 1.38; the desert hinterland 1.17. The light mineral assemblage, of the dune sands along the river banks, the river sand and the stratum sand are very similar, and, that of dune sands in the oasis' peripheries and the desert's hinterland are almost the same.

3.3. Chemical Composition of Sand Material The sand samples are respectively collected from the river sand, the flood-plains (including the Quaternary sandy sediments underlying) and the dune sand along the river banks. Table 1 shows the main chemical composition of the dune sand is closed to that of the flood plain. After further comparing, it can be seen that there is no evident difference between chemical composition of the dune sand and that of river sand, and the former is fluctuated on the latter (Tab. 2).

Tab.1. Some oxide contents for sand materials (%)

Location	Sediments	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	K_2O	Na_2O	TiO_2	P_2O_5	n
The Hotian River and Keliya River Basin	Dune sand	10.62	2.81	0.07	1.93	6.92	2.21	2.51	0.41	0.09	28
	River sand	11.15	3.49	0.08	2.07	7.09	2.30	2.33	0.45	0.13	13
	Flood plain sand	10.60	2.81	0.06	1.94	6.92	2.28	2.37	0.41	0.12	14

Tab.2 The main chemical composition of sand material in the Hotian River basin

No.	Sand type	Grain size (mm)	Frequency (%)	Al_2O_3	K_2O	Na_2O	CaO	MgO	Fe_2O_3
15	River sand	0.25~0.06	76	12.00	2.60	2.50	6.00	1.80	3.10
3	Dune sand	0.17~0.06	81	11.75	2.45	2.10	7.90	2.20	3.30
19	Dune sand	0.17~0.06	80	11.50	2.70	2.15	8.05	2.23	3.25
20-1	Dune sand	0.25~0.13	89	11.50	2.10	2.40	5.55	1.45	2.95

3.4. Oxygen Isotope Composition of Quartz in Sand The samples of basement rock are collected from the mountain zone in the upper reaches of the Hotian River. The samples of sand are from the dunes on the flood plains and the riverbanks. Table 3 indicates the $\delta^{18}O$ values of quartz for 5 samples are near, which all settled in the range of $\delta^{18}O$ for metamorphic quartz (Taylor, 1967)[6]. It is related to the Archeozoic gneiss and the Paleozoic schist, which are widely distributed in the upper reaches of the rivers[7].

Tab.3. Oxygen Isotope Composition of Quartz in Sand Materials and Basement rock

No.	Sample type	Quartz content (%)	Grain size (mm)	$\delta^{18}O$ SMOW (‰)	Mean
9	Mica-schist	35.8	0.09-0.3	+17.8	
11	Biotite-gneiss	4.6	0.14-0.3	+15.9	16.9
12	Potash-feldspar granite	21.8	0.25-0.96	+11.5	
15	River sand	-	0.16-0.25	+12.3	
19	Dune sand	-	0.08-0.11	+13.3	
18	Dune sand	32.3	<0.06	+15.1	13.2
3	Dune sand	-	0.08-0.11	+13.2	
20	Dune sand	-	0.16-0.25	+11.9	

The analyses above-mentioned show the sand materials for desertification in the oases mainly evolve from the river sands and sandy sediments of ground surface. The morphology and microtexture features of quartz-grained also prove the conclusion. The roundness of quartz in the oases is not high, being mainly secondary edges-corners to secondary rounded ones, and the microtextures commonly keep the imprints of glacial and river actions. Some similarity of the sand materials from the dunes of the oases and the windward such as the desert hinterland and others, again indicates the sand materials for desertification come from not only "the spot", but also "foreign" place of long-distance transported by wind in the process of homogenization of the Taklimakan desert's sand materials.

4. Man-made Factors in Desertification

Except for the disadvantage of natural conditions, a human hand is important factor in the oasis desertification.

4.1. Irrational Utilization of Surface Water Resources Since water conservancy facilities is poor, surface water resource are not well utilized. The drought of the spring season is severe, however, when the summer flood season comes, there is still no water discharging to the peripheries of the oases. Vegetation can not get irrigation, thus die, and, wind erosion can occurs at any time.

Riverbeds or lakes not cleansed by running water become *tamarix* sand corn and mobile dunes.

4.2. Blind Reclamation of Wasteland Blind reclamation, especially reclamation by destroying forests not only destroys "green protective shelter", resulting in forestland to draw back, but also loosens sandy ground surface, making the land susceptible desertified. New reclaimed lands are gradually wasted due to lacking of water, at last they change into sand-shifting land. According to statistics, the area of the reclamation by destroying forests is 520 km^2 in 1960, now the most have been abandoned to cultivate.

4.3. Overcutting Trees Most of residents in the oases have been taking forestwood as fuel, so, the phenomenon of overcutting *Tamarix* and *Populus diversifolia* is very severe. For example, *Populus diversifolia* forest in the middle-upper reaches of the Hotian River was 106.7 km^2 in the beginning of the 50's, only 11.7 km^2 was left in the beginning of the 80's. Because fuel is scarce in the oases, people fell *Tamarix* forest in the peripheries of the oases and even in the depths of the desert, so that, the desert vegetation in the peripheries of the oases are basically lost. On the other hand, in the last ten years more, people indiscriminately dig licorice root along the river banks, making its regrowth difficult, in addition, ground surface is loosened so that a vast of land is gradually desertified under action of wind force.

4.4. Population Growth The population of Hotian oases increases from 661,900 in 1949 to more than 1,200,000 in 1980. The overrapidness of population growth intensifies the development to water, land and biological resources in the way of plunder, which hastens environmental deterioration.

Lack of an environmental ethos also hasten the process of land desertification. For example, people randomly clear away mud and sand in the beside of farmland's irrigation canal and the river courses abandoned, under wind action, the dunes and sand-shifting land are formed in the interior oases.

5. Conclusion

To sum up, dry and windy climate condition, loose sandy ground surface and rich sand sources are all the latent natural factors of desertification occurrence and development. As soon as human beings damage the fragile ecological equilibrium of the oases, these latent factors will be aroused and activated, land desertification will occur and develop.

References

[1] ZHOU, X. et al (1989): Deterioration of desert environment in Xinjiang, its harmful and countermeasures concerned. Research on Ecological Environment in Xinjiang, Beijing: Science Press, 121-125 (in Chinese).

[2] QIAN, Y., ZHANG, X., LI, X. (1995): A study on grain-size features of sand material of the oases in the oases in the southern margin of the Taklimakan desert. Journal of Desert Research, 15-2:131-134.

[3] QIAN, Y., T. Ishii, K. Mizuno (1991): A preliminary study on the origin of sand in the Hotian River basin of the Taklimakan desert. Arid Zone Research, 8-4:50 (in Chinese with English summary).

[4] WU, Z., QIAN, Y. (1992): Geochemical studies of various sand sediments in the Hotian River and the Keliya River basins. Arid Land Geography, 15-4:72 (in Chinese with English summary).

[5] QIAN, Y., WU, Z., T. Ishii et al (1993): The constituent characteristics of sand materials and sand sources of the Taklimakan desert. Journal of Desert Research, 13-1:34-38 (in Chinese with English summary).

[6] Brownlow, A.H. (1979): Geochemistry. USA: Prentice-Hall, Inc., 58-70.

[7] QIAN, Y., WU, Z., K. Okumula, Y. Matsuhisa (1993): The chemical composition of amphibole and oxygen composition of quartz in sands and bedrock in the Hotian River basin. Arid Zone Research, 10-2:24-25 (in Chinese with English summary).

沙漠研究 10S, 49-52 (2000)
Journal of Arid Land Studies

— Special Issue — "Desert Technology V"
Refereed Paper

Salt and Water Movement in Desert Plantation: Effect of Distillate Water Produced By Recycled Waste Material

S. SINHA*, T. MATSUMOTO*, H.HAMANO* and T. KOJIMA*

Abstract – Sustaining the productivity of plantations under changing micro-climate of arid areas and deserts in would need concerted and coordinated efforts. In the present paper, a unique application of commonly used pet bottles for drinks, is proposed for solar distillation and subsequent distillate application to salt leaching and afforestation. Laboratory experiments are conducted to study water and salt movement under various conditions. It is concluded that distilled water as low as 5ml/day gives rise to higher salt deposition on the upper surface and can be used effectively for salt leaching. The effect of leaching combined with underground saline water irrigation maintains salt content below 2mS/cm and water content enough for plantations in sandy soil.

Key words: arid areas, salt leaching, underground irrigation, solar distillation, afforestation

1. Introduction

One third of the land in the world today falls in the category of dry lands or prone to desertification. With increase in population pressure, it has become more and more imperative to reclaim these lands for developmental activities without causing any environmental aberrations. Deserts are the natural destination of scientists working on the menace of Green House Effects for large-scale plantations as a sink to fix the atmospheric of Carbon Dioxide (KOJIMA, 1998). But sustaining the productivity of plantations under changing micro-climate of arid areas and deserts in sustainable manner would need concerted and coordinated efforts. In the present paper, a unique application of commonly used pet bottles for drinks in particular and otherwise uses, is envisaged for producing distillate for surface/drip irrigation. The movement of salt and water is investigated further for possible application of distilled water in salt leaching and desert plantation. This unique method uses waste materials, solar energy, brackish water and minimum manual control and reduces environmental hazards (associated with disposal of pet bottles), have the potential to change the micro-climate of deserts and reduce the aberrations caused by high level of Carbon Dioxide concentration in the atmosphere. The minimum distillate from single pet bottle has been found to be more than 10 ml per day under desert like conditions with surface temperature as low as 40°C. Laboratory experiments are conducted to study water and salt movement under four conditions including a combination of surface and underground irrigation. The results show that the method can be used not only for irrigation of plantation but also for salt leaching in arid areas.

2. Salinity and Irrigation

Salt accumulation in soil leading to desertification has long been a serious problem in arid and semi-arid areas besides heavily irrigated or otherwise fertile areas (FAO/UNESCO, 1967). The first step to address the salinity problem is to determine the exact cause of salinity and to eliminate it. Thereafter, steps are taken for the reclamation such as leaching soil by saturating with water or using chemical reagents. Water has often been used to solve salinity problems as though there is no limit to its availability. The result on irrigated lands is often a harmful concentration of salts within the topsoil where most crops get nutrients. Soil salinity is most serious in arid and semi-arid regions where surface water is scarce and ground water tends to be saline. No more than 7×10^9 ha of land are arable on the earth and only 1.5×10^9 ha of land is cultivated while, 10% of the arable land (59% of cultivated land) are either saline or sodic. Human activities are responsible for saline conditions on about 77 million hectares globally, of which about 45 million hectares are in irrigated areas (TANJI, 1990). Most of the water in the hydrosphere is salty (97.3%), and much of fresh water (only 2.8%) is frozen 77.2% and 22% in ground water basin, much of which are economically irretrievable. This leaves only small percentage of readily manageable fresh water as a resource of water supply. Similarly, to purify the brackish water various techniques like ion-exchange or membrane separation method can be applied but they may not be economically feasible.

*Dept. of Industrial Chemistry, Faculty of Chemical Engg, Seikei Univ,3, Kichijoji Kitamachi, Musashino-shi, Tokyo 180-8633, Japan. FAX: 81-422-37-3871, E-mail: kojima@chgw.ch.seikei.ac.jp

Recent field studies on salinity assessment indicate that the spatial and temporal distribution of soil salinity is strongly correlated to irrigation and soil properties. In most tracts, some salts are inherent in the soil profile making it difficult for leaching where fresh water availability is scarce. If they are in the root zone, it is necessary to wash them down before irrigated agriculture can be successfully developed. Ideally, the volume of water is applied directly to the root zone in quantities that approach the consumptive use of the plants. Through good management of the micro irrigation systems the root zone moisture content can be maintained near the field capacity throughout the season providing a level of water and air balance close to optimum for plant growth. Field capacity is a point of static equilibrium. It is the water content of the soil following drainage of a saturated soil profile for about 48 hours or when downward water movement has materially ceased. For different soil texture, the field capacity differs as shown in Table 1. The water content of the soil should be maintained equal or above to the field capacity for growth of plants.

Table 1 : Density and Field capacity for a few types of soil texture

Soil texture	Bulk density(Mg/m-3)	Field capacity (%)
Sand	1.65	6
sandy loam	1.5	14
loam	1.4	22
clay loam	1.35	27
silty loam	1.3	31
clay	1.25	35

3. Experimental Setup

3.1 Pet-bottle Distillation System Commonly used pet bottles for various types of soft drinks, water etc. is used for distillation process utilizing solar energy. Various designs were experimented. However the following design is found to be the most effective one. Three 1.5 lt pet bottles of base area 49.76 cm2 each, are used to construct a small system. The system was irradiated for 8 hours by infrared radiation to maintained surface temperature 40°C. Average daily distillate output of 12ml is obtained from the system. The system is designed in such a manner that the flow of inlet brackish water can be automatically controlled in the basin. The output is expected to increase in direct sunlight since pet bottles doesn't allow full transmission of infrared radiation. On the other hand, infrared radiation heats the bottle surface, thereby, decreasing the temperature difference between the basin water and the bottle surface. Distillate output strongly depends upon this difference of temperature for condensation. In desert conditions, high wind speed and sharp decrease in temperature in evening hours has a positive effect and are likely to result in more output.

3.2 Column Experiment Thirteen individual acrylic resin tubes of 3cm height and 5cm diameter (hereafter called cell) are fixed together to form a column height of 39cm. These columns are placed over a square box of 3cm height and 11cm widths. Four such columns are filled with standard sand of average diameter 0.25 mm. Sandy soil is chosen for the present experiment since brackish water and sea water are usually available in proximity to such soil. These can be used both for distillation and underground irrigation. The sand is saturated with 5% saline water having Electrical conductivity (EC) of 76-80mS/cm. Saline water of the same salinity is used for underground irrigation through the bottom box of the columns. The specific treatments of the four columns are as follows,

Column -I : 5% saline water irrigation from the bottom; 5 ml distilled water each day surface irrigation; IR radiated for 2 days

Column -II : No underground irrigation; 5 ml distilled water each day as surface irrigation from the top; IR radiated for 14 days

Column -III: 5% saline water irrigation from the bottom; 5 ml tap water each day as surface irrigation; IR radiated for 14 days

Column -IV:5% saline water irrigation from the bottom; 5 ml distilled water each day as surface irrigation; IR radiated for 14 days

Other conditions remained the same and 305ml of saline water was required for saturating each column. The electrical conductivity of the ordinary tap water used was 170μS/cm. Temperature at the surface of the columns are maintained at 40 °C throughout the experiment. Relative humidity is maintained at 25%. Cell no. 1 represents the bottom cell and cell no. 13 represents the uppermost layer.

4. Results and Discussion

Table 2 shows the salinity (%) and total salt content of each cell of the four columns at the end of the respective periods. Total salt in column I, II, III and IV are 18.83gms, 15.23gms, 27.38gms and 24.26gms respectively. In Column II, III and IV, salts accumulate in the 13th and 14th cell. Figures 1 and 2 show the variation of EC (mS/cm) and water content (Wt %) for the columns II, III and IV. Total salt in the column II is 15.23 which is the same as the salt content of the total saline water required for saturating the column. This signifies similarity of initial conditions for each of the cells. As evident from the Fig. 1, Column II has lower salinity but as shown in Fig. 2, the corresponding water content may be too low for any productive plantation with the use of a small amount of water (~ 5 ml per day) obtained from pet bottle solar stills. This emphasizes need for underground irrigation for plantation. Therefore, in the following discussion, Column III and IV with underground saline water irrigation are only considered.

Table 2: Variation of salt content and total salt for the four columns in each cell

Cell no.	Col. - I Salt content (%)	Col. - I Total Salt (gm)	Col. - II Salt content (%)	Col. - II Total Salt (gm)	Col.- III Salt content (%)	Col. - III Total Salt (gm)	Col. – IV Salt content (%)	Col. - IV Total Salt (gm)
1	0.4775	3.26	0.305	2.104	0.29	2.01	0.296	2.06
2	0.405	1.79	0.2455	1.065	0.316	1.36	0.171	0.74
3	0.415	1.76	0.2765	1.205	0.386	1.65	0.226	0.973
4	0.2125	0.92	0.183	0.799	0.316	1.35	0.226	0.968
5	0.378	1.66	0.149	0.649	0.3205	1.38	0.271	1.21
6	0.4415	1.89	0.1515	0.680	0.3875	1.633	0.2195	0.992
7	0.3365	1.49	0.107	0.474	0.371	1.61	0.272	1.214
8	0.2635	1.17	0.0505	0.224	0.3725	1.586	0.1605	0.688
9	0.177	0.765	0.034	0.148	0.3365	1.54	0.068	0.29
10	0.13	0.546	0.0267	0.112	0.1655	0.724	0.0565	0.25
11	0.0645	0.287	0.0246	0.108	0.162	0.78	0.092	0.42
12	0.105	0.505	0.036	0.166	0.4155	1.89	0.1605	0.754
13	1.072	2.022	1.11	4.74	1.69	7.96	1.565	7.08
14	—	—	4.8	2.76	6.955	2.91	7.675	6.625

Results can best be analyzed after dividing the cells into three parts and considering effects of the underground and surface irrigation separately. Upper layer will be defined as cells 9 to 13 (approximately 15cms), middle layer, cells 5 to 8 (approximately 12cms) and lower layer, cells 0 to 4 (approximately 12cms). Each layer is having different effects of surface and underground irrigation. In the upper layer, as distilled water evaporates faster, initial salts (approximately 15gms) are leached out over the upper surface as compared to Col. no. II in which only initial salt of 15.23gms (due to saturation with 305ml saline water) is distributed all over the cell that are also evident from the result in Table 2. Accumulation of salt in case of

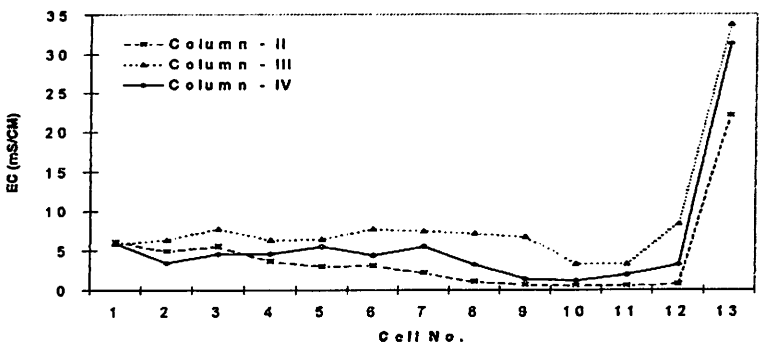


Figure 1: Variation of EC with cell no. for three columns

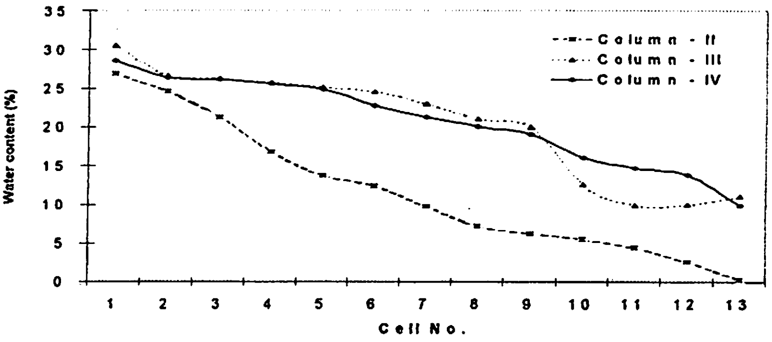


Figure 2: Variation of Water Content (Wt %) with cell no.

distilled water surface irrigation in upper layer is maximum. However, faster evaporation of distilled water reduces the effect of surface irrigation on the salt movement in the middle and lower layers. In case of tap water (column III), the effect of surface irrigation is felt to the middle layer. The evaporative effect is combined by underground irrigation. Due to evaporation taking place deep inside, salt from the underground saline water tends to be absorbed and transported to the middle layer. This explains precisely higher overall salt content in all the cells when irrigated with tap water. However, salt accumulation in the middle layer and less evaporation in the upper part reduces leaching of salt on the upper surface in case of Column III. In turn high salt concentration in the middle layer gives rise to lower evaporation from the underground water. Which is probably the main cause of low water content of upper layer in the case of tap water irrigation (Fig. 2).

5. Conclusion

It may be concluded on the basis of the results and discussion that the best way for surface irrigation would be use of fresh/slightly saline water and distilled water in rotational matter in addition to brackish underground irrigation. This would help in the transport of salt from lower to middle layers and consequently from middle to upper layers. The salt deposited at the upper layer can then be leached out. At the same time the water content would be maintained to a reasonable level due to effect of underground irrigation. However in the present paper, only a one-dimensional analysis has been put forth. To describe the salt and water movement precisely, a two dimensional approach would be more appropriate. The amount of water required for surface irrigation can be obtained from solar distillation systems easily. Its usefulness can be increased by drip irrigation since it would increase the range of the upper layer and more salt is likely to be deposited on the upper surface. Further, drip irrigation can be used to replace surface irrigation. Drip irrigation, if properly designed, minimizes salinity and matric stresses in general because the soil water content is maintained at a high level and salts are leached to the perimeter of the wetted volume, where rooting activity is minimal and these salts can be evaporated and deposited on the upper surface.

Acknowledgment

The investigations described in this article have been financially support by the Japanese Society for Promotion of Science to whom we are greatly indebted. Without their support, our work could not have been accomplished.

References

Kojima, T. (1998): The Carbon Dioxide Problem – Integrated Energy and Environmental Policies for the 21st Century, Gordon and Beach Publishers, Amsterdam.

FAO/UNESCO (1967): International Source-book on Irrigation and Drainage of Arid Lands in Relation to Salinity and Alkalinity.

Tanji, K.K (1990): Agricultural Salinity Assessment and Management, American Society of Civil Engineers, NewYork.

沙漠研究 10S, 53-56 (2000)
Journal of Arid Land Studies

—Special Issue— "Desert Technology V"
Refereed Paper

Monitoring Soil Temperature under a Stone Mulching System in Djibouti

Satoru TAKAHASHI*, Fumio WATANABE*, Hisamitsu TAKAHASHI**, Tabarek M. ISMAEL*** and Kenji FUKUNAGA*

Abstract- Soil temperature in arid zones, which somehow makes the process of greening harder because it adversely affects the germination and growth of plants. It is necessary to reduce the soil temperature below threshold temperatures to allow the germination and the growth of plants. A stone mulching system was used to cover the soil surface. This prevented evaporation, retained soil moisture and reduced soil temperature allowing germination and plant growth. We conducted this experiment in two plots: one was covered with stones and the other was not. The stone mulching process reduced soil temperature compared to the plot without stones. The size of the stones affected soil temperature, the bigger stones the greater the reduction in soil temperature. It is concluded that stone mulching may help the greening process in arid zones where high soil temperature is an obstacle by reducing soil temperatures.

Key Words : Desert Greening, Stone Mulching System, Soil Temperature, Djibouti

1. Introduction

Djibouti is located in north east Africa and in an arid climate zone, Figure1. The average annual rainfall is 138mm and the monthly air temperatures range from 25 to 35℃. The annual evaporation is approximately 3000 mm.

Since 1991 we have been conducting the re-vegetation in the Republic of Djibouti(Takahashi et al.(1995);Takahashi et al.(1998a); Takahashi et al. (1998b); Takahashi et al. (1998c)). In such an arid region, re-vegetation is important to decrease the soil temperature which slows evaporation reducing salinisation of the soil at its surface. Mulching system is one of the main processes used to manage these problems.

Fig. 1 Location Map Djibouti

There are multiple aims of this re-vegetation study using selected mulching materials. The first is to show that locally available, low cost materials such as stone other mulching materials and can be used successfully establish a planning. the second is to demonstrate that these materials are easily manipulated by local farmers or original peoples, and last that this process creates jobs, increases food production and raises the living standard for locals. According to these purposes and in harmony with local conditions, we introduced the stone mulching system using volcanic basalt rocks found everywhere in Djibouti. In this paper, we described the effect of the stone mulching system on re-vegetation by monitoring soil temperature.

* Faculty. of Regional Environment Science, Tokyo University of Agriculture, 1-1-1, Sakuragaoka, Setagaya, Tokyo, Japan . Fax: +81-3-5477-2333
**Faculty. of International Food and Information, Tokyo University of Agriculture, 1-1-1, Sakuragaoka, Setagaya, Tokyo, Japan .
***Ministry of Agriculture and Water Development of Djibouti

2. Stone Mulching System

The Republic of Djibouti lies a belt of ancient volcanos. Consequently, the rocks and soils are volcanic in origin. The volcanic rocks are composed mainly of basalt and they have been greatly weathered. Stone mulching is done by covering the soil surface with stones as shown in Photo 1. This process is followed by randomly seeding between the stones. The benefit of stone mulching system can be described as follows: -decreasing soil temperature-keeping soil moisture and preventing the evaporation from soil surface.: preventing soil erosion by water and wind -benefiting from dew water -preventing the damage of seedlings by grazing animals.

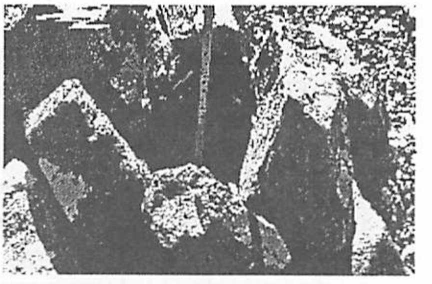


Photo-1 Stone Mulching

3. Method

In 1991 we started the desert greening process in Djibouti. The experimental plots are located in 10 km east from the capital Djibouti on a research facilities of the Ministry of Agriculture. Soil temperature were monitored between December 1, and December 23, 1995. Three plots were used : one plot was covered with big stones, 20cm of diameter, a second plot was left uncovered as the control, and the third plot was covered with small stones 5 to 10cm in diameter. The size of these plots is 1 m^2(1m x 1m). Temperature and humidity sensors were placed 5cm above the soil surface at the surface of the soil and at 5cm and 10cm below the soil surface. Temperature and humidity readings were taken hourly, every day during the period described previously. The variation of soil temperatures is analyzed by using the harmonic analysis(1996 .

4. Results and Discussion

The relation between air temperature and soil temperature in the control plot for December 14th, as an example, is plotted in Fig.2. The range of air temperature was from 22.0 ℃ to 33.3 ℃ while the soil temperature on surface was between 21.5℃and 47.3℃. At 5cm below the soil is surface, the temperature ranged from 22.8℃ to 37.9 ℃ while at 10cm below the surface the temperature varied from 27.4℃ to 34.6 ℃. The variation of the temperature is slightly different from one location to another with in each plot.

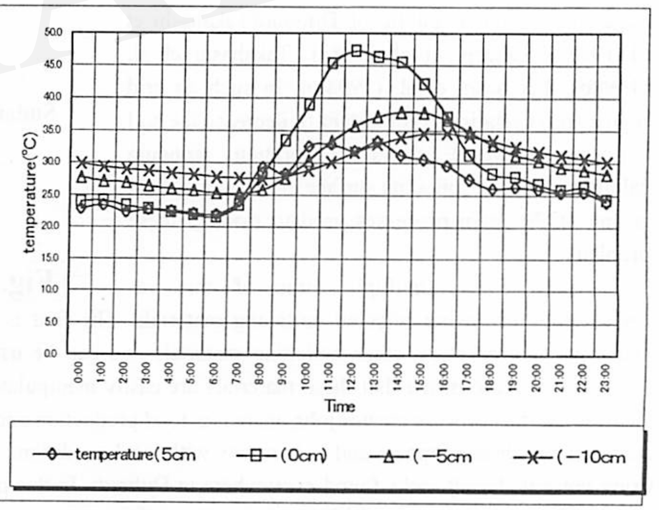


Fig 2 Relation between Air Temperature and Soil Temperature of Control Plot(14th Dec.1995)

These temperatures are believed to be lower than usual temperatures in Djibouti because the season was cooler. Although the temperatures more than 40 ℃ are not appropriate for crop cultivation during the hot season, the temperature of soil's surface is around 80 ℃ without stone mulching. The mulching system is important during hot periods to reduce the temperature at the soil surface.

Fig. 3 shows temperature variations at the soil surface over time between the big stone plot and the control plot. At the maximum temperature of the two plots on December 14,1995, the big stone plot was 14 degrees lower than the control plot. The minimum temperature of the control plot was 3 ℃ lower than the minimum temperature of the big stone plot. The variation patterns of maximum and minimum temperatures at depths 5 and 10 cm below soil are approximately same as those on the surface.

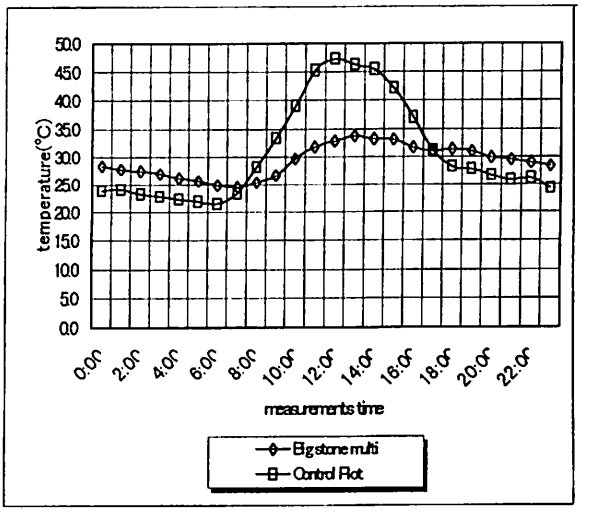


Fig 3 Comparison between Big stone multching Plot and Control Plot of Soil Surface Temperature (14th Dec.1995)

Fig. 4 describes relationship between soil depth and soil temperature amplitude (estimated by the harmonic analysis) for control and big stone plots. It appeared that the amplitude for big stone plot is lower than its counterpart which means that the variation for the control plot was higher. In such arid zones like Djibouti stone mulching system is important to grow plants and keep soil moisture because of its reduces soil temperate.

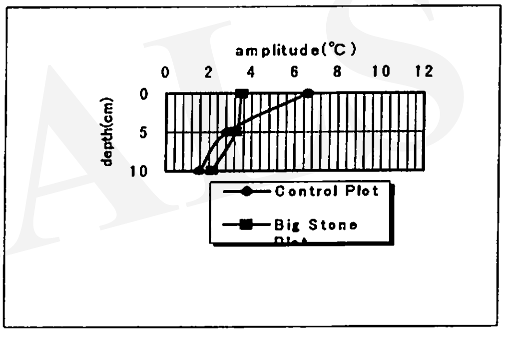


Fig. 4 Relationship between Depth and Amplitu of Soil Temperature

Fig. 5 shows relationship between time and temperature for big stone and small stone plots to compare the effect basing on the stone size. The difference of maximum temperature shows that the big stone plot maximum temperature was around 7 ℃ higher than that of small stone plot. While the minimum temperature of the small stone plot was 0.5 ℃ lower than that of big stone plot.

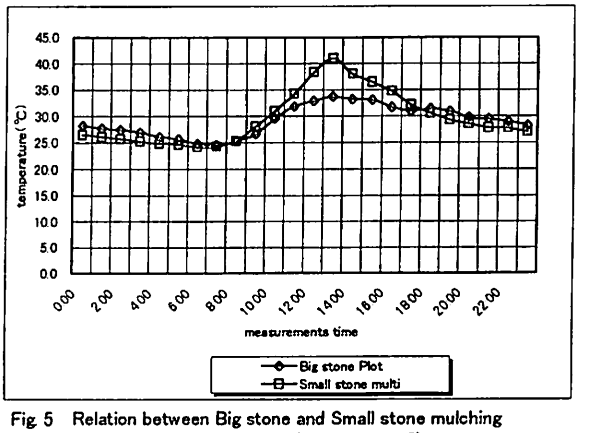


Fig 5 Relation between Big stone and Small stone mulching of soil surface temperature (14th Dec.1995)

Fig. 6 amplitude against depth. It shows that the amplitude of temperatures for big stone plot was smaller than that of small stone plot that is to say the variation of soil temperature was higher for small stone plot. The results proved that for better plant growth for the purpose of greening using stone mulching system the best way is big stone mulching system which effectively reduce soil temperature.

5. Conclusions

Our main purpose for greening using stone mulching system is to reduce soil temperature which effect is summarized as follows:

- stone mulching system reduces the soil temperature.
- larger stones is a mulch reduce soil temperature more than smaller ones.

A stone mulching system with large rock reduces soil temperatures in the Djibouti region which is dominated by "Rocky desert".

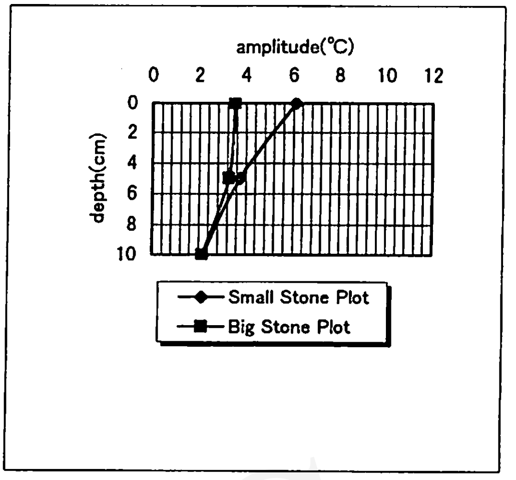


Fig. 6 Relationship between Depth and Amplitude of Soil Temperature

References

Takahashi, S.,Watanabe, F.(1995):Physical properties and erodibility of soil in the southern district of the republic of Djibouti, Journal of Agricultural Science, Tokyo Nogyo Daigaku, Vol.40(1),pp32-45

Shirai, K(1996):Physical analysis of soil, Life Research Press Tokyo, p227(in Japanese)

Takahashi, S. Watanabe, F., Tabarek M,I., Takahashi, H.,and Fukunaga, K. (1998): Possibility of dry farming in the Republic of Djibouti, Journal of Agricultural Development Studies, Vol.8(2),pp9-17.(in Japanese with English summary)

Takahashi, S. Watanabe, F., Tabarek M,I., and Sakurada, K.(1998): The characteristics of rainfall in the Republic of Djibouti, Journal of arid land studies, 7S,pp47-50

Takahashi, S. Watanabe, F. Tabarek M,I., Takahashi, H., and Fukunaga, K. (1998):Estimation of Water Surface Evaporation and greening in the Republic of Djibouti, the Japanese for Arid Land Studies,Vol.8(1),27-35(in Japanese with English summary)

沙漠研究 10S, 57-60 (2000)
Journal of Arid Land Studies
—Special Issue— "Desert Technology V"
Refereed Paper

Modeling Constituents of Concern in Drainwater Reuse by Eucalyptus Trees

Kenneth K. Tanji*

Abstract – Saline subsurface drainage water are reused as irrigation for salt-tolerant trees and plants in the San Joaquin Valley of California because the disposal of poor quality waters into the San Joaquin River is restricted. Eucalyptus camendulensis trees are being irrigated with drain waters that are saline and contain high concentrations of boron and selenium. The long-term impacts of these waters on the performance of trees and soil quality are of concern. A conceptual mass-balance model of rootzone chemistry and accumulation of TDS, B and Se in tree leaves has been formulated and is being validated. For illustrative purposes, model simulation and partial validation results are presented for the Mendota agroforestry site. The modeling effort provided a greater understanding of the complex interactions in this system.

Key words: Salts, boron, rootzone accumulation, leaf accumulation, Excel model

1. Introduction

The potential ability of agroforestry systems to utilize marginal quality waters in the San Joaquin Valley is under investigation because discharge of irrigation drainage into the river is constrained. In regard to eucalyptus trees, salinity is a major concern in the performance of these trees when irrigated with these saline drainwaters. There is, however, increasing evidence that buildup of boron (B) in the root zone, causing tree leaf toxicity, may also become limiting for the performance of eucalyptus trees (Tanji and Karajeh, 1993). Although selenium (Se) does not appear to be phytotoxic to trees, its accumulation in the food chain of animals attracted to agroforestry systems is also of concern.

The overall modeling goal is to develop and apply conceptual models to simulate water, B, salinity and Se fluxes in the eucalyptus root zone and the uptake and accumulation of B, TDS (Total Dissolved Solids) and Se in leaf tissues of eucalyptus trees on an annual basis for ten consecutive years. The models simulate the physical, chemical and biological processes considered to be important and provide extensive output data, some of which are measured in the demonstration agroforestry projects, but many are not due to difficulties in monitoring and/or high costs as well as the comparatively short time span (few years) of monitoring trees, water and soils in demonstration projects. Thus, this Excel spreadsheet modeling effort allows for extrapolation to a wider range of initial and imposed conditions, water qualities, and water and soil management options than present field studies. Such a modeling effort will provide a sounder scientific basis to evaluate the longer-term sustainability of eucalyptus plantations under varying scenarios.

2. Modeling Approach

The conceptual model initially simulates water fluxes in the root zone in four layers (quartiles) on a yearly time scale and consecutively for 10 years. Then, the model simulates the reactivity of B, TDS, and Se in the rootzone and finally the annual tree uptake of these constituents and accumulation in younger and older leaves of eucalyptus trees.

*Professor Emeritus, University of California, Davis, CA 95616 (e-mail kktanji@ucdavis.edu)

The underlying principle for the models is mass balance of the state variables (water, boron, salts and selenium) by considering inputs and outputs and change in storage (Tanji, 1977). Input data, among others, include effective (infiltrated) crop irrigation, root water extraction patterns, initial concentrations of boron, salts and selenium in the root zone, and the applied water concentrations of boron, salts, and selenium. The output data, among others, include evapotranspiration and drainage from the rootzone, uptake of boron, salts and selenium by plants, and microbial and plant volatilization of selenium. Change in storage includes changes in chemical concentrations in the root zone as well as in leaf tissues. Complex physical, chemical and biological processes are considered but are simplified to allow for comparatively simpler computations and smaller number of required input data and model coefficients. As more information and data sets become available, the model can be readily updated, especially in regard to model coefficients. Due to space limitations, selenium modeling is not offered in this paper.

2.1 Rootzone modeling

The rootzone is subdivided into quartiles. Leaching fraction (LF) in the bottom of each quartile is calculated (Ayers and Westcot, 1985) based on irrigation application rates and quartile rootwater extraction to meet tree ET requirements. Rootwater extraction is assumed to be identical to the distribution of roots found in the Mendota eucalyptus plantation which was 42-34-18-6 % (Karajeh et al., 1994). LFq, the quartile LF, is obtained from $LFq = (Deci - \sum Wq*Dcet) / (Deci)$ (Eq. 1) where Deci is the depth of effective crop irrigation in cm/yr, Dcet is the depth of crop ET in cm/yr, and Wq is the decimal fraction for quartile rootwater extraction. The tree ET in mm/yr is obtained from $\text{Tree ET} = Kc * ETo$ (Eq. 2) where Kc is the age-dependent crop coefficient and ETo is the reference ET in mm/yr obtained from a nearby weather station.

The EC (electrical conductivity in dS/m) in the bottom of each quartile is obtained from $ECq = (ECiw) / LFq$ (Eq. 3) where ECiw is the EC of the applied water and $LFq > 0.0$. When initial or prevailing soil salinity is considered in annual rootzone salt accumulation, Eq. (3) is extended to $ECq,j = 0.5*[(ECq,j-1) + (ECiw/LFq)]$ (Eq. 4) where subscript q is the rootzone quartile and subscript j is the year of calculation so that subscript ECq, j-1 is the salinity from the previous year. Eq. (4) assumes complete mixing between resident soil salinity (j-1) and current salinity buildup (j). Furthermore, assuming that salts are reactive, participating in mineral dissolution (Msp, a source mechanism) and mineral precipitation (Msd, a sink mechanism), then an additional term (Msp-Msd) is added to Eq. (4) where $Msp-Msd = -1{,}700 + 5{,}667*LFq$ (Eq. 5) in kg/ha (Rhoades et al., 1974). With appropriate conversion factors, Msp-Msd may be expressed in terms of EC in dS/m.

The computational steps for B are similar to that given for EC except for differences in reactivity in the rootzone. Biw is substituted for ECiw in Eqs. (3) and (4). The sorption of soil B is considered by the Freundlich isotherm, $Qb = Kb*Cb^{1/n}$ (Eq. 6) where Qb is the adsorbed B in mg/Kg, Kb is the adsorption equilibrium constant in L/Kg, Cb is the solution B in mg/L, and 1/n is a coefficient. If 1/n is unity, the adsorption isotherm reduces to a linear isotherm. Changes in solution B from adsorption and desorption are accounted for by $Cbq = Cb - (1/SP)*Qb$ (Eq. 7) where Cbq is the new solution B and 1/SP is the reciprocal of soil saturation moisture percentage in L/Kg to convert mg/L solution B to mg/Kg adsorbed B and vice versa. Initial or prevailing solution B is considered as in Eq (4).

2.2 Tree canopy modeling

The annual uptake of TDS and B from the rootzone is heavily dependent on the quartile distribution of EC and B as well as quartile rootwater extraction as given in the rootzone modeling. Moreover, the computation for concentration of TDS and B in the leaves of the trees begs simulation of age-dependent leaf biomass. The leaf biomass production (LBP) is obtained from LBP (kg/ha) = Age-dependent tree height (ft)* LBP coefficient (Kg/ha.ft) (Eq. 8). Age-dependent tree height is an empirical input data in which annual height ranges from 2 ft for age 1 yr, 31 ft for age 3 yr and 48 ft for age 10 yr. The LBP coefficient is also an empirical input data that ranges from 14 kg/ha.ft for age 1 yr, 12 Kg/ha.ft for age 5 yr and 15 Kg/ha.ft for age 10 yr. Eq. (8) gives 14 Kg/ha for age 1 yr, 372 Kg/ha for age 5 yr and 720 Kg/ha for age 10 yr.

The annual uptake and leaf accumulation (ALU) of TDS in Kg/ha is obtained from ALU = [Quartile-weighted average TDS (mg/L) * 10^{-6} Kg/mg] * [ET (ha.mm/ha.yr) * 10^{10}mm^2/ha * 10^{-6} L/mm^3] * [TDS leaf translocation coefficient] (Eq. 9). Only a small fraction of the TDS is taken up by the roots and translocated to the leaves. The annual accumulation of TDS in mg/Kg in younger leaf tissues is obtained from the ratio of Eq. (9) and LBP for that year while that of older leaves is assumed to be TDS from cumulative accumulation for the specified age of the trees. The uptake and accumulation of B is treated in a manner similar to TDS. The exception being, bioavailable B is better evaluated with hot-water extractable soil B (Bhw) than cold-water extractable B (Bse) as in traditional soil saturation extracts (John, 1972). Bhw is obtained from Bse by Bhw = -0.60 + 1.17 Bse (Eq. 10).

3. Model application and partial validation

Several lines of Eucalyptus camendulensis were planted in 1992 at the Mendota II agroforestry site. The trees were furrow-irrigated with saline subsurface drainage waters from croplands having an average EC of 8.5 dS/m and average B concentration of 8.4 mg/L. The rootzone was assumed to be the depth to the water table (2.2 m from the land surface) in this under-drained site. The initial EC from surface to bottom rootzone quartiles was 10, 14, 15, and 15 dS/m, and B, 10, 18, 22 and 26 mg/L. The reactivity of salts is that given by Eq. (5). Freundlich K for B (Kb) was taken as 0.56 in Eq. (6) and Freundlich 1/n, 0.9. The LF ranged from 0.25 to 0.35 and Dcet 1,350 mm/yr for 3 yr old trees and ETo, 1500 mm/yr.

Observed data are available for year 3 (1995) at this site at 4 locations with 4 differing lines of Eucalyptus camendulensis. Table 1 shows simulated and observed data for rootzone chemistry. The simulated results for soil EC indicate a LF of 0.35 fits closer to observed data than LF of 0.25 while for soil B, LF 0.25 fits closer. Table 2 gives simulated and observed data for leaf tissue accumulation. The simulated TDS for LF of 0.35 and 0.25 brackets the observed data for younger leaves while simulated data for older leaves were substantially higher than observed which appeared to be too low, lower than the younger leaves. The simulated boron content in younger leaves bracketed the observed data in younger leaves. In contrast to TDS, the simulated boron in older leaves grossly over-predicted the observed data.

4. Discussion and summary.

An attempt was made to simulate rootzone salinity and boron as well as accumulation of salt and boron in the younger and older leaves of eucalyptus trees irrigated with saline crop irrigation water. The complex interactions of physical, chemical and biological processes involved in this system were simplified into a conceptual model run on Excel. Although the simulated results appeared to be reasonable, the results were only partially confirmed by observed data from year 3. Some simulation results were close to observed values while others were off substantially. The discrepancy between model and observed results may be attributed to deficiencies in the model and/or observed data. The observed data is sparse since it is comprised of only 4 soil sampling sites and 4 trees. Clearly, more work is needed in modeling and obtaining model validation. Nevertheless, this initial modeling attempt shows substantial promise considering that such modeling efforts for this kind of complex system to the best of my knowledge have not been made yet.

Table 1. Simulated and observed rootzone salinity and boron in Year 3.

Description	Quartile 1	Quartile 2	Quartile 3	Quartile 4
Observed EC, dS/m	11	10	12	15
Simulated EC, dS/m, LF 0.35	10	15	19	23
Simulated EC, dS/m, LF 0.25	11	16	23	29
Observed boron, mg/L	10.7	13.0	11.0	13.8
Simulated boron, mg/L, LF 0.35	4.4	4.8	6.8	8.3
Simulated boron, mg/L, LF 0.25	4.6	5.5	8.7	11.5

Table 2. Simulated and observed TDS and B content in leaf tissues in Year 3.

Description	Younger leaves		Older leaves	
	LF 0.35	LF 0.25	LF 0.35	LF 0.25
Observed TDS, mg/Kg	1880		1693	
Simulated TDS, mg/Kg	1837	2070	2886	3225
Observed boron, mg/Kg	406		1268	
Simulated boron, mg/Kg	328	590	384	686

References

Ayers, R.S., and Westcot, D.W. (1985) FAO Irrigation and drainage paper # 29 (Rev. 1).

John, M.K. (1972) Soil Sci. Soc. Amer. Proc. 37: 332-333.

Karajeh, F.F., Tanji, K.K., and King, I.P. (1994) ASCE Jour. Irrig and Drainage Engrg. 120(2): 363-381.

Rhoades, J.R., Oster, J.D., Ingavalson, R.D., Tucker, J.M., and Clark, M. (1974) Jour. Environ. Quality 3(4): 311-316.

Tamji, K.K. (1977) Proc. Intern. Salinity Conf., Texas Tech Univ., Lubbock, Texas.

Tanji, K.K., and Karajeh, F.F. (1993) ASCE Jour. Irrig. and Drainage Engrg. 119(1): 170-180.

沙漠研究 10S, 61-64 (2000)
Journal of Arid Land Studies

—Special Issue— "Desert Technology V"
Refereed Paper

Water Management of New Crops for Commercialization in Arid Environments

F.S. NAKAYAMA*, D.J. HUNSAKER*, and J.M. NELSON**

Abstract - Water must be used efficiently in arid climates. Thus, understanding water requirements of crops grown in the desert environment is crucial. Guayule (*Parthenium argentatum*, latex rubber and resin), lesquerella (*Lesquerella fendleri*, oilseed), and hesperaloe (*Hesperaloe funifera*, fiber), three crops with potential commercial application, are being investigated in Arizona and elsewhere. While these plants are native to semiarid climates, proper water management is required for obtaining profitable commercial production. The objective of this report is to present information on the water-use studies and water management practices applied to these crops to maximize yields.

Key words: Guayule, Lesquerella, Hesperaloe, Water management, New crops

1. Introduction

New or alternative crops are continually being considered for cultivation in the arid environments throughout the world. In Arizona, the focus is on three crops with unique products having potential commercial applications. Guayule (*Parthenium argentatum*) is being grown for its hypoallergenic latex rubber (Nakayama et al., 1995). This plant also has resin material with insect and fungal control properties that have commercial possibilities (Bultman et al., 1991). Hesperaloe (*Hesperaloe funifera*) synthesizes quality fiber for making specialty paper equivalent to abaca (*Musa textilis*) and cordage comparable to sisal (*Agave sisalana*)(McLaughlin, 1993). Lesquerella (*Lesquerella fendleri*) produces a hydroxy fatty acid similar to castor oil and has commercial uses in the cosmetic and plastic industries (Dierig et al., 1992). Guayule and hesperaloe are cultivated as perennials and can tolerate extended dry periods, whereas lesquerella is grown as an annual and needs judicious water application to obtain adequate yields. In this presentation, the water management studies and results for these three crops will be discussed.

2. Guayule

Guayule is a perennial shrub native to northern Mexico and southwestern Texas of the Chihuahuan Desert. The plant was cultivated in Mexico and the United States in the early 1900s for its rubber for making automobile tires (Hammond and Pohlhamus, 1965). The shrubs used for the initial extraction of rubber were obtained from the wild with no cultural control. Hevea (*Hevea brasiliensis*), a South American native, replaced guayule as a commercial rubber source because of its economic advantage. Renewed interest in guayule culture has begun because of its hypoallergenic latex rubber, which does not cause the allergies associated with Hevea products.

Water management has been a key part of guayule cultivation. It is especially important during plant establishment, which is done either by direct seeding or transplanting of seedlings. Seed conditioning (Chandra and Bucks, 1986) has greatly improved plant establishment by direct seeding. The seedbed must have adequate moisture during the establishment period (Nakayama, 1990; Foster et al., 1992). Transplanting gives a 95% survival rate, whereas direct seeding only about 50%. Caution must be taken during plant establishment to avoid extended waterlogging, which can kill the young plants.

Dryland production based on natural rainfall with limited supplemental irrigation used primarily for plant establishment has been tried in Texas (Gonzalez, 1988). Rubber yields for three-year-old guayule in the 400-500 mm per year rainfall regions average about 900 kg/ha. Rubber yields under controlled

* U.S. Water Conservation Laboratory, USDA-ARS, 4331 E. Broadway, Phoenix, AZ 85040, USA (Fax: +1-602-379-4355)
** The University or Arizona, Maricopa Agricultural Center, Maricopa, AZ 85239, USA

irrigation applications range from 600 to 1200 kg/ha for two-year-old shrubs with a total water application (rainfall + irrigation) of 300 to 800 mm per year (Nakayama et al., 1991a).

The guayule roots extend deep into the soil profile (180 cm), which permits the plant to extract water from a large volume of soil and, thus help in its drought tolerance (Bucks et al., 1985). However, extensive studies have shown that even though guayule can withstand drought, supplemental irrigation can increase the biomass production and rubber yield much beyond that of its native habitat. Rubber yields can be related to water and nitrogen applications by the equation

$$Y = -1301 + 0.515\,W + 5.35\,N - 3.90 \times 10^{-5}\,W^2 - 7.23 \times 10^{-3}\,N^2 + 2.98 \times 10^{-4}\,W \times N, \quad R^2 = 0.93, \qquad (1)$$

where Y is yield in t/ha, W is water application in mm, and N is nitrogen application in kg/ha (Nakayama et al., 1991b).

Estimates of the water requirements for acceptable commercial production under different environmental conditions are listed in Table 1. The semiarid native habitat has about 125-350 mm rainfall per year. Much of this region was decimated of native shrubs when guayule was used for making rubber in the early 1900s (Hammond and Polhamus, 1965). Most of the cultivated guayule would be in this semiarid or intermediate zone and will require supplemental irrigation for commercial production. For comparison, cotton production in this area of Arizona requires about 900 to 1000 mm total water. Cotton is cultivated as an annual crop with a 6 to 7 months growing season, whereas guayule is handled as a perennial.

Table 1. Estimated annual water requirements for commercial guayule production (Nakayama et al., 1991a)

Suitability Class	ZONE Arid (mm)	 Intermediate (mm)	 Coastal (mm)
Good	1500	1200	900
Permissible	1200-1500	900-1200	600-900
Doubtful	900-1200	600-900	300-600
Unsuitable	<900	<600	<300

Note: Intermediate zone has late spring rains, and coastal zone has fog and cooler temperature than the arid zone.

A relation between rubber yield (Y, t/ha) and evapotranspiration (ET, mm) has also been developed as

$$Y = 848.2 + 0.242\,ET, \quad R^2 = 0.87 \quad \text{(Nakayama et al., 1991b).} \qquad (2)$$

When water stress is imposed on the plant, rubber yield is decreased. This water stress has been defined in terms of a stress index called the "crop water stress index" or CWSI with a higher fractional value related to a larger stress on the plant (Nakayama and Bucks, 1983). The relationship observed between the CWSI and rubber yield (Y, t/ha) was observed to be

$$Y = 2.81 - 1.63\ CWSI,\ R^2 = 0.93 \quad \text{(Nakayama, 1991)}, \qquad (3)$$

showing that the yield becomes smaller as the water stress increases.

3. Lesquerella

The majority of the lesquerella species occur in western North America with the greatest abundance in the semiarid and arid areas of southwestern U.S. and northern Mexico. Although the plant is a perennial, it is treated as an annual for oilseed production. It is treated as a winter crop in Arizona with direct seeding for plant establishment made from September through October and seed harvesting occurring in late May to mid-June. This is about the same period for wheat cultivation in this area. In addition to proper water application during plant establishment, appropriate nitrogen fertilization promotes the growth of the seedling (Nelson et al., 1996).

Maximum seed yield is obtained with 630-670 mm water (rainfall + irrigation) for the growing season with a major portion of the water (70-80%) applied after the onset of flowering, which occurs during February. Water control is important for seed production. When water is withheld during mid-flowering or during seed formation and ripening, seed yield is drastically decreased. Thus, adequate water is needed during the seed formation period in May to prevent yield reduction. To achieve this, biweekly irrigation of 60-65 mm per application is needed until seed maturity. Managing soil water to 50% depletion of available soil water from the onset of flowering through seed ripening gives the maximum biomass production and seed yield.

A curvilinear relation is obtained between seed yield (Y, kg/ha) and ET (mm) with

$$Y = -1875 + 8.10\ ET - 0.055\ ET^2,\ R^2 = 0.47 \quad \text{(Hunsaker et al., 1998)}. \qquad (4)$$

4. Hesperaloe

Hesperaloe is a perennial plant native to the Chihuahuan Desert of northen Mexico. It is a slow growing Crassulaceaen acid metabolitic (CAM) plant whose agronomic management is just being developed. Two Hesperaloe species, *H. funifera* and *H. nocturna*, have potential as new sources of fiber for paper making. These species have high physiological water-use efficiency, which suggests that they should have low water requirements and might be adapted to irrigated agriculture in the semiarid southwestern United States.

Agronomic research has been underway for several years to develop cultural and water management practices for Hesperaloe production in Arizona. A proposed production scheme is to start the plants in the greenhouse and then transplant the seedlings to the field in the fall months. The first harvest of leaves would take place in 3 to 5 years with subsequent harvests every 2 to 3 years. Weed control, nitrogen fertilization, and irrigation management practices are currently under investigation.

Irrigation research indicates that Hesperaloe plants are able to survive with very little water; however, supplemental irrigation water must be supplied to obtain adequate biomass production (Nelson and McLaughlin, 1997) similar to that of guayule. Growth is greatly reduced when plants are not irrigated before 55% or more of the available soil water is depleted. Fresh plant yields ranged from 0.71 to 2.67 kg/plant for three-year-old plants with a total water application (rainfall + irrigation) of 260 to 620 mm/year. The highest fresh plant yield at the end of three years was obtained with 515, 540 and 625 mm of water (rainfall + irrigation) in the first, second and third years of production, respectively. In the third year of production, ET for hesperaloe appears to be about 600 mm to achieve maximum fresh weight yields. This is about the same amount of ET for lesquerella production, which is grown during the winter months.

Hesperaloe develops a shallow, horizontal root system. In the third year of production, more than 85% of water is removed from the top 50 cm of the soil. A subsurface drip system could be used as an option to flood irrigation to manage water application in Hesperaloe cultivation.

5. Summary

Timing of irrigation application during flowering and seed development is important for lesquerella where seed production is the primary objective. Less problems are encountered with scheduling water application for guayule and hesperaloe when biomass production is the main yield component. Careful water management is required for obtaining adequate plant establishment for direct-seeded lesquerella and guayule. Lesquerella is handled as a winter crop in semiarid regions, but could be managed as a spring crop similar to wheat culture in other regions. Biomass increases in guayule and hesperaloe for commercial production are possible with supplemental water applications. All three crops can provide yields at about 650 mm ET per year under semiarid growing conditions; however, guayule and hesperaloe can continue to produce higher biomass with higher water application. There is no limitation for cultivating these crops in an arid environment. The three crops discussed here have good commercial potential once appropriate agronomic and water management practices are developed.

References

Bucks, D.A., Nakayama, F.S., French, O.F., Legard, W.W., and Alexander, W.L. (1985): Agricultural Water Management, 10: 61-79.

Bultman, J.D., Gilbertson, R.L., Adaskaveg, J., Amburgey, T.L., Parikh, V., and Bailey, C.A. (1991): Bioresource Technology, 35: 197-201.

Dierig, D.A., Thompson, A.E., and Nakayama, F.S. (1992): Industrial Crops and Products, 1: 289-293.

Chandra, G.R. and Bucks, D.A. (1986): In: Fangemeier, D.D. and Alcorn, S.M. (Eds.). Guayule, A Natural Rubber Source. Tucson, Arizona. pp. 59-68.

Foster, M.A. and Moore, J. (1992): Journal of Production Agriculture, 5: 163-167.

Gonzalez, C.L. (1988): Journal of the Rio Grande Valley Horticultural Society, 41: 51-57.

Hammond, B.L. and Polhamus, L.G. (1965): Research on Guayule (*Parthenium argentatum*): 1942-1959. USDA Tech. Bull. No. 1327. U.S. Printing Office, Washington, D.C.

Hunsaker, D.J., Nakayama, F.S., Dierig, D.A., and Alexander, W.L. (1998): Industrial Crops and Products, 8: 167-182.

McLaughlin, S.P. (1993): In: Janick, J. and Simons, J.F. (Eds). New Crops. John Wiley and Sons, N.Y. pp. 435-442.

Nakayama, F.S. (1990): Proceedings National Conference American Society of Civil Engineering. Durango, Colorado. pp. 210-214.

Nakayama, F.S. (1991): In: Whitworth, J.W. and Whitehead, E.E. (Eds.). Guayule Natural Rubber. USDA, CSRS, Office of Arid Lands Studies. Tucson, Arizona. pp. 217-240.

Nakayama, F.S. and Bucks, D.A. (1983): Journal Arid Environment, 6: 269-272.

Nakayama, F.S., Bucks, D.A., Gonzalez, C.L., and Foster, M.A. (1991a): In: Whitworth, J.W. and Whitehead, E.E. (Eds.). Guayule Natural Rubber. USDA, CSRS, Office of Arid Lands Studies. Tucson, Arizona. pp. 145-172.

Nakayama, F.S., Bucks, D.A., Roth, R.L., and Gardner, B.R. (1991b): Bioresource Technology, 35: 173-178.

Nakayama, F.S., Cornish, K., and Schloman, W.W., Jr. (1995): Journal of Arid Lands Studies, 58: 203-206.

Nelson, J.M., Dierig, D.A., and Nakayama, F.S. (1996): Industrial Crops and Products, 5: 217-222.

Nelson, J.M. and McLaughlin, S.P. (1997): International Conference of the Association for the Advancement of Industrial Crops. Saltillo, Mexico, Sept. 14-18, 1997. p. 15.

沙漠研究 10S, 65-68 (2000)
Journal of Arid Land Studies

—Special Issue— "Desert Technology V"
Refereed Paper

Role of Chloroplastic α-Amylase in Drought Tolerance: Changing the Microclimate of Deserts.

Rupali DATTA* and Sanjay KUMAR**

Abstract - In arid areas, lack of water affects the uptake of nutrients from the soil, resulting in changes in the concentrations of many metabolites in plants. These changes lead to disturbances in carbohydrate and amino acid metabolism. Acclimation to drought requires responses that enable plants to maintain their normal metabolism, so that they are able to tolerate the harmful effects of stress. It is now known that carbohydrate (C) and nitrate (N) metabolism in plants are co-regulated, and efficient carbohydrate metabolism favors high rate of nitrate assimilation. In this paper, we report that water and salt stress severely impair the activities of enzymes like sucrose phosphate synthase and nitrate reductase, that are involved in C and N metabolism respectively. At the same time, β–amylase activity is strongly induced. These results hint at the overall strategy adopted by plants to tolerate stress. We also report the isolation of a novel α-amylase isoform in maize chloroplasts. Plants with higher activities of cytosolic β–amylase and chloroplastic α-amylase could counter the damaging effects of stress by efficient mobilization of nutrients in the stressed tissues. This finding could be used to develop plants better suited for growth in arid areas by breeding and biotechnological manipulation.

Key words: Maize, Pearl millet, carbohydrate metabolism, nitrate metabolism, stress.

1. Introduction

Ecological instability and the expansion of deserts and arid areas have left no alternative to the scientific community but to direct their efforts towards changing the climatic conditions of these areas for viable and sustainable developmental activities. Development of stress resistant, genetically engineered plant species for afforestation of these areas is the most sought after solution. During prolonged periods of drought, water deficit affects the uptake of nutrients from the soil. Nitrogen is one of the nutrients needed in greatest abundance by plants. Plants assimilate inorganic forms of nitrogen such as nitrate by uptake from the soil. The first step of the nitrate assimilation pathway is catalyzed by the enzyme nitrate reductase (NR), and constitutes the rate limiting step of the pathway. The lack of nutrients like nitrate affects nitrate metabolism and also the overall growth and development of plants. NR is regulated by its substrate nitrate, in addition to light, plastids, sugars and reversible phosphorylation (Mohr et. al., 1992).

Since carbohydrate (C) and nitrate (N) metabolisms are co-regulated, disruption in N metabolism also affects C metabolism. Energy and carbon skeletons required for N assimilation is provided directly or indirectly by photosynthesis. Some studies have shown that NR activity is linked to the bye products of C fixation. Increase in NR activity was reported in the night due to starch degradation and mobilization from the chloroplasts in dark (Deng et. al., 1989). Sucrose is the major form of photo-assimilate in leaves and the production and accumulation of sucrose determines the availability of C for export from the leaves. Sucrose phosphate synthase (SPS) catalyzes the penultimate step of sucrose synthesis in the leaf. Over-expression of maize SPS in tomato resulted in increased rate of photosynthesis in leaves (Galtier et. al., 1995). Constitutive over-expression of SPS can increase plant biomass production. Decrease in SPS results in increased starch accumulation. The other form of photo-assimilate, transitory starch, is formed inside the chloroplasts, where it is stored till it is mobilized. It is thought that a combination of amylolytic and phosphorolytic pathways mobilize transitory starch in the chloroplasts.

Amylases play a crucial role in the break-down of starch to meet the energy needs of the growing embryo during seed germination. Seed amylases have been very well studied as compared to leaf amylases. Leaf amylases have been reported to be regulated by light, hormones, metabolites, stress and positional effects. Since transitory starch is generated in the chloroplasts, it is reasonable to assume that leaf amylases are chloroplastic in localization. However, we have very limited evidences of the localization of α-amylases in the chloroplasts. β–Amylases have also been reported to be extra-chloroplastic in localization. In several species β–amylase activity is regulated by factors causing stress to plants. Stresses such as mechanical wounding, photo-oxidative loss of chloroplasts caused by treatment with herbicide norflurazon (NF), elevated temperature and lowering of water potential stimulated β–amylase activity (Drier et. al., 1995). The localization of β–amylase outside chloroplasts indicates that it has functions other than the degradation of photosynthetically generated transitory starch. However, the fact that it is very stringently regulated indicates that it plays an important role in plant metabolism.

In the present paper, laboratory tests were conducted to study the effect of stress on β–amylase, NR and SPS using maize and pearl millet leaves under artificially created conditions of salt and water stress. Maize and pearl millet were chosen as these are crops specially suited for growth in arid and semi-arid areas, and can be expected to have an

*1453 Fifield Hall, Department of Plant Pathology, University of Florida, Gainesville, Florida 32611-0680. Fax: +1-352-335-4487.
**Department of Global Environmental Engineering, Faculty of Engineering, Kyoto University, Sakyo-Ku, Kyoto 606-01.

efficient in-built stress tolerating mechanism. We report that in maize and pearl millet leaf, β–amylase is induced significantly by stress, while NR and SPS are inhibited. Also, we have identified a novel chloroplastic isoform of α–amylase. This isoform is likely to play a major role in the break-down of transitory starch formed in the chloroplasts during photosynthesis. The chloroplastic α–amylase and the cytosolic β–amylase could help in efficient mobilization of nutrients to stressed tissues. Since C and N metabolism are closely linked, the induction of β–amylase is likely to be important for better nitrate metabolism and the overall growth and development of plants under conditions of stress.

2. Materials and Methods

2.1 Plant Materials and treatments: Maize (*Zea mays*) var. Ganga-5 and pearl millet (*Pennisetum americanum*) var. WCG-75 seeds were obtained from AP State Seed Corporation, Hyderabad, India. Seeds were first soaked in distilled water for 12 h and then sown on moist germination papers. The seedlings were grown at 25°C in continuous white light (100 mmol m^{-2} sec^{-1}) or darkness. A set of seedlings grown in darkness for six days were also transferred to light for 24 h to study the influence of light on β-amylase activity. For the herbicide norflurazon (NF) treatment, seeds were presoaked in a 0.4 mM NF solution for 12 hours and sown on germination papers moistened with the same solution and grown as above.

Four-day-old seedlings grown in distilled water were subjected to water stress. Seedlings were transferred to various concentrations (100-500 mM) of sorbitol or Sodium chloride solution. Thereafter, the seedlings were grown under white light or darkness for four more days and irrigated with the respective solutions. Control seedlings were grown similarly, but in distilled water. Since 300 mM sorbitol and Sodium chloride were found to be optimum for β-amylase induction, all the subsequent experiments were done using seedlings grown in 300 mM sorbitol and Sodium chloride.

2.2 Enzyme assay: NR assay was performed according to the procedure of Whitelam et. al. (1979). SPS assay was done according to Salerno et. al. (1979) and amylase assay was done according to Vally and Sharma (1991).

2.3 Western Blotting: SDS-PAGE was carried out following the procedure of Laemmli (1970). Western blotting after SDS-PAGE was done using the procedure described in Sharma et. al. (1993), using antibodies against maize seed β-amylase and the bands were visualized using an alkaline phosphatase conjugated anti-rabbit sheep antibody.

2.4 Carbohydrate analysis: Glucose, sucrose and starch content of the leaves were measured according to Galtier et. al. (1995).

3. Results and Discussion

The chloroplastic α-amylase was partially purified by affinity chromatography using a cyclo heptaamylose-sepharose column. After concentrating the eluate of the CHA-sephaorose column, western blotting showed chloroplastic α-amylase had a molecular weight of 57 kD, as against 46 kD of seed α–amylase 1,2 (Fig 1A). The partially purified chloroplastic α–amylase showed a single precipitin line on Ouchterlony double immuno-diffusion, against seed α-amylase antibodies, and this precipitin line could be stained for α-amylase activity. This precipitin line was not observed in the case of extracts from etioplasts, or in leaves grown in the inhibitor norflurazon, which destroy chloroplasts, confirming the absence of this isoform in darkness and in the absence of intact chloroplasts (Fig 1B).

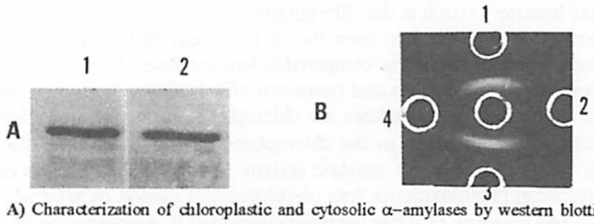


Figure 1 A) Characterization of chloroplastic and cytosolic α–amylases by western blotting. Lane 1, chloroplastic α–amylase; lane 2, cytosolic α–amylase. Their respective molecular weights are indicated.
B) Ouchterlony double immuno-diffusion of chloroplastic α–amylase. Extracts from isolated chloroplasts or etioplasts were loaded into peripheral wells and subjected to immuno-diffusion using α–amylase antibodies loaded in the central well. 1, mesophyll chloroplast extract; 2, etioplast extract; 3, bundle sheath chloroplast extract; 4, extract from norflurazon-treated leaves.

Maize being a C-4 plant consists of both mesophyll and bundle sheath chloroplasts. While β–amylase was completely absent in the chloroplasts of both mesophyll and bundle sheath cells, about 15% of the total α-amylase activity of the mesophyll cells and about 40% of the total α-amylase activity in the bundle sheath cells was found to be chloroplastic (data not shown). Isolated etioplasts failed to show α-amylase activity and also, α-amylase protein could not be detected in isolated etiolated by western blotting.

Since etioplasts possess no α-amylase activity, evidently α-amylase activity in chloroplasts appears during chloroplast biogenesis. The presence of α-amylase activity in chloroplasts is in conformity with its likely role in mobilization of photosynthetic starch, since most of the photosynthesized starch is localized in the bundle sheath chloroplasts.

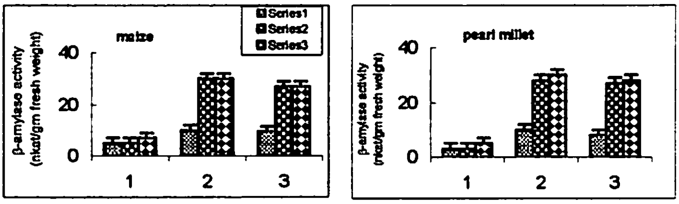


Figure 2 Effect of stress on β-amylase activity in maize and pearl millet. Seedlings were grown for 4 days in distilled water and for 4 days in 300 mM Sorbitol (2), 300 mM Sodium Chloride (3), or for 8 days in distilled water (1). Seedlings were grown either in continuous darkness (series1), white light (series2) or for 7 days in darkness followed by 1 day in white light (series3). The first leaf was assayed for β-amylase activity.

Figure 2 shows that dark-grown maize and pearl millet seedlings possess low levels of β-amylase activity compared to light-grown seedlings, which possessed significantly higher activity. The transfer of dark-grown seedlings to light for 24 h stimulated β-amylase activity to a level nearly equivalent to light-grown seedlings. In seedlings subjected to water stress by transferring them into sorbitol and sodium chloride solutions, exposure to stress strongly stimulated β-amylase activity in light-grown seedlings as well as in seedlings transferred to light.

The view that stress mediated stimulation of β-amylase activity results from an increase in its protein level was ascertained by immunoblotting of leaf extracts from the stressed and control seedlings. Immunoblotting indicated that the stimulation of β-amylase activity in stressed leaves causes a strong stimulation of β-amylase protein levels in maize seedlings (Fig 3). In all cases, the stimulation of β-amylase activity was also accompanied by a similar increase in protein levels.

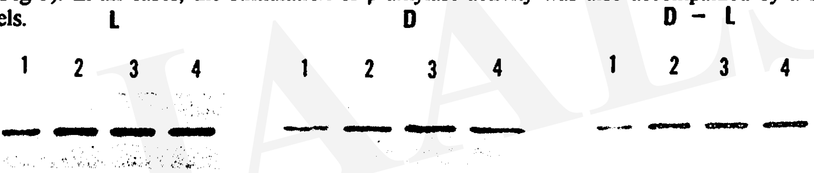


Figure 3 Effect of stress on β-amylase protein level. Maize seedlings were grown either in distilled water or NF for 8 days or for 4 days in distilled water followed by 4 days in 300 mM sorbitol or sodium chloride in white light (L), dark (D) or for 7 days in darkness followed by 1 day in white light (D-L). First leaves from the seedlings were harvested and subjected to immuno-blotting using β-amylase antibodies after SDS-PAGE. Lane 1, Distilled water, Lane 2, NF; Lane 3, Sorbitol; lane 4, Sodium Chloride.

Table 1 Accumulation of carbohydrate in leaves.

Plant Material	Treatment	Starch (mmol/mg chl)	Glucose (μmol/mg chl)	Sucrose (mmol/mg chl)
Maize	Control	0.04	0.17	0.21
	Sodium Chloride	0.08	0.70	0.22
	Sorbitol	0.07	0.65	0.22
Pearl millet	Control	0.14	0.14	0.20
	Sodium Chloride	0.63	0.63	0.24
	Sorbitol	0.59	0.59	0.23

All the values above represent the average of three independent experiments.

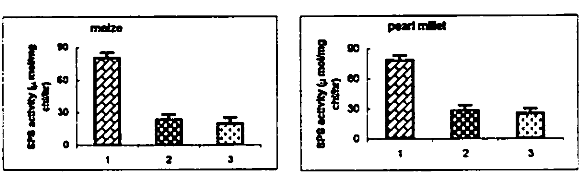


Figure 4 Effect of stress on SPS activity. Maize and pearl millet seedlings were grown in distilled water for 4 days and and for 4 days in 300 mM Sorbitol (2), 300 mM Sodium Chloride (3), or for 8 days in distilled water (1). The first leaf was assayed for SPS activity.

On the contrary, when the effect of sorbitol and sodium chloride on SPS activity was checked, SPS was found to be inhibited by the stress treatments in both maize and pearl millet leaves (Fig 4). The activity was 4 fold less than that of control seedlings. Similarly, in the case of NR, there was a reduction in activity by about 3 fold (Fig. 5). Levels of sucrose, glucose and starch in the leaf was examined (Table 1). While starch accumulation increased 2 fold, there was a 4 fold increase in the glucose concentration. Interestingly, the level of sucrose remained the same in stressed and normal leaves.

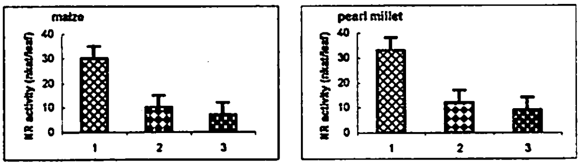


Figure 5 Effect of stress on NR activity. Maize and pearl millet seedlings were grown in distilled water for 4 days and and for 4 days in 300 mM Sorbitol (2), 300 mM Sodium Chloride (3), or for 8 days in distilled water (1). The first leaf was assayed for NR activity.

The results obtained in this study indicate that, environmental stress potentiates a strong stimulation of β-amylase activity both in pearl millet and maize leaves indicating that extra-plastidic β-amylase may be a stress-induced protein. In the present study, maximal elevation of β-amylase activity in water and salt-stress treated seedlings could be observed only when the seedlings were either grown in light or were transferred to light, indicating that exposure to light is necessary for the full expression of stress-induced β-amylase activity. During early stages of drought, dehydration causes stomatal closure and CO_2 fixation is limited by its availability. The decrease in SPS activity could be due to the decrease in net photosynthesis, leading to the lowering of sucrose synthesis. Since NR is induced by C and N, not only reduced uptake of N from the soil but also the reduced availability of photo-assimilates lower NR activity. Stress results in increased starch accumulation and increased glucose show that there is an increased starch turnover, and this is corroborated by increased β–amylase activity.

4. Conclusion.

A novel α-amylase isoform was identified and isolated from maize chloroplasts. This isoform comprised of about 40% of the total α-amylase activity in the bundle sheath cells. This isoform could play an important role in the mobilization of photosynthesized starch from the chloroplasts. It is known that NR is induced by starch mobilization from chloroplasts. Also, environmental stress potentiates a strong stimulation of β–amylase activity in both pearl millet and maize leaves. At eh sme time, SPS and NR activities are impaired showing that C and N metabolism are affected by stress. Since C and N metabolism are closely linked, and water deficiency in arid areas could severely impair N metabolism, chloroplastic α–amylase and cytosolic β–amylase are likely to play a crucial role in enabling plants to overcome the harmful effects of stress. This finding could be used in future to identify species and/or develop plants over-expressing these proteins by breeding and biotechnological manipulation having better chances of survival and growth for plantation in arid and semi-arid areas.

References

Deng, M., Moreaux T., Leydecker, M., and Caboche, M. (1990) : Nitrate reductase expression is under the control of a circadean rhythm and is light inducible in *Nicotiana tabacum* leaves. Planta, 180 : 257-261.

Drier, W., Schnarrenberger, C. and Börner, T. (1995) : Light- and stress dependent enhancement of amylolytic activities in white and green barley leaves: β-amylases are stress induced proteins. J. Plant Physiol. 145 : 342-348.

Galtier, N., Foyer, C. H., Murchie, E., Alred, E., Quick, P., Voelker, T. A., Thepenier, C., Lasceve, G and Betsche, T. (1995) : Effects of light and atmosphere CO_2 enrichment on photosynthetic carbon partitioning and carbon/nitrogen ratios in tomato (*Lycopersicon esculentum* L.) plants over-expressing sucrose phosphate synthase. J. Exp. Bot. 46 : 1335-1344.

Laemmli, U. K. (1970): Cleavage of structural proteins during the assembly of the head of Bacteriophage T4. Nature 227 : 680-685.

Mohr, H., Neininger, A. and Seith, B. (1992) Control of nitrate reductase and nitrite reductase gene expression light, nitrate and a plastidic factor. Bot. Acta 105 : 81-89.

Salerno, G. L., Gamundi, S. S. and Pontis H. G. (1979) A procedure for assay of sucrose synthase and sucrose phosphate synthase in plant homogenate. Anal. Biochem. 93 : 196-199.

Sharma, R., López-Juez, E., Nagatani, A. and Furuya, M. (1993) Identification of photo-inactive phytochrome A in etiolated seedlings and photo-active phytochrome B in green leaves of the *aurea* mutant of tomato. Plant J. 4 : 1035-1042.

Vally, K. J. M. and Sharma R. (1991) Interaction between chloroplast biogenesis and photoregulation of amylases in *Pennisetum americanum* leaves. Photochem. Photobiol. 54 : 651-657.

Whitelam, G. C., Jhonson, C. B. and Smith, H. (1979) The control by phytochrome of nitrate reductase in the curd of light-grown cauliflower. Photochem. Photobiol. 30 : 589-594.

沙漠研究 10S, 69-72 (2000)
Journal of Arid Land Studies

—Special Issue— "Desert Technology V"
Refereed Paper

A model for future technology transfer at the 'grass roots'

Adrian WILLIAMS*, Zahid HUSSAIN**, Bob SVENDSEN* and Brian FERGUSSON*

Abstract - Lack of effective extension services, use of scientific language, literacy, and lack of mutual trust between farmers and scientists were cited at Desert Technology IV as obstacles to technology transfer. This paper suggests a way to overcome the problem. Models have been proposed in the past, commonly based on group extension. This model is innovative in that it proposes that researchers, farmers and extension specialists jointly identify training and skill needs, and organise concurrent training for researchers and farmers' leaders.

Key Words: Technology transfer, training, funding.

1. Introduction

Fitting the conference theme of 'Deserts in Changing Climates' this paper considers technology transfer in times of changing economic climates.

The true value of research depends upon the benefit it brings through implementation of its results. Implementation of research results in an agricultural or environmental sphere has long depended in many countries on 'extension services'. There are many definitions of 'extension'. To quote one, the Food and Agriculture Organisation of the U.N. (Maunder, 1972) has defined agricultural extension as:

> "An informal out-of-school educational service for training and influencing farmers (and their families) to adopt improved practices in crop and livestock production, management, conservation and marketing. Concern is not only with teaching and securing adoption of a particular improved practice, but with changing the outlook of the farmer to the point where he will be receptive to, and on his own initiative continuously seek, means of improving his farm business and home".

Today it is of concern that extension services, staffed by people trained in agricultural and related sciences, communication and facilitation, are being reduced, often for reasons associated with rapidly rising travel costs and salaries. Yet this is the very time when an effective extension service is most needed, to assist farmers evaluate new production systems that will be economically and environmentally sustainable. Without effective 'extension' we are wasting our time as researchers and our dreams of improving environmental conditions and sustainable productivity will not be realised.

At Desert Technology IV we identified problems in communicating 'extension messages' to farmers and pastoralists in arid areas. Lack of extension services, use of scientific language, illiteracy, and lack of mutual trust and understanding between farmers and scientists were cited as obstacles to technology transfer. The conference identified seven 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.

This paper proposes one method by which these goals might be achieved.

*Curtin University of Technology, PMB 22, Kalgoorlie, W.A. 6430 (Fax: +61890 886715)
**Pakistan Agricultural Research Council, Plot 20, G-5/1, Islamabad-44000, Pakistan

2. Some examples of positive steps to technology transfer based on the experience of the authors

Land Conservation Districts (LCDs) in Western Australia work with varying degrees of success. LCDs have elected committees recognised by Western Australian law. The committees are made up of farmers, and other land users like mining company or aboriginal community representatives as appropriate to the location. All committees are supported by staff of the State Agriculture Agency. Other support may come from commercial organisations, other government departments, and from research institutions (CSIRO, universities), depending on the needs of the LCDs from time to time. LCDs have been known to invite government ministers to their meetings, resulting in most useful two-way exchanges of information! LCDs are encouraged by the fact that there are research and demonstration funds for which they can apply. Such funds are used to investigate a particular problem, install demonstrations of new techniques, or to carry out field scale projects.

In Pakistan the Welfare Association of Salt Land Users (WASLU) was formed at the Satiana Pilot Project by farmers whose main interest is the revegetation of salt affected lands. The farmers organise meetings to discuss problems, and invite technical experts to speak at their meetings. Farmers have voluntarily formed land drainage groups in other areas, while a major achievement has been the formation of eight Water Users' Associations for the control of irrigation water. This has led to improved irrigation scheduling, and sale of excess water. Returns from these sales have funded road improvements and the building of Community centres (Zahid Hussain - pers comm).

In Uttar Pradesh, India, a sodic land rehabilitation project commenced in 1993 has also emphasised the key role of farmers. The project system of participatory management emphasises transparency, decentralised decision making, capacity building and accountability. Beneficiaries are involved in decision making from the earliest planning stages.

In Kalmykia farmers' groups are starting to form to address problems such as wind erosion, rising saline groundwater and the sustainable re-use of rehabilitated areas of the Chernye Zemli District. Groups are starting to receive support from the Government staff involved in the rehabilitation project, and from key, committed researchers (Williams, 1997).

From these examples we see similarities between successful farmers' groups:

- The group has, or feels, ownership for the problem, the activity or the resources that the group is called upon to manage.
- Groups have a recognised and respected status.
- Government or Non-Government Organisations have been involved as a catalyst to facilitate the development of the groups.
- Groups have commenced simply with a single tier.
- Unlike many governments, farmers' groups are not authoritative.
- Groups have sufficient funding to operate. Ideally the members of the group contribute the major share of the financial requirements (in cash or in kind).

3. A new extension methodology

The 'extension service' in many countries is a thing of the past. Future extension will come about through a meeting of those who develop information and solutions through research on the one side and groups of those who apply the information on the other. It is time for researchers and farmers to appreciate that they can assist each other in ways that may not be immediately obvious.

Researchers are trained to be reductionist in thinking, removing all stray variables from research work to ensure that the answers they find are significant and meaningful. Farmers need people with this training and discipline to help them solve problems objectively.

Farmers are the great mental integrators. Differing from researchers in their decision-making processes, farmers have to integrate all the information at their disposal when making a sound production decision. As an example this may include, but not be limited to, costs and returns of inputs and products, soil conditions, weather patterns, stock conditions, social commitments, family needs, and personal ambition. Shaxson (in press) asserts that farmers will also consider their relationship with the land, which may border on a spiritual connection. Researchers need farmers to identify where more information is needed to improve the decisions farmers make, and where there are particular problems that need solving. Farmers are the ultimate 'testers' of research findings, slotting the new information into their mental decision matrix to see how useful it is, and how comfortably it integrates with the other items they must consider.

The present economic climate means that research funds are harder to attract. Again the researchers and farmers have the opportunity to work together to attract funding. Research projects are increasingly scrutinised for their practical value and farming industry support. In discussion farmers and researchers can identify real problems that need addressing. Farmers can lend their support to applications for funding made researchers. (In some cases writing the application for research funds could be a shared undertaking.)

So the first part to our new extension methodology is that the farmers and researchers must work together for their mutual benefit, using the different thinking and perception skills that each has developed. They must learn from each other.

How can this start to happen, and how will mutual trust and confidence be established? The system is most likely to develop and flourish where researchers are able to meet with existing farmers' groups. Initial contact could be from either side. Where farmers' groups recognise that they have problems that need solving they are likely to be open to assistance from researchers. It will be important for researchers to be pro-active, and accepting of opportunities to work with farmers.

Identifying the root cause of practical farming problems may be beyond both the farmers and the local researchers. Sometimes people can be too close to a problem to perceive it clearly and objectively. Problem definition and scoping of the different facets that go to make up a research or development program may require the help of an 'outsider' with wider experience and specialised skills. The outside specialist should involve the farmers and local researchers in developing a program to research and counter the identified problems. From then on the farmers and researchers should 'own' the problems and the solutions.

In our model this will be a critical time for the 'outside specialist' to undertake a skills and information audit. The purpose of this will be to identify any new skills or extra information that will be required by the local researchers and farmers to solve the identified problems. Training can also be designed to give the farmers the confidence to identify and tackle new problems. The 'outside specialist' should be in a position to propose appropriate training programs, and identify a high quality institution capable of providing the required training.

Concurrent training of researchers and leading farmers, offered outside their normal environment, is a major initiative in this new 'extension' model. This will promote understanding and 'bonding' between the farmers and researchers. While the topics studied by the chosen farmers and the researchers will most likely be different, the training courses should be designed to bring the researchers and farmers together outside their training sessions for informal discussions. At such times they can exchange what they have been learning, and discuss how it is relevant to the problems they wish to solve.

Representatives of the farmers' group would be chosen for the training by their peer group on the basis of their position in the community, the respect they command amongst their peers, their ability as farmers and communicators, and their willingness to be innovative.

Having given the chosen farmer representatives and researchers new information and skills they would return to the farmers' group to act as 'mentors' to the other farmers, explaining new techniques, seeking grant funding, setting up group demonstration projects, and identifying and solving new problems. The training institution would provide on going support by providing information and further training programs as necessary.

4. Problems with the model, and suggested solutions

Farmers and researchers would be sent out of their home environment for training, thereby creating a neutral but foreign training environment. This should promote 'bonding' between these trainees. Funding will be required, therefore, for travel and accommodation as well as for the cost of the training. Training grants from government departments, non-government organisations (NGOs), International Agencies and commerce would be required.

Farmers are often loath to leave their farming enterprises unattended. Training away from home can only occur at certain times, during lulls in activity in the farming year.

Researchers may need replacements to maintain on-going trials while they are away on training courses. Such replacement researchers could be junior researchers or senior research students supplied on a temporary basis by the institution that provides the training packages for the researchers and farmers. This system has been employed for a number of years by the Centre for Arid Zone Studies, Bangor, North Wales, U.K

Funding will be a major consideration in the development of the form of technology transfer that we are proposing. While governments, NGOs and international donor agencies can be expected to play a part new funding opportunities should be investigated. One possibility is that the funding for the 'outside expert' could be provided by a training institution in return for its nomination as the chosen training provider. It is likely that commercial organisations would consider providing funding for the training costs in return for the use of their products in the ensuing development projects. As trading in carbon credits becomes established projects which involve tree planting for a range of environmental benefits could attract funding from companies and instrumentalities in return for agreed carbon credits. Such a system would require verification.

Monitoring of the effectiveness of this model for technology transfer, and verification of quantities of carbon sequestered in projects where trees are being grown will be on-going requirements. These could be an on-going role for the institution that provides the training.

5. Conclusion

The paper has proposed a model that will address the seven goals for better technology transfer identified during Desert Technology IV. Some of the likely attendant problems have been identified, and solutions have been offered. It remains for the model to be tested and evaluated.

References

Maunder, A. (1972) (Ed.) Agricultural Extension: A Reference Manual. F.A.O. Rome

Shaxson, T.F. (In press): "Land Husbandry's Fifth Dimension - Enriching our understanding of farmers' motivations" Paper presented at 8th International Soil Conservation Conference, India, Dec. 1994.

Williams, A. (1997) "Report on visit to Moscow, the Astrakhan Region and the Republic of Kalmykia, GEDC, Kalgoorlie.

沙漠研究 10S, 73-76 (2000)
Journal of Arid Land Studies

—Special Issue— "Desert Technology V"
Refereed Paper

Trend Of Acidic Deposition And Its Likely Impact In An Arid Area Adjacent To The Great Indian Desert

Sanjay KUMAR*, M. MOHAN** and A. GHOSH***

Abstract - Acidic deposition in alkaline rich soil of tropical region, is likely to have fertilizing effect. However, vulnerability of ecosystems cannot be assessed on the basis of mean weighted annual rain water pH values alone. In the present paper, reasons of high pH values in tropical region are investigated. Further, the trend of acidic deposition in Jodhpur, India (Latitude- 26° 18', Longitude- 73°01', and Elevation - 217m), an arid area adjacent to 'Thar Deserts' is discussed and projections of ecosystem vulnerability are put forth on the basis of 'RAINS ASIA' Model. In this analysis, mean weighted annual pH values of rain water is replaced by the pH values of the first shower. Results are based upon the decrease of pH values from 7.0 rather than 5.65 for the temperate region.

Key Words : acidic deposition, RAINS ASIA Model, Jodhpur, Arid area afforestation

1. Introduction

Economic activities are sustainable only if the life support systems on which they depend are resilient. Not only our resource base is finite but also the environmental aberrations caused by them reduces the options of development. Acid rain is one such phenomenon caused by rapid industrialization and excessive use of fossil fuel based energy consumption. Acidic deposition is defined as total Hydrogen ion unloading over a given period of time, e.g., one year. Chemical and biological processes both in soil and water, are badly affected by hydrogen ion level. Damage to lakes, forests and materials, destabilization of various ecosystems and dramatic increase in natural calamities are attributed to direct and indirect effects of excessive acidic deposition in many countries. However, there exists distinct differences between tropical and temperate regions. In tropics, meteorological conditions contribute towards higher pH values of rain water in general. Moreover, a slight decline in pH value has positive effects since most of the tropical and sub-tropical regions are nutrient-limited, especially in Nitrogen and Sulfur, atmospheric deposition of these substances through acidic deposition have a fertilizing effect. Nevertheless, given our understanding of the impact of acidic deposition on temperate zone vegetation in North America and Europe, supplemented with the few such studies in the Asian region and on tropical and sub-tropical species, the vegetation in these areas are likely to be at higher risk (Manju Mohan and Sanjay Kumar, 1998). The great Indian desert, "Thar Desert" in the North-West of India and its surrounding areas have been receiving excessive acidic deposition due to meteorological conditions from high economic activities zones of Delhi, Bombay and Gujarat, causing strain to natural ecosystem..

The first likely casualty of these strains are surrounding arid areas like Jodhpur with scarce forest cover and considerable population. Though massive Governmental and Non-Governmental efforts are directed towards arresting the expansion of deserts by afforestation and improving the micro-climatic conditions, the effect of acid rain has further complicated the process. In the present paper, reasons of high pH values in tropical region and its adverse effect on vegetation is investigated. Further, acidic deposition in Jodhpur, its trend and likely impact on efforts to arrest the expansion of deserts by afforestation are discussed. Projections by 'RAINS ASIA' model show that

* Kyoto University, #502 Shugakuin International House, 1 itchodo-cho, Yamabana, Sakyo-ku, Kyoto-606-01
** Centre for Atmospheric Sciences, I.I.T. Delhi, India-110016
*** Dept. of Physics, Muzaffarpur Institute of Technology, Muzaffarpur, India-842003

the acidic deposition is fast approaching critical level and is likely to adversely affect the newly planted saplings. Acidic deposition is not a continuous and equally distributed phenomenon in this region. Its impact is maximum in the first few days of monsoon showers. The overall effect is likely to add to the desertification rather than reducing the salinity in the soil and acting as fertilization.

2. Acid Rain In Tropical Region

Theoretical neutral value of rain water pH value (5.65 at 20 deg. C) had been based on the assumption that only Carbon Dioxide is present in the atmosphere and the dissolved CO_2 in rain water is in equilibrium with atmospheric CO_2. However, if a trace amount of ammonia (3 micro gram per meter cube) in the atmosphere is present, the pH of rain water would be 7.0. Absorption of NH_3 is not the only way in which the pH value can be raised. Soil particles which are usually slightly basic when swept into the atmosphere by wind get dissolved and release solution base cations such as Calcium, Magnesium, Potassium and Sodium (Ca^{++}, Mg^{+}, K^{+} and Na^{+}) with bicarbonate usually the corresponding anion or negative ion. In addition to the above, an another important physical reason for higher pH of tropical rain is the high temperature dependence of solubility of Carbon Dioxide in water. pH of rain water directly depends upon the amount of CO_2 which actually dissolves into the water.

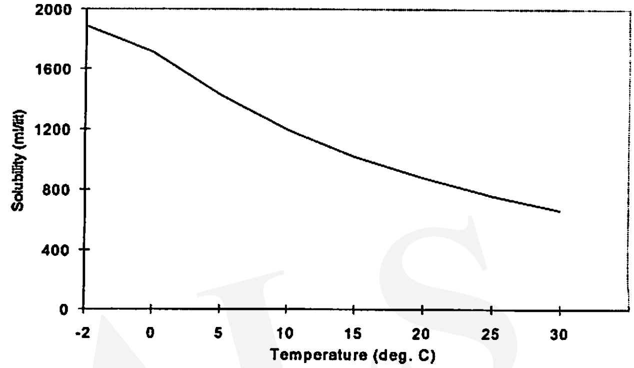


Figure 1 : Variation of solubility of CO_2 in water with temperature

Figure 1 shows the solubility of CO_2 in water at different temperature. Figure 2 shows the typical mean vertical temperature profile over Bombay and Stockholm in July and variation of partial pressure of Carbon Dioxide. Computations reveal that the neutral pH value of rain water in tropical region should be closer to 7.0 against 5.65 (at 20 deg. C) in European regions where temperature are quite low in comparison to tropical countries like India. Solubility of CO_2 in water is quite high in tropics (1.5 times approximately) and the dissolution rate of CO_2 in rain water is also higher by a factor of approximately 1.5 times. Rapid process of cloud formation in tropics also results in higher pH value. Any reduction in pH value therefore, should be investigated in this background. It may be concluded here that the high level of pH value is not due to low sulfate and nitrate levels but due to other reasons. The same level of pH in tropics and temperate zones doesn't mean the same level of acidic content in the environment. Ecosystem vulnerability depends not only on the acidity

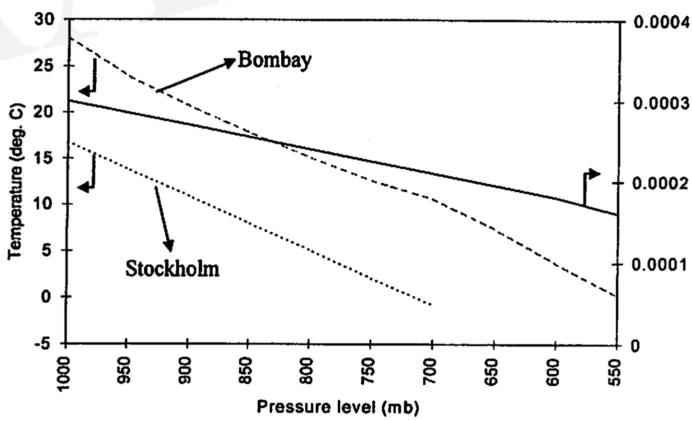


Figure 2 : Vertical temperature profile and Variation of partial pressure of CO_2.

of the deposition impinging on it but also on the total quantity of sulfates and nitrates it receives; these later cations can contribute to surface acidification after they are deposited, even if they are not acidic at the time of deposition.

3. Trend of Acidic Deposition in Jodhpur

Jodhpur (Latitude - 26° 18', Longitude - 73°01', and Elevation - 217 m) is essentially an arid area with scarce forest cover and considerable population density. It is adjacent to the Great Indian Desert, "Thar Desert" in the North-Western Part of India which has definite trend of expansion. The region has experienced a rapid land-use change. Prevailing meteorological conditions allows transportation of pollutants from high economic activity zones of Delhi, Bombay and Gujarat. It is important to note that Gujarat has a GDP growth rate of 12% as compared to a national average of approximately 5%. Delhi and Bombay are the two mega cities. The former has the dubious distinction of having highest no. of vehicles on the roads and 4^{th} most polluted city in the world. Bombay is the economic capital of India. To study background trends of rainwater pH, ten Background Air Pollution Monitoring (BAPMoN) stations were established in India over the period 1974 - 1984 as per instructions of World Meteorological Organization (WMO) (Khemani et al., 1989 and Varma, 1989). Jodhpur (WMO Index 42339) was observed to have received rain fall with pH variation of 6.35 to 8.70 and a decreasing trend over the years (Prakasa Rao et al., 1992).

Table 1 : Mean rainfall weighted mean for the monsoon season

Years	1976	1977	1978	1979	1980	1996	1997
pH value	7.96	8.28	---	7.16	---	6.1*	5.9*

* pH values correspond to the first three shower of the monsoon

Table 1 shows the monsoon period (June - September) rainfall weighted mean of pH values for the years for which data are available. These data are more significant than the Annual rainfall weighted mean of pH values since most of the wet deposition takes place during monsoon season. At the same time, monsoon season is considered best period for planting new saplings for afforestation. Data for 1996 and 1997 for the first few monsoon showers were also shown in table signifying the acidic nature of the rain water.

4. RAINS ASIA Model

The Regional Acidification Information and Simulation Computer Model is developed under the "RAINS - ASIA" project funded by World Bank to provide full regional picture of the problems associated with the entire casual process from energy systems and emissions through to the ultimate impact on natural and man made systems (Foell et al., 1995). Table 2 shows the SO_2 emissions and its projections for the major areas which affects Jodhpur most. Projections are made assuming that the basic control technologies would be used in future to control the emission. The major contribution to

Table 2 : SO_2 emission (kt) from Area and Large Point Sources and projections when basic Technologies are used to control emissions.

States/ Places	1990 LPS	1990 AREA	2000 LPS	2000 AREA	2010 LPS	2010 AREA	2020 LPS	2020 AREA
Bombay	108.82	31.92	203.46	48.69	313.92	66.30	488.64	95.33
Delhi	25.32	19.25	48.04	37.10	105.56	67.53	248.16	96.15
Gujarat	288.79	10.11	404.44	150.64	660.17	294.58	1113.68	547.04

the acid rain is reported to be due to sulphur component (~ 70%) and oxides of nitrogen (~30%) (Manju Mohan and Sanjay Kumar, 1998). However, the former is more likely to be transported to long distances in the prevailing meteorological conditions. The critical level in the 'RAINS ASIA' Model is defined as highest deposition level that is not likely to cause chemical changes leading to harmful effects on the ecosystem. By defining the relationship between chemical status and vegetation response, Critical Level for that particular ecosystem is derived by a relative sensitive approach using the steady state mass balance model (Foell et al., 1995). Projections in the present analysis are made on the basis of this model with minor modifications to include pH values of first showers of monsoon rather than mean annual average. Further, the neutral value of pH is considered 7.0 instead of 5.64, due to reasons explained in the text.

5. Discussions and Conclusions

Computations show that though TSPM from Thar desert is likely to counter the adverse effects of the acidic pollution around Jodhpur, projections for 2010 show that Jodhpur shifts its status from stable to highly critical. This signifies possible ill effects of acid rain specially on plantations, thereby, frustrating afforestation efforts to contain desertification. The ecosystem in and around Jodhpur in general is likely to be affected irrecoverably by 2020.

The effect of acid rain in the temperate zone vegetation in North America and Europe can be classified into two parts, 1) direct effect on leaf and other plant surfaces e.g., leaching of nutrients from leaves, erosion of protective surface layers and 2) indirect effect through soil-mediated effects. However, in temperate areas, receiving the highest levels of acidic deposition, there is little conclusive evidence of wide spread direct foliar damage to trees and crops. In tropics, on the other hand, the average life of leaf is greater than in temperate zone. Which indicates that the cumulative effects of acidic deposition could be large enough to cause direct damage. As explained in the previous section, the same level of pH value in tropics and temperate zones doesn't mean the same level of acidic content in the environment. Therefore, acidic deposition and its effect around the main desert should be monitored more closely. Shifting of polluting industries from areas prone to acid rain such as Delhi and Bombay with high population density, if required, should be towards more western part due to long range transportation trend of pollutants. This would reduce its effect on arid areas adjacent to the main desert and the limited acidic depositions would contribute as fertilizers rather than indirectly helping in desertification.

References

Foell W., Amanm M., Carmichael G., Chaduich M., Hettelingh J., Hordjick L. and Dianwa Z., (1995) : Report on the World Bank Sponsored Project, "Acid Rain and Emission Reduction in Asia".

Khemani L.T., Momin G. A., Prakasa Rao P. S., Safai P. D., Singh, G. Chattterjee R. N. and Prem Prakash, (1989) : Long - Term Effects of Pollution on pH Rain Water in North India. Atmospheric Environment 23(4) : 753-756.

Manju Mohan and Sanjay Kumar, (1998) Review of Acid rain Potential in India : Future Threats and Remedial Measures. Current Science 75(6) : 579-593.

Prakasa Rao P. S., Khemani, L.T., Momin G. A., Safai P. D. and Pillai A. G., (1992) : Measurement of Wet and Dry Deposition at an Urban Location in India. Atmospheric Environment 26B(1) : 73-78.

Varma G. S., (1989) Background Trends of pH Precipitation Over India. Atmospheric Environment 23(4) : 747-751.

沙漠研究 10S, 77-80 (2000)
Journal of Arid Land Studies

—Special Issue— "Desert Technology V"
Refereed Paper

Formation of Arid Areas and Destruction of Plant Physiology : Effect of Acidic Deposition

Jung Sung YANG* and Sanjay KUMAR**

Abstract - Excessive salinity is not the only major cause of desertification. In the coming years, excessive acidic deposition is likely to contribute decisively to the desertification process in many parts of the world. Acidic deposition is a necessary fall out of dramatic increase in the consumption of fossil fuel based energy sources. It changes gradually the physico-chemical properties of the soil and contributes to degeneration of plants leading to their complete destruction. In the present paper, the effect of acidic deposition on soil and plant physiology leading to desertification is discussed.

Key words : salinity, acidity, desertification, plant physiology

1. Introduction

The most dramatic threat to our environment is the speed with which plants and animal species are disappearing from the planet. Everyday about ten species become extinct. This not only destabilizes ecosystems instigating natural calamities in frequency and intensity, but also renders various alternative means of sustainable development enviable. For example, loss of plant cover has degenerated many fertile lands. Excessive salinity is not the sole cause of desertification as popularly believed. Excessive acidic deposition, i.e., total hydrogen ion unloading over a given period of time, is another major cause of destruction of flora and fauna leading to desertification in many parts of the world (Bredemeier, 1988; Garten et al., 1988). The phenomenon is widely attributed to fossil fuel based energy consumption pattern to achieve rapid economic growth. There seems to be no letting up in the use of fossil fuel derived energy sources. Asian energy demand is doubling every twenty years and the demand for electricity in particular is increasing two to three times faster than the GDP growth. Acidic deposition has been an issue of widespread concern in Europe and North America for decades and has been perceived a major threat in Asia recently with economic activities picking up (Bhatti et al., 1992). The major contribution to acid rain is reported to be from Sulfur compounds (~70%) and oxides of nitrogen (~30%) (Manju Mohan and Sanjay Kumar, 1998). Historical data in Europe provide evidence of increase in acidic deposition due to emission and transport of sulfate, up to a factor of 2 in 1950 and 3.5 in 1980 in comparison to pre-industrial levels. Air pollution, in the form of SO_2 and NO_x may cause adverse effects to the natural environment depending upon the ability of an ecosystem to assimilate a substance without degrading or damaging its ecological integrity, once concentration levels or deposition loads exceed certain limits (Freiesleben et al., 1986; Percy, 1989). It is found that serious direct effects occur on a local rather than a broad geographical scale. Episodic excessive concentrations are most likely to cause acute, short-term damage including yield-loss and may affect the long-term sustainability of the ecosystem. Long term excessive deposition, however, affects the sustainability of a natural ecosystem rendering recovery less likely and ultimately changing the soil chemical composition to an extent where there is a shift in natural functions also. These factors reduce the forest cover in quality and quantity, leading to loss of plant cover and desertification. In the present paper, the effect of acidic deposition on soil and plant physiology and its subsequent destruction leading to desertification is discussed.

2. Effect on Soil

Crops and plants thrive on a soil with pH value higher than 6. The plants' water uptake is then most efficient, nutrients are easily available and harmful metals are least absorbed. Deposition from the atmosphere is not the only cause of farmlands and forests being acidified. Several acidifying process take place even naturally in the soil. One of the most prominent being connected with the uptake of materials by plants, mostly in the form of positively charged ions. The plants compensate for this by releasing hydrogen ions. Thus growth in itself is acidifying. Whereas, the break down of the dead plant material has an opposite effect. It follows that in an ecosystem where growth and decay are about equal, there will be no net acidification but if the cycle is broken by harvesting whether it be crops or trees, acidifying processes dominate. For example, whole tree harvesting, which involves the removal of the branches, twigs and other

* Dept. of Chemistry, Kyungnam University, 449 wolyyoung-dong, Happo-gu, Masan, Kyungnam, S.Korea - 631-701
Fax : 82-551-49228
** Kyoto University, #502 Shugakuin International House, 1 itchodo-cho, Yamabana, Sakyo-ku, Kyoto-606-01

residue, makes only a small portion of the nutrients stored in the tree available for recycle. The natural circulation is broken and soil becomes more acidic. Consequently, there is a gradual deterioration of soil's buffering capacity. This may however be offset by weathering - depending more or less on the characteristic of the soil. Nevertheless, it is the principal cause of acidification in various farmlands in Europe.

Present day agricultural practices also contribute to a great extent in reducing the pH value of farmland soil. A great many hydrogen ions are released in the soil when ammonium of the fertilizer is converted to nitrate. Such fertilizers are believed to account for 15-50% of the total acidification. Similarly, application of acidifying fertilizer in intensive forest management also acidifies forest soil. The potential for long term soil mediated effects of acidic deposition is further increased at high elevation because of the high levels of atmospheric deposition and generally thin soils. Controlled experiments on low elevation forests where seedlings are exposed to varying doses and concentration of ozone (also an acidifying precursor) show decreased growth with increase in ozone concentration above 50 ppb. It is important to note that five years average maximum seven hours daily mean ozone concentrations are generally in the range of 40-60 ppb. It is therefore, possible that such stress is retarding the growth of forest trees. Ozone injury increases with elevated humidity, reaching a maximum with continuous nightly mist. Therefore above cloud based forests may experience even greater stress.

The dynamics of soil acidification are very site specific and depend on soil characteristics such as weathering rate, sulfate adsorption capacity and CEC. Numerous hypothesis of the detrimental effects of acidic deposition on forest soil mediated mechanism has been proposed. The main hypothesis are,

1) reduction of the productivity of the micro-organism that decomposes litter,
2) reduction of the efficiency of michrorrhizae
3) leaching of essential nutrients such as, K, Ca and Mg
4) reduction of monomeric Aluminium into the soil solution and
5) mobilization of trace materials

These effects have been experimentally demonstrated in simulated exposure at acidities higher than ambient. Increase of Aluminium concentration in the soil solution inhances the risk of vegetation damage. Changes in nutrient availability (such as magnesium and phosphate) and form (such as nitrate or ammonium) affects the fertility of the soil and influence vegetation structure and functions. Damage to forests in Europe including defoliation, foilar discoloration, growth rate decrease and die back have been reported over the last decades, and has been attributed to a large extent, to soil acidification.

To determine the critical load for an ecosystem, the steady state Mass balance Method may be applied within the convention on Long Range Transboundary Air Pollution of the United Nation Economic Commission for Europe to compute critical loads for forest soils and ecosystems. The method uses the response of single species to the balance between base cation nutrients and Aluminium in the root zone as one of the inputs to critical load computation. Relation between growth and Al, Ca/Al and BC/Al were tested in laboratory experiments and it was found that BC/Al gave the best correlation. The pattern remained consistent for a range of species. Several types of response expression can be derived from assuming antagonism between base cations and Al through different types of ion exchange at the root. The general equations for the damage functions can be expressed in terms of BC/Al ratio as,

$$f(BC/Al) = \frac{[BC]^{n-m}(BC/Al)^{m}}{[BC]^{n-m}(BC/Al) + K(l + (n(H/Al))^{m}}$$

where,

$[BC]$ = Concentration of base cations Ca, Mg and K
K = Response function
BC/Al = Base cation to Al ratio
H/Al = Proton to Aluminium concentration in soil solution

3. Effects on Plants

Today the primary agents of concern are acidic deposition (wet and dry), and their precursors SO_2, NO_x and volatile organic compounds as well as their associated oxidants, such as ozone and H_2O_2. All forests experience natural stresses caused by plant competition, nutrient limitations, adverse weather, insects, disease and other factors acting alone or in competition. Man caused stress such as incompatible land use, wild fire, and regional pollution can also contribute to reduced forest health. It is often difficult to establish a connection between any one type of damage and its cause. Though damage may arise due to different reasons, any one stress factors may sometimes trigger off a chain reaction.

The effect of excessive acidic deposition leading to the destruction of plants is shown in fig. 1. The following damages are attributed to excessive acidic deposition,

1) corrosion of the protective wax layer of needles and leaves by dry or wet acidic deposition,
2) damage to stomata which among other thing regulate the evaporation of water,
3) injury to membranes inside the needle or leaf, causing loss of nutrient through leakage and upsetting of water balance,
4) triggering of synergistic effects,
5) indirect damage occur when the soil becomes acidic (as explained in the previous section),
6) the combination of the acidic environment and toxic metals damage the roots. As a result, the nutrient supply diminishes and toxic effect of the Aluminium make the root hair unable to suck up sufficient water and nourishment,
7) possibly the micorrhizae i.e., symbiosis of the root hair with fungi is also disrupted so as to impede, if not entirely cut off the exchange of nutrients between the tree and the fungus, and
8) all these factors impair the vitality of the vegetation, and its ability to cope with diseases and insects. The situation becomes worse when weather is unfavorable and parasites finish off an end of already weakened tree.

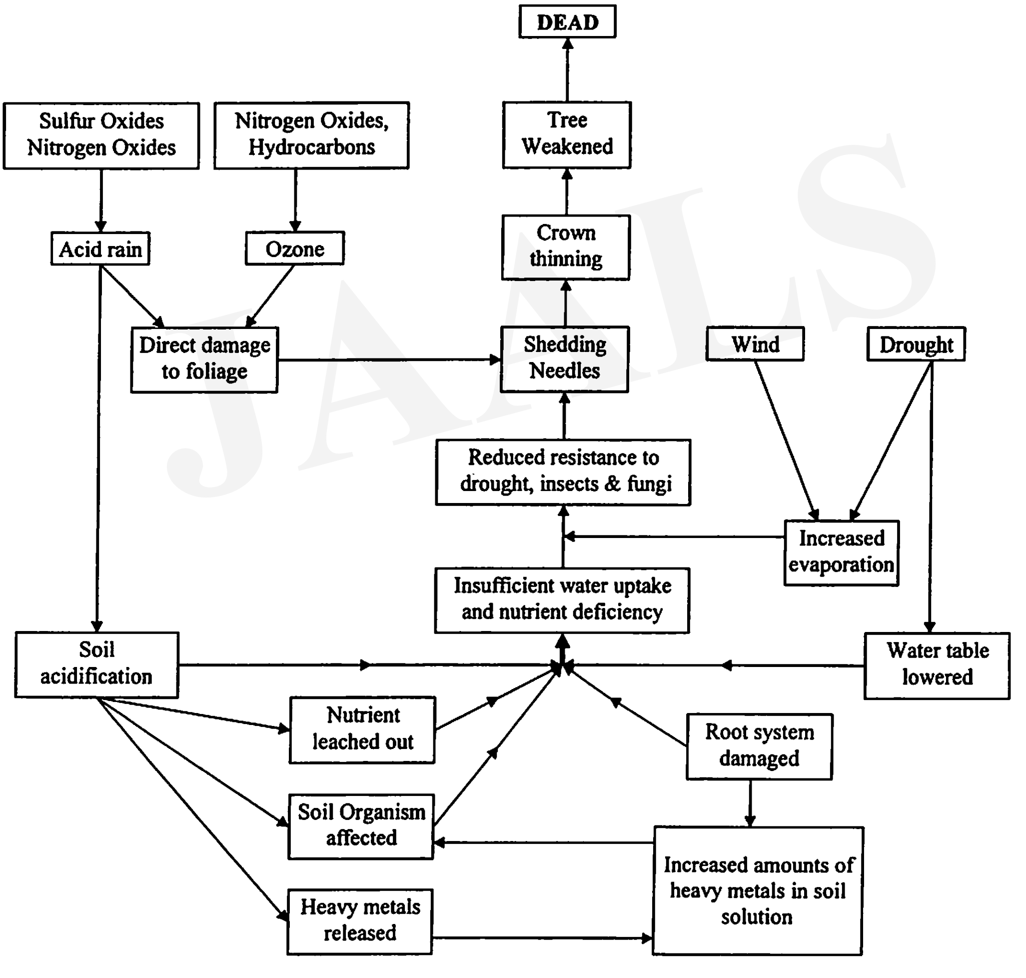


Figure 1 : Effect of acidity and its precursors on forests

Deciduous trees are found to be less sensitive than the conifers, partly because the leaves fall off every autumn. The spruce pine and beech have been observed to suffer maximum damage. Yellowing and browning of the needles, loss of needles and growth of adventitious shoots, loss of root hairs and reduced root growth, shortened needles, narrower annual rings, a higher incident of ruptures in the trunk, and dropping branches are some of the signs of weakening of trees due to direct/indirect effects of acidic deposition.

The most sensitive flora are lichens and mosses, neither of which have protective wax coating. They take up water directly through their leaves or tchalli. These have a very active growth period during autumn, which makes them particularly vulnerable to increased acidic deposition. Lichens can even serve as the indicator of SO_2 level. On the other hand species resistant to acidic deposition and thriving on nitrogen is increasing. Nitrogen fixing legumes are another vulnerable group. Increasing deposition of nitrogen in the form of nitrate inimical to those bacteria which in symbiosis with the roots of legumes convert atmospheric nitrogen into an available form. But the change may take place unnoticed, since an already established plant can withstand a great deal. On the other hand reproduction and seeding are endangered. A handful of common species, such as, nettle, wavy grass and raspberry - are likely to proliferate initially at other plants' expense before giving way to complete desertification.

4. Conclusion

Causes of tree damage are of course complex and involve the actions of other pollutants, climate and interactions with pests and pathogens. However, the long term nature of change in soil from acidification, interacting with other stresses, emphasizes the importance of acidification relative to other causes. Nevertheless, when pH goes down, anyone stress factor may trigger off a chain reaction, creating conditions detrimental to the plant physiology. The vitality of the tree gets impaired due to excessive acidic deposition and so its ability to cope with disease and insects . This ultimately leads to its destruction which is a visible sign of desertification process. It may be concluded that in the coming years, acidification would be one of the major causes of desertification in many areas. However, studies are limited and soil-mediated effects of acidic deposition on intensively managed plantations are found to be negligible, because these trees are treated as crops and their soils can be amended to provide proper nutrition and pH.

References

Bhatti N., Streets D.G., Foell W.K. (1992) : Acid Rain in Asia. Environmental Management. 16(4) : 541-562.

Bredemeier M. (1988) : Forest Canopy Transformation of Atmospheric Deposition. Wat. Air Soil Pollut. 40 : 121-138.

Freiesleben N.E.V., Ridder C. and Rasmussen L. (1986) : Patterns of Acidic Deposition to a Danish Spruce Forest. Wat. Air Soil Pollut. 30 : 135-141.

Garten C.T., Bondietti E.A. and Lomax R.D. (1988) : Contribution of Foilar Leaching and Dry Deposition to Sulfate in Net Throughfall Below Deciduous Trees. Atmospheric Environment 22, 1425-1432.

Manju Mohan and Sanjay Kumar (1998) : Review of Acid rain Potential in India : Future Threats and Remedial Measures. Current Sc. 75(6) : 579-593.

Percy K.E. (1989) Vegitation, soils and ion transfer through the forest canopy in two Nova Scotia Lake Basin. Wat. Air Soil Pollut. 46 : 73-86.

沙漠研究 10S, 81-84 (2000)
Journal of Arid Land Studies

—Special Issue— "Desert Technology V"
Refereed Paper

A STUDY ON POSSIBILITY OF BAUXITE UTILIZATION TO IMPROVE SOIL PROPERTIES FOR AFFORESTATION OF ARID LAND

Hiroyuki HAMANO*, Shigeru KATO*, Tomohiro SHIMIZU*,
Toshinori KOJIMA* and Koichi YAMADA**

Abstract - Recently, various measures to improve the soil condition have been proposed for arid land afforestation and cultivation. The Leonora region in Western Australia was selected as a research area where rainwater does not fully permeate into soil rapidly, then fairly large amounts run off on the surface. In the present study, we propose a measure with calcined bauxite as a new soil conditioner to improve water penetration. Results so far indicate bauxite is a good soil conditioner for arid land afforestation when calcined and mixed moderately with soil.

Key Words: Soil conditioner, Bauxite, Afforestation

1. Introduction

Securement of adequate amount of water for arid land afforestation is difficult due to small rates of precipitation and high rates of evaporation in such areas. Soil improvement by mixing with Super Absorbent Polymer (SAP) and others have been proposed as one of the promising technologies for growing plants efficiently with a limited amount of water. A soil conditioner such as SAP gives efficient water retentivity. However, this efficient water retentivity sometimes acts as negative factor toward water permeability. Furthermore, the production cost of SAP is high and its life is short because of its degradation by ultraviolet ray. From this viewpoint, development of a low-cost new soil conditioner with both water retentivity and permeability is desirable.

In some arid areas, such as in Western Australia, rainwater does not permeate through the soil quickly enough due to the hardness of their soil. Much of the rainwater often runs off on the surface even for small amount of rainfall and finally evaporates without being utilized by trees. In this study, Australian bauxite, which becomes porous with moderate water retentivity when calcined, was selected because of its low cost of production and its abundant local availability. Water retentivity and permeability of the soil mixed with bauxite calcined under various conditions were evaluated experimentally by column tests using glass beads as model soil. The critical factors controlling its water retentivity and permeability, i.e., thermal properties, pore size distribution, porosity, specific surface area of calcined bauxite, were measured and their effects on soil properties are discussed. The effectiveness of calcined bauxite is compared with commercially available SAP.

2. Experiment

2.1 Property and preparation

The chemical composition of bauxite employed is shown in Table 1. The color of bauxite before calcination is reddish-brown, and the original bauxite particle diameter is about 1-3cm. In this study, we focused on how to change the property of bauxite by calcination. Bauxite was crushed and sieved into several groups with different particle diameters (0.053-0.090mm, 0.250-0.350mm, 0.350-0.420mm, 0.700-1.000mm, 1.190-1.680mm).

Table 1 Composition of bauxite

Constituent	%
Al_2O_3	50.5
SiO_2	3.9
Fe_2O_3	16.5
TiO_2	2.8
L. O. I*	26.1

* weight loss by ignition at 1088K

* Department of Industrial Chemistry, Seikei University, Musashino-shi Tokyo 180-8633, Japan
** Department of Fine Materials Engineering, Shinshu University
(Fax: +81-422-37-3871, E-mail: kojima@chgw.ch.seikei.ac.jp)

The minimum fluidization velocities of these particles are given as follows for particle diameter range of 0.250-1.68mm

$$U_{mf}=\frac{\mu}{d_p\rho_g}\left[\left(31.6^2+0.0425GaMv\right)^{0.5}-31.6\right]\qquad\left(Ga=\frac{d_p^{\,3}\rho_g^{\,2}g}{\mu^2},\quad Mv=\frac{\rho_p-\rho_g}{\rho_g}\right)$$

and particle diameter range of 0.053-0.090mm;

$$U_{mf}=\frac{\mu}{d_p\rho_g}\left[\left(33.7^2+0.0408Ar\right)^{0.5}-33.7\right]\qquad\left(Ar=\frac{d_p^{\,3}\rho_g\left(\rho_p-\rho_g\right)g}{\mu^2}\right)$$

2.2 Calcination condition

Fig.1 is a schematic diagram of the fluidized bed apparatus employed for bauxite calcination. The experimental fluidized bed was a stainless steel column of 78.1 mm ID and 900 mm height. Air as fluidization gas was supplied from an air compressor through a pressure regulator. The gas flow rates into the bed were controlled by needle valves and measured by manometers. Gas velocity was set at 1.5 times of minimum fluidization velocity (U_{mf}). Then, bauxite sample was supplied from the top of the bed at about 250g/min keeping the bed temperature unchanged. Thus a rapid heating was realized. After being calcined for 1 hour at various temperatures, it was taken out from the bottom of reactor.

2.3 Analysis

The thermogravimetric analyses (TGA) of bauxite with and without calcination were conducted by Shimadzu DT-40. Before the analyses the following pretreatment was conducted. 1) 10g of bauxite sample was soaked in 30ml distilled water and stirred well, 2) kept in room temperature for 24 hours, 3) filtered with reduction of pressure using glass filter (1G-3/4) until drainage stops, 4) kept under saturation vapor pressure for 24 hours, 5) and finally, the sample was weighed. TGA was conducted under the heating condition of 10℃/min until 110℃, holding 110℃ for 20 minutes, and reheated by 10℃/min up to 500℃, holding at 500℃ for 10 minutes. Specific surface area, total pore volume, average pore diameter were also measured by an automatic surface area analyzer (Shimadzu GEMINI 2360).

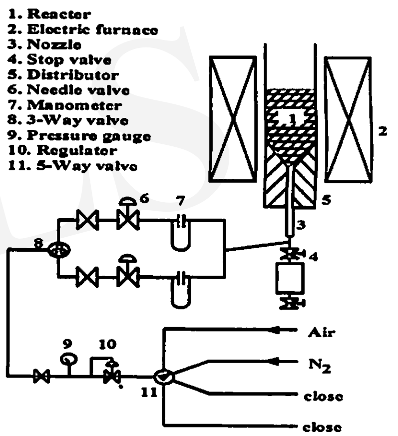


Fig.1 Experimental Apparatus

Saturated hydraulic conductivity (K_s) was measured using a constant-head permeameter method. In this measurement, 0.4mm glass beads was used for simulating soil and mixed with the bauxite samples. Effects of mixing ratio and particle diameter of the bauxite sample are discussed.

3. Results and Discussion

3.1 Water permeability

Fig.2 shows the influence of bauxite as soil conditioner on the water permeability. In this study, 0.4mm glass beads were used to mimic soil as a fundamental research. A maximum value of K_s was found under the condition that particle diameter of bauxite was nearly same as that of the glass beads. On the other hand, mixtures with larger or smaller particles than the bed glass beads showed smaller permeabilities. These

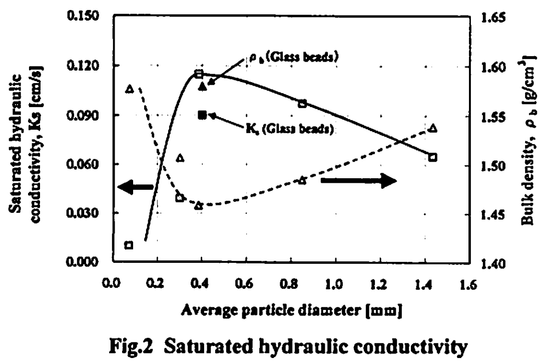


Fig.2 Saturated hydraulic conductivity with 10wt% uncalcined bauxite

results indicate that a suitable mixing ratio reduces the bulk density of the soil layer. The reduction in bulk density corresponds to an increase in the voidage in the soil layer, which leads to an increase in its permeability.

Increasing the ratio of SAP to soil decreases permeability (Tahara et al., 1994; Yabashi et al., 1998). A soil mixed with SAP had no more than one tenth worse poorer permeability than the original soil. Thus it appears that SAP causes a reduction in permeability by its infiltration into and plugging soil voids. After the absorption/release process of rainwater, SAP will shrink and may adhere to the soil particles and may cause some possibilities of reduction in permeability after a long-term use. On the other hand, mixing of bauxite was found to have some improvement on the soil permeability using a suitable mixing ratio. It is expected that bauxite kept its quality as soil conditioner and structure of soil even in the case of evaporation. It was pointed out, however, that there is some suitable particle diameter and mixing ratio for the improvement in the permeability of the soil.

Furthermore, SAP will degrade in a couple of years when exposed to ultraviolet ray. In case of bauxite, there will not be any possibility of degradation. Thinking about long-term use, it is necessary for a soil conditioner to keep its ameliorative effectiveness.

3.2 Water retentivity

Fig.3 shows the relation between temperature and weight loss ratio. It can be regarded that the amount of weight lost within 110℃ is that of free water and the amount of remaining weight is that of structural water. It was thought that the water which was lost before 110 ℃ could be used for plant growth. From this result, the bauxite before calcination had 20% free water and 18% structural water, while the bauxite calcined rapidly in a fluidized bed had 38% free water in the sample saturated with fresh water. It was found that the rapid calcination of bauxite converted the structural water to free water and increased the absorbed water that is available by plants. On the other hand, most of the weight of SAP saturated with fresh water is water which can be released below 110℃. SAP has a 1000 times water retentivity of its dry weight, and the SAP is thought to be superior to the bauxite when it is used in a agricultural land for high-priced farm products with annual digging up of soil, while bauxite will be suitable for soil conditioner for afforestation.

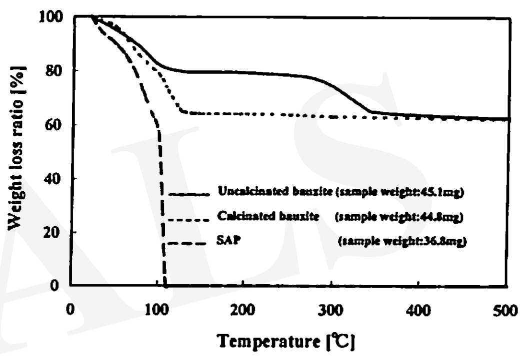


Fig.3 Thermogravimetry data

3.3 Effects of particle diameter and calcination temperature on properties of bauxite

Figs.4-7 show the effects of particle diameter and calcination temperature on the amount of absorbed free water, and specific surface area of bauxite before and after rapid calcination at 900℃. The bars below zero indicate the values for bauxite before calcination and bars above zero indicate additional absorbed water introduced by the calcination; while the total values of bars indicate the value for calcined bauxite. The bauxite before calcination showed a tendency to have a larger amount of absorbed free water per 10g-dry-bauxite as particle diameter becomes smaller. On the other hand, the amount of free water absorption introduced by the calcination was increased with the particle diameter while total free water absorption was not influenced so much by the diameter. In comparison with the surface area data in Fig. 5, it can be suggested that the additional amount of fresh water absorbed should be introduced by the increase in the surface area. Though the details of the results are not shown here, both of the surface area and total pore volume increased with the decreasing average pore diameter, with the increase or particle diameter.

Figs.6 and 7 show the influences of calcination temperature on the amount of absorbed water and surface area for 0.35-0.42mm bauxite. As calcination temperature rises, the amount of additionally absorbed water becomes smaller, with the decrease in the specific surface area as shown in Fig.7. Though the details of the results are not shown here either, the total pore volume increased while average pore diameter decreased with temperature increment. The present results indicate that micro-pore surface was sintered to form macro-pores which leads to the decrease in surface area and water retention capacity. The present results indicate the optimum temperature will be a rather lower temperature than 700 ℃ though most of the processes of absorbent production from bauxite are operated around 900 ℃.

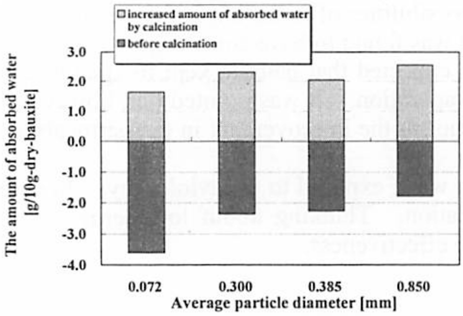


Fig.4 Influences of particle diameter on absorbed water by bauxite before and after rapid calcination at 900℃

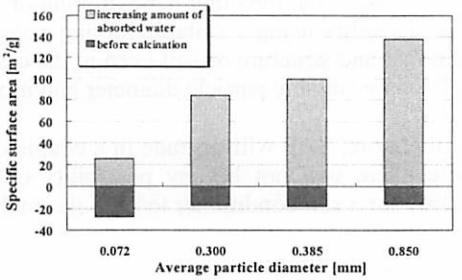


Fig.5 Influence of particle diameter on specific surface area of bauxite before and after rapid calcination at 900℃

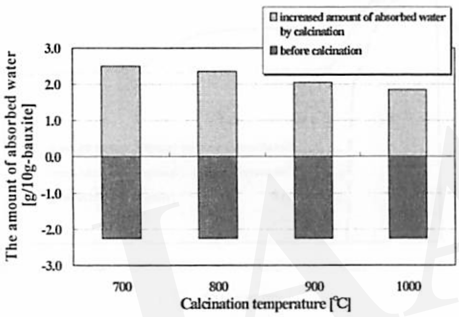


Fig.6 Influences of calcination temperature on absorbed water for 0.35-0.42mm bauxite before and rapid alcination at 900℃

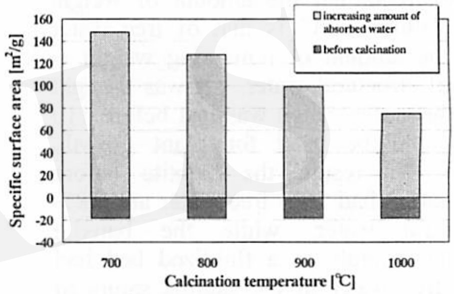


Fig.7 Influence of calciaton temperature on specific surface area for 0.35-0.42mm bauxites

4. Conclusion

Bauxite has good properties and probabilities as a soil conditioner for arid land afforestation. Its absorption capacity of free fresh water was found to be increased by its rapid calcination. The increase in the water retention capacity was well correlated with its specific surface area.

Acknowledgement

This work was financially supported by NEDO (New Energy and Industrial Technology Development Organization) of Japan. The authors would also like to acknowledge to Sumitomo Chemical Co. for its supply of bauxite sample.

Nomenclature

Ar	=	Archimedes number	[-]	U_{mf}	=	Superficial minimum fluidization velocity	[m/s]
d_p	=	Primary particle diameter	[m]	μ	=	Viscosity of gas	[Pa s]
g	=	Gravitational constant	[m/s]	ρ_g	=	Gas density	[kg/m³]
Ga	=	Galileo number	[-]	ρ_p	=	Density of particles	[kg/m³]
Mv	=	Density ratio	[-]				

References

Kunii D. and O.Levenspiel (1991), Fluidization Engineering, 2nd ed., Butterworth-Heinemann, Stoneham, MA, USA

Thonglimp, D. (1985), in FLUIDIZATION, J.F. Davidson, R. Clift, D. Harrison ed., p.33, Academic Press, London, England

Tahara K., K. Horiuchi, S. Uemiya, T. Kojima and T. Mori (1994), Journal of Arid Land Studies, 4: 15-19.

Yabashi S.,Andreas Hamacher, Jun Liu, Yukuo Abe, Satoru Takahashi (1998), Journal of Arid Land Studies, 7S: 133-136

沙漠研究 10S, 85-88 (2000)
Journal of Arid Land Studies

－Special Issue－ "Desert Technology V"
Refereed Paper

Estimation of Present Biomass in Leonora, Western Australia

Masahiko TANIGUCHI*, Yukuo ABE**, Toshinori KOJIMA,
Masahiro SAITO****, Koichi YAMADA***** and John LAW******

Abstract – A complete understanding of ecosystems is necessary before under taking forestation as a measure to combat global warming. In this study, the present volume of biomass and the correlation among the biomass, the topography and the soil condition were researched in Leonora, Western Australia. As a result, it was clarified that the most important factor for the increase of biomass was the action of surface runoff after a rainfall event.

Key Words: forestation, biomass, surface runoff

1. Introduction

Effective counter measures against global warming are mandatory, but are difficult to enact according to existent social systems and technology. Large-scale forestation is looked upon as one possibly counter measure against increasing CO_2. The kind of area that would be most suited for large-scale forestation is considered to be:

1) An area where potential biomass is much larger than present biomass, such as an area of desertification
2) An large area which carbon fixation could be increased with little money investment
3) An area which could be used semi-permanently as carbon storage

Leonora, in Western Australia, was chosen as the potentially suitable arid area following those requirements. Now, research is being carried out and consideration is being given, whether large-scale forestation should be undertaken.

Proper understanding of present ecosystem in Leonora allows an estimation of the carbon fixation volume after large-scale forestation as well as environmental modification needed to better plant growth. The aim of this study is to clarify the plant growth distribution and to elucidate the relation between biomass and the environment, such as topography and soil condition within the defined research area.

*Doctoral Program in Agricultural Sciences, University of Tsukuba, Tsukuba, Ibaraki 305,Japan (FAX. +81-298-55-2203)
**Institute of Agricultural & Forest Engineering, University of Tsukuba, Tsukuba, Ibaraki 305, Japan
***Faculty of Engineering, Seikei University, Musashino, Tokyo 180, Japan
****Community Dynamics Laboratory, Forestry and Forest Products Research Institute, Tsukuba, Ibaraki 305, Japan
*****Dept. of Fine Materials Engineering, Shinshu University, 3-15-1, Tokida, Ueda, Nagano 386-8567, Japan
******Minesite Rehabilitation Services PTY LTD, Kalgoorlie, Western Australia 6430, Australia

2. The features in research area

The target area for forestation, Leonora, is located at latitude 28°53' S and longitude 121°45' E, in Western Australia. Mean annual rainfall is approximately 200mm. Because a crust forms on the soil surface, rainfall runs off the soil and into huge salt lakes. Hardpan, where soil water infiltrates very slowly, exists under topsoil and its depth from the surface decides the total water volume accumulated in soil. Plant composition varies from temperate forest to bare soil in the degree of biomass.

A research area 40km × 50km (Figure1) in size was obtained in the target area. Eight sites, where the geology and the rate of plant growth are different, `were selected. The biomass of plants and land, including litter and grass, was measured in the 8 sites. Then the correlation between the biomass and the brightness on aerial photographs were examined in the same sites. The means used to investigate the factors are as follows.

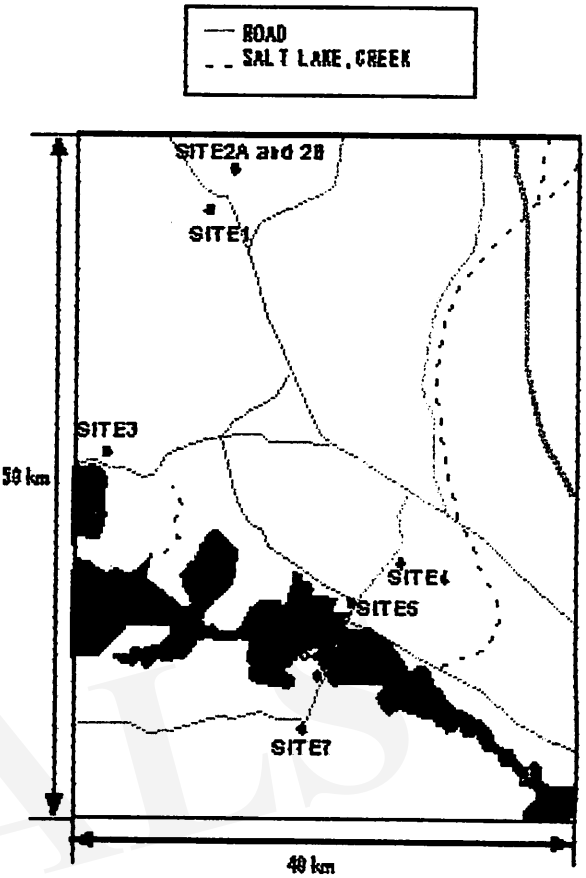


Figure1 The location ofthe research sites in the research area

3. Methods to research the biomass and soil

First, land cover biomass, which included litter and grass, was measured by a quadrat method. TRAPS (Transect Recording And Processing System) method was adopted to survey plant biomass and to understand the condition of ecosystem in each site. Following the TRAPS method, plant height, canopy diameter, brunch and trunk area at 30 and 130cm height from ground as the representative values of plant shape, and the position of each plant in transects were recorded. Sample plants, which determined as dominant species in each site, were selected and each mass and the given values were measured.

Next, the soil profile was divided into 3 parts, and EC, pH and the depth of hardpan were measured. It was assumed that EC and pH expressed the degree of salt accumulation and the type of salt, while hardpan depth represented the maximum water volume in soil. Then, the research area was divided into 6 parts according to the brightness on aerial photographs. Besides ground truth points were selected, and correlation between the result of ground truth and the brightness on same points of aerial photographs was surveyed. As a result, the total biomass was estimated by approximating the classified areas to one of the research sites.

4. Estimation of biomass in each research site

It is reported that stem volume, plant height and canopy diameter are related to plant mass. In this study, stem volume and mass showed the best correlation. Therefore, this correlation was applied to estimate the total biomass of plants in each site. In case that the plant was too small to measure the area at the height, 30 and 130cm, the correlation between the plant height and the mass of sample plants was applied to estimate.

Table1 Biomass in each research site

Site No.	Biomass of Grasses and litters (t/ha)	Biomass of plants (t/ha)	TOTAL (t/ha)
1	28.6	258.0	286.6
2A	10.3	138.0	148.3
2B	1.4	0.0	1.4
3	0.1	1.6	1.7
4	8.4	47.4	55.8
5	11.8	32.8	44.6
6	1.1	37.7	38.8
7	15.0	86.3	101.3

Estimated biomass for each site is shown in Table1. It shows that the maximum biomass per unit area was over 100 times that of the minimum in the research site. The biomass of land covers was 0.1-0.3 times as heavy as the biomass of plants. From the fact that litter is decomposed quickly and glass biomass varies greatly when season changes, the effect of long-term carbon fixation as land cover was very little.

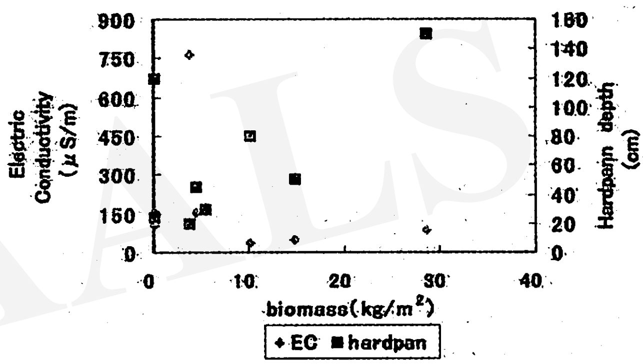


Figure2 The rellation of soil and biomass

5. The relation between biomass and soil

Figure2 shows the relationship between soil and estimated biomass in each site. It is apparent that biomass is strongly influenced by the depth of hardpan. Areas with good plant growth are those that receive surface runoff and where eroded soil accumulates. Surface runoff would be slow enough in areas where eroded soil accumulated. In the areas more water infiltrates and stores than in other areas. As a result the hardpan would become deeper and the water, which is the most important factor for plant growth in arid areas, increases in the soil accumulating areas.

6. The relation between biomass and topography

Total biomass and distribution of biomass in the research area were estimated from aerial photographs. The areas representing the highest productivity of biomass were overlaid on topography map (Figure3). Figure3 shows the areas of good plant growth are along creek lines. From this fact, it was clear that the former speculation was confirmed and large-scale forestation would be possible.

7. The possibility of large scale forestation

Runoff that flows into salt lakes is not used for plant growth, but lost through evaporation from lakes. Biomass could be increased if water storage, the essential factor for plant growth, could be increased with dams, such as water ponding bank.

8. Conclusion

In this study, it was identified that the differences in plant growth were related to surface runoff. Consequently large-scale forestation could be successful in local areas where runoff is dammed using water-harvesting techniques.

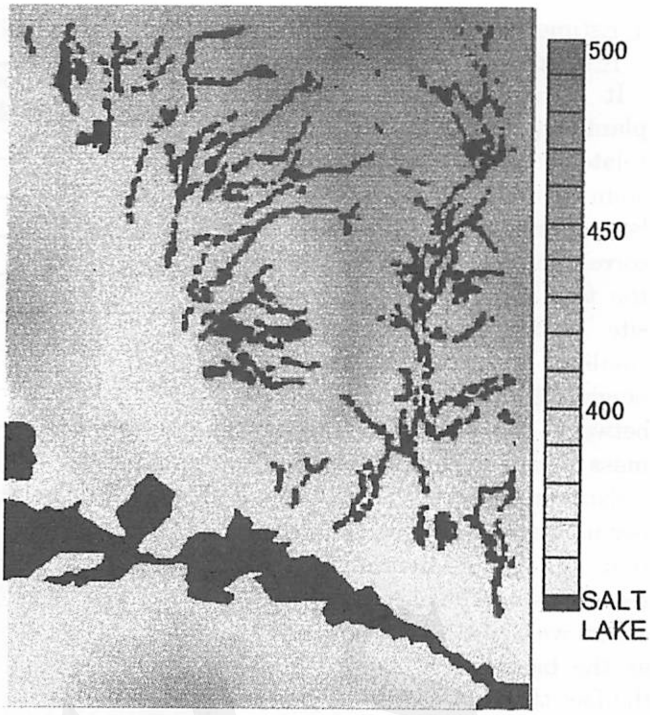


Figure3 The relation between topography and the largest biomass areas

9. Acknowledgement

This work was financially supported by NEDO (New Energy and industrial technology Development Organization) of Japan and JST (Japan Science and Technology corporation). Furthermore, this work was carried out by the Committee of Biological CO_2 Fixation organized by the Society of Chemical Engineers, Japan.

Reference

John Law, Adrian Williams: Resource Information for Research Sites in the Leonora area, Western Australia (1996)

John Law: A Summary of the Biomass & Soil Sampling (1998)

Masahiko TANIGUCHI, Yukuo ABE, Koichi YAMADA, Toshinori KOJIMA and Adrian Williams: Possibility of Large Scale Afforestation in Arid Lands as a Measure against Increases in CO_2 Concentration, Journal of Arid Land Studies, Vol.7S pp.249-252 (1998)

沙漠研究 10S, 89-92 (2000)
Journal of Arid Land Studies

－Special Issue－ "Desert Technology V"
Refereed Paper

Extinction of Winnemucca Lake , Nevada: A Small-Scale Analog of What Has Happened to Similar Desert Lake Basins

Thomas LUGASKI*

Abstract - Winnemucca Lake, Nevada (USA) was a alkaline remnant of Pleistocene Lake Lahontan that do to changing weather patterns, evaporation, diverted irrigation and consumptive use, went dry in 1939. The lake's history is a small-scale analog of what can and has happened in the Aral Sea region of Central Asia and other similar desert lake basins. Even without consumptive use and associated diversions, a combination of factors would have affected it, causing the lake to go dry sometime in the historic past. Other recent major weather events most likely would have again increased its volume and formed another large lake and associated wetlands. (Such is the water-cycle in this desert basin.)

Key words: extinct lake, extinct species, agricultural diversion

1. Introduction

In January 1844, Capt. John C. Fremont discovered Pyramid Lake (Fremont, 1845), located about 64.4 km (40 miles) northeast of Reno. Winnemucca Lake, located 8 km (5-6 miles) east of Pyramid lake, and connected by the Mud or Winnemucca Slough, was a wet mud flat or small playa lake. Winnemucca Lake, had been at a low level or dry for some 10-15 years prior to Fremont's arrival and would remain so until the late 1850's. By 1882, I.C. Russell of the United States Geological Survey (USGS)(Russell, 1885), would record a lake on the basin with a depth of 25.9 m (85 ft.). Both Pyramid and Winnemucca Lakes receive a major portion of their water-supply from the Truckee River which drains from the Lake Tahoe and surrounding areas of the Sierra Nevada. A narrow channel at the base of Marble Bluff in the Lake Range called Mud or Winnemucca Slough, connects the two lakes at a bifurcation of the Truckee River (Russell, 1885, Hardman and Venstron, 1941).

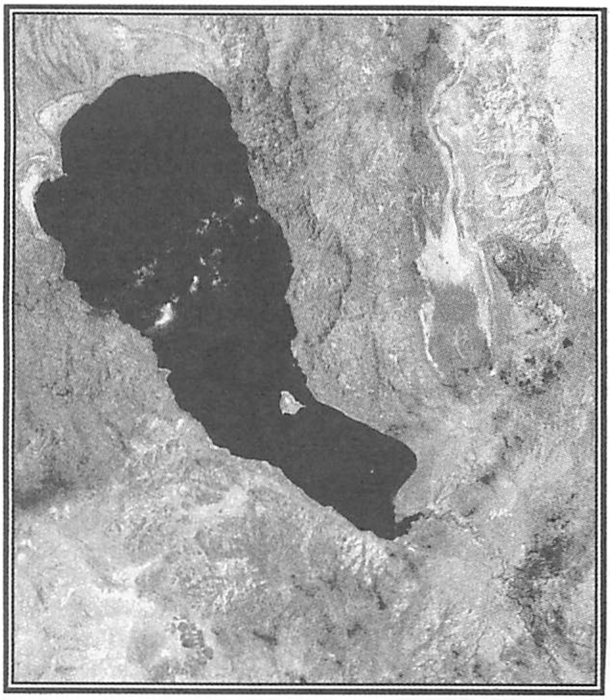


Fig. 1. Landsat TM image of Pyramid Lake Area and Winnemucca Lake area right of center connected by the Winnemucca Slough (see map below)

2. Comparative Lake Size

In historic time, Pyramid Lake has had a maximum area of 5,261 km^2 (130,000 acres), a maximum depth of 106.75 m (350 ft.) and a maximum volume of 30.492 x 10^9 m^3 (25,000,000 acre ft.); Winnemucca Lake on the other hand had a maximum area of 2,428.2 km^2 (60,000 acres), a maximum depth of 25.9 m (85 ft.) and a maximum volume of 4.268 x 10^9 m^3 (3,500,000 acre ft.). During historic time, Winnemucca Lake was a major wetlands

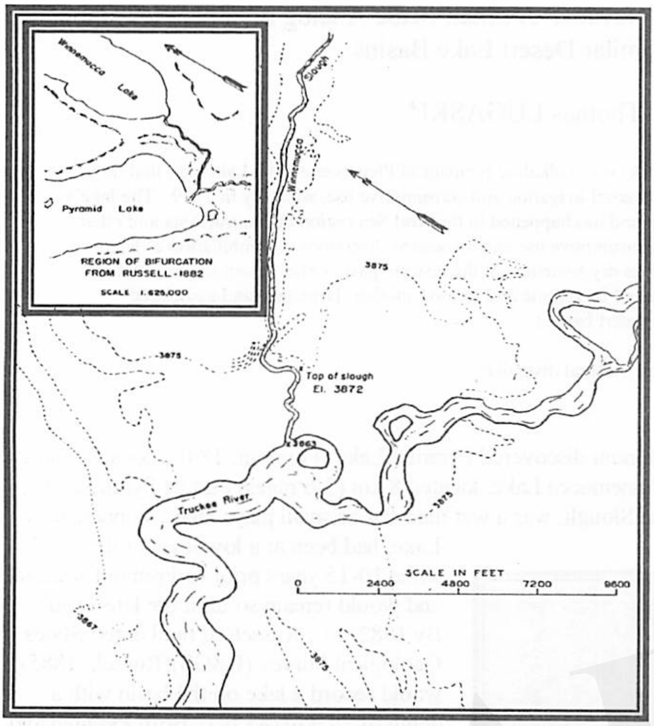


Fig. 2. Map of the Truckee River bifurcation at the Winnemucca Slough. Inset map shows the relative position of Pyramid and Winnemucca lakes. (Modified from Russell, 1885)

area in western Nevada and home to a variety of waterfowl that were utilized by both Native Americans and non-native alike. Both Winnemucca Lake and Pyramid Lake were home to the Lahontan cutthroat trout (Oncorhynchus clarki henshawi) and the Cui-ui lakesucker (Chasmistes cujus). The former was commercially fished in the lakes and became extinct in the late 1930's-40's and is an endangered species in other areas of the state. The lakesucker is also an endangered species and is confined to Pyramid Lake (Hardman and Ventstrom, 1941, LaRivers, 1962, Harding 1965).

When Fremont visited the area in 1843-44, the water elevation of Pyramid Lake covered most if not all of the white-line (calcium carbonate) layer seen in the lake today. The top of this layer has an elevation of 1181.1 m (3872.5'). A similar white-line can be seen in the Winnemucca lake basin but at a lower elevation since the basin itself is lower in elevation than the Pyramid lake basin. The highest elevation of the white-line in the Winnemucca Lake basin is not high enough to submerge the connecting slough with Pyramid Lake. In 1882, when I. C. Russell visited the area, the elevation of Pyramid lake was at 1179.4 m (3867') (Russell, 1885, Harding, 1935, 1965). The lowest historic elevation for Pyramid Lake has been estimated at 1174.9 m (3852'). This is based upon the growth of trees that existed in the river delta area at the time of Fremont's visit and indicates a drought in the drainage area for the previous 15-20 years. Winnemucca Lake at this time was essentially dry with a base elevation of 1149.8-1151.4 m (3770-3775')

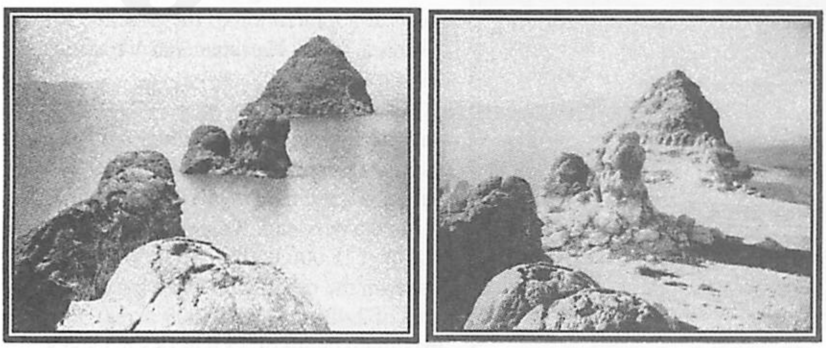


Fig. 3. Pictures of Pyramid Lake tufa domes in 1868 as they were seen by Russell (1885). The picture on the left hardly shows the white carbonate zone that Fremont saw (1844) but the picture on the right in 1961 shows the entire white carbonate zone. The lake had dropped some 21.5 m (70') and Winnemucca Lake is dry. (Modified from La Rivers, 1962)

(Harding, 1935, 1965, Hardman and Venstrom, 1941).

During a typical sequence of events, runoff from the Truckee River, during years when the average annual runoff was exceeded, the Truckee River would either do one of two things. The river would fill Pyramid Lake to and above the lake level indicated by the white shoreline feature first noticed by Fremont and the lake would back- flow into the Winnemucca Slough, filling Winnemucca Lake. A second method for filling Winnemucca Lake would be for a gravel bar to form in the Truckee River where the river bifurcated to form the Slough. This gravel bar would apparently form during low flow from the previous year and block the natural channel to Pyramid Lake, allowing water to flow directly into Winnemucca lake. This apparently happened in 1876.

3. Estimate of 100-year Runoff

Hardman and Venstrom (1941) estimated the 100 year average annual runoff of the Truckee River at Pyramid Lake at about 903 x 10^6 m^3 (741,000 acre-feet) for the period between 1839-1939. During this time the river exceeded this flow 36 times (27 times at 101%-199%; 6 time at 200%-299%; 2 times at 300%-399% and 1 time at +400%) was between 51 and 99% of this flow 39 times and at or below 50% flow for 25 times. During the period between 1920 and 1939 when Winnemucca Lake dried up, the flow exceeded 100% only 3 time, fell between 51% and 100% 8 times and dropped below 50% 8 times. This indicates that the Winnemucca Lake, regardless of the upstream diversions and utilizations would have gone dry during this time.

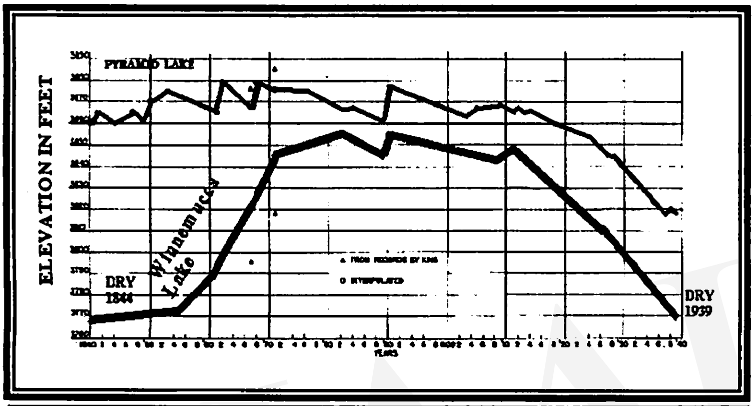


Fig. 4. This graph show the flucuation in lake levels for both Pyramid and Winnemucca lakes from 1840 until 1938 when Winnemucca Lake goes dry. A major decline in both lakes can be seen starting after 1907-1908 when the Truckee canal starts diverting irrigation water to the Lahontan basin. (Modified from Hardman and Venstrom 1941)

4. Diversion of Water

While it can be shown that the rise and fall of each lake in the area is the result of climatic conditions, the fate of the lakes has been greatly influenced by the activities of humans in the area. During the Comstock era (1870's-1889), when mining and associated lumbering activity in the Sierra Nevada's caused large amounts of sawdust to be flushed down the Truckee River, barriers of sawdust and gravel were formed in the area near the Winnemucca Slough, causing a larger then normal amount of water to flow into Winnemucca Lake. To prevent this diversion, the Indian Service during 1889 or 1890 built a rock and brush dam across the slough and may have increased the depth of Pyramid lake during this time. This dam was not maintained and soon was eliminated. The next development in the diversion of the Truckee River waters would eventually finally cause Winnemucca Lake to become dry, the Lahontan cutthroat trout to become extinct and the Cui-ui lakesucker to become endangered. In 1904 the Newlands Reclamation Project was authorized by the U.S. Congress and by 1907 a diversion canal, the Truckee Canal, was diverting Truckee River water to the Carson basin some 96.5 km (60 miles) to the east. This diversion would greatly accelerate the demise of Winnemucca Lake and cause Pyramid lake to drop in elevation some 21.3 m (70') (Hardman and Venstrom, 1941, La Rivers, 1962). Today, water agreements now provide for more of the runoff to flow back again to Pyramid Lake and water stored upstream is maintained for fish spawning.

However, the fate of Winnemucca Lake has been sealed, literally, since the highway grade at Marble Bluff now buries the beginning of the Winnemucca Slough.

5. Literature Cited

Fremont, J. C. 1845, Report of the exploring expedition to the Rocky Mountains in the year 1842, and to Oregon and Northern California in the years 1843-44. Printed by order of the Senate of the United States. Washington. Gale and Seaton Printers. 583 p.

Harding, S. T. 1935, Changes in lake levels in the Great Basin area. Civil Eng., 5(2): 87-90.

Harding, S. T. 1965, Recent variations in the water supply of the western Great Basin. Water Resources Center Archives, Univ. California, Berkeley. 226 p.

Hardman, G. and C. Venstrom. 1941, A 100-year record of Truckee River runoff estimated from changes in levels and volumes of Pyramid and Winnemucca lakes. AGU Trans. 1941(1): 71-90.

LaRivers, I. 1962, Fishes and Fisheries of Nevada. Nev. Fish Game Comm.782 p.

Russell, I. C. 1885, Geological history of Lake Lahontan, A Quaternary lake of northwestern Nevada. U.S.G.S. Monog. 11: 288 p.

沙漠研究 10S, 93-96 (2000)
Journal of Arid Land Studies -Special Issue- "Desert Technology V"
Refereed Paper

Local Climate Changes with Oasis Development - Some Observation Results

Mingyuan DU* and Taichi MAKI**

Abstract - This paper presents some observation results of changing climate with oasis development in the Caidamu Basin. Meteorological observations were made inside an oasis at the time of oasis expansion. With oasis development, air temperature decreased in summer and increased in winter, although there was no marked difference in mean annual temperature. Air humidity increased proportionally and number of days with dust storms decreased exponentially. Precipitation increased with oasis development.

Key Words: Local climate change, oasis development, Caidamu Basin

1. Introduction

The impact of vegetation changes on local and regional climates in desert regions has been received considerable attention since the mid-1970s. Many investigators have found that a decrease in vegetation cover reduces evapotranspiration thereby allowing an increase in local temperature levels. Balling (1988, 1989, 1991) has revealed that severe overgrazing and resultant land degradation in the semiarid areas of northern Mexico created significantly higher temperatures in the border area and Balling suggest that any greenhouse-driven desertification may amplify regional and global warming. On the other hand, when an oasis is developed in a desert area, the local climate will be changed somewhat. Increase in vegetation due to oasis development would have different impact to local climate. In recent several years, a series of papers was published regarding the climatic change in the western part of arid area of China (Du, 1996, Du et al., 1996, Du and Maki, 1997). In the past 43 years (1951-1993), air temperature increased in winter, but decreased in summer. Precipitation in summer has increased 5 to 100 percent since 1977. It is suggest that the decrease in temperature and increase in precipitation in summer is caused mainly by the oasis development in the western part of arid China. However, only the monthly mean air temperature and precipitation data were analyzed. The purpose of this paper is to explore how other climate elements changed with oasis development (expansion of area of the oasis) in Caidamu Basin, China.

2. Data

During the years from 1955 to 1960, there were several state farms (oases) were built up in the Caidamu Basin, Qinghai province, China. The Caidamu Basin is located to the north of Tibet Plateau (36° 30′ N—39° 30′ N、90° E—97° 40′ E). It is one of the desert areas in China. The annual precipitation is about 50mm to 100mm

* National Institute of Agro-Environmental Sciences, Tsukuba, Ibaraki 3058604, Japan (Fax: +81-(0)298-388199)
** University of Ehime, Matsuyama, Ehime 790-0905, Japan

in the basin and the annual air temperature is about 2.0° C to 3.0° C. Therefore the oasis development is depends on water supply. One of the state farms is called Delingha State Farm, which is located in the northeast part of the basin.

One meteorological station (37° 15′ N, 90° 08′ E) was set up at the beginning of the state farm established. Before the state farm, there was a small natural oasis or grassland. From 1955, irrigation system was built up first and the area of the oasis expended gradually by changing desert land to agricultural land from 1955 until 1968. From 1968 till now, the area of the state farm remains the same or decreases slowly. The total area of the oasis in 1968 was about 40000ha and now is about 38000ha. There was no other meteorological station within the surround's 10,000km^2. Therefore, only this station's data was used. The station was moved to a town called Delingha 15km north to the state farm in 1972. 15 years (1956-1970) data were used in this paper.

3. Results

3.1 Air temperature

As shown in Fig. 1, air temperature decreased in summer and increased in winter as the oasis development. Air temperature in summer (mean of June, July and August) decreased 0.9° C within 15 years after the oasis built up (0.0607° C/year) and air temperature in winter (mean of December, January and February) increased 0.4° C (0.0273° C/year). Therefore, annual difference of the temperature became lower. However, annual mean air temperature did not change much.

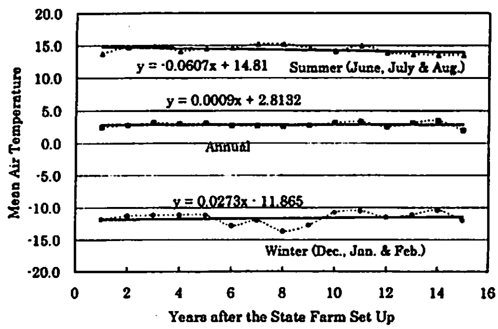


Fig. 1 Variation of Air temperature after the state farm set up

3.2 Humidity

Accompany with the air temperature change, relative humidity increased in summer and decreased in winter (Fig. 2). However, annual mean of relative humidity increased gradually and water vapor pressure increased all the seasons as show in Fig. 3.

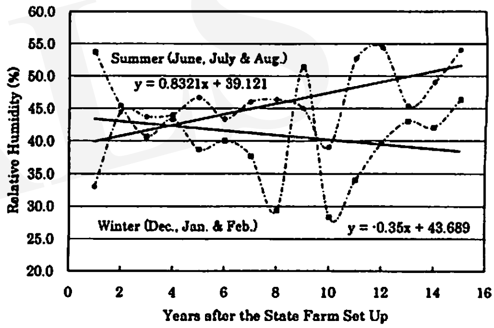


Fig. 2 Variation of relative humidity after the state farm set up

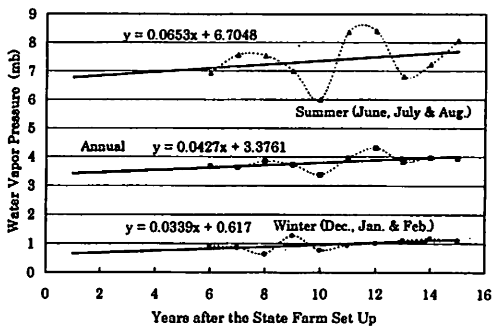


Fig. 3 Variation of water moisture after the state farm set up

3.3 Precipitation

As shown in Fig. 4, annual precipitation increased with large variation. The proportional regression shows that the annual precipitation had increased over 100% during the 15 years (5.5mm/year, that is about 7.3%/year) This increase in precipitation was mainly due to the increase in summer. Precipitation decreased a little bit in winter.

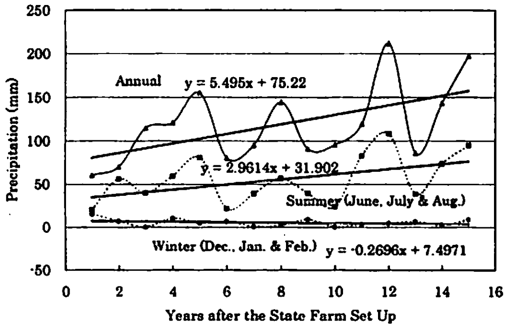


Fig. 4 Variation of precipitation after the state farm set up

3.4 Wind speed and duststorm

Wind speed decreased gradually in all seasons after the state farm built up as shown in Fig. 5. However, in 1969 and 1970 wind was strong again. In Caidamu Basin, there is a strong wind season. Usually, strong wind (wind speed is over 16.0m/s) occurs in March and April and duststorm (or sand shifting) appears. As shown in Fig. 6, the numbers of day in which the strong wind occurred decreased from 1956 to 1968. In 1969 and 1970, as same as the wind speed, the numbers of strong wind increased. However, the numbers of duststorm occurred did not increased in 1969 and 1970. Duststorm decreased exponentially from 1956. Duststorm occurs less than 5 times during a year now. This data shows that the agricultural activities (especially planting the windbreak forest) in the oasis fixed the desert sand to the ground and prevented sand shifting.

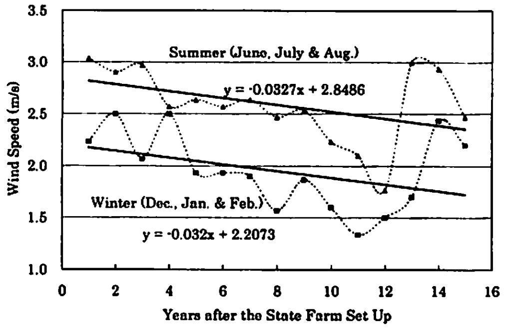


Fig. 5 Variation of wind speed after the state farm set up

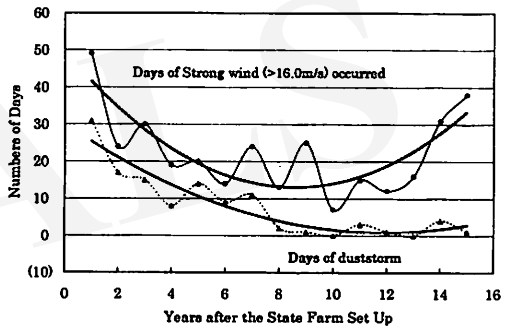


Fig. 6 Variation of the numbers of dust storm occurred after the state farm set up

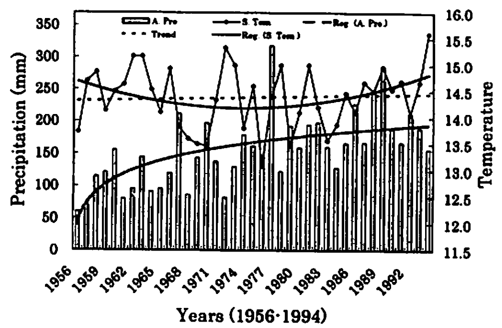


Fig. 7 Variations of air temperature in summer and precipitation from 1956 to 1994

4. Discussion and conclusions

According to Sun (1990), Ling (1990), Du and Maki (1994), the climate in an oasis is characterized by a comparatively lower wind speed; smaller temperature variation, higher air humidity and evapotranspiration and more precipitation than in the desert area due to increase in irrigation of water and vegetation growth. The climate changes mentioned above show these characters clearly. Figure 7 shows the variations of air temperature in summer and precipitation in the Delingha meteorological station from 1956 to 1994. It can be seen that the trend for the temperature and precipitation has changed since 1970 when the oasis development (expansion of the area of the oasis) stopped. Decreasing trend in air temperature in summer became increasing trend. Increasing trend in precipitation stopped. This indicates that the changes in air temperature, humidity, precipitation, winds and duststorm during 1956-1970 was caused mainly by the oasis development (expansion of the oasis area).

Therefore, the observation data does not only reinforce the conclusions that has been revealed by Du (1996), the decrease in air temperature and increase in precipitation in summer in the western part of the arid China are caused mainly by the expansion of oases. It is also shows that expansion of oasis could increase air humidity and could reduce duststorm occurring. The results continue to show a positive feedback in which oasis development in drylands decrease local temperature and increase precipitation in summer and decrease potential evapotranspiration levels thereby promoting the oasis development.

References

Balling, R. C., Jr.(1988): The climatic impact of a Sonoran vegetation discontinuity. *Climate Change*, 13 : 99-109.

Balling, R. C., Jr.(1989): The impact of Summer rainfall on the temperature gradient along the United States-Mexico border. *J. Appl. Meteorol.* 28 : 304-308.

Balling, R. C., Jr.(1991): Impact of desertification on regional and global warming. *Bull. Amer. Meteorol. Soc.* 72 : 232-234.

Du, M. and Maki, T., 1994: Climate differences between an oasis and its peripheral area in Turpan, Xinjiang, China. *JIRCAS Journal*, 1: 47-55.

Du, M. (1996): Is it a global change impact that the climate is becoming better in the western part of the arid region of China. *Theoretical and Applied Climatology.* 55 : 139-150.

Du, M., Yoshino, M., Fujita, Y., Arizono, S., Lei, J. and Maki, T. (1996): Climate Change and Agricultural Activities in the Taklimakan Desert, China in Recent Years. *Journal of Arid Land Studies.* 5 : 173-183.

Du, M. and Maki, T. (1997) : Relationship between oases development and climate change in Xinjiang, China in recent years. *J. Agric. Meteorol.*, 52 : 637-640.

Ling, Z (1990): A comparison study on climate change in Alar region. In: Li, J. ed., Studies on climatic environment and area development in arid semiarid regions in China. China Meteorological Press, Beijing, 136-139

Sun, Y. (1990): Climatic Characteristics of Tarim Basin. In Li, J. ed., Studies on climatic environment and area development in arid semiarid regions in China. China meteorological Press, Beijing, 157-164.

沙漠研究 10S, 97-100 (2000)
Journal of Arid Land Studies −Special Issue− "Desert Technology V"
Refereed Paper

Intensive Agricultural Production in the Desert Conditions of the San Luis Valley of South-central Colorado

Randal J. RISTAU *

Abstract – The unique natural resources of the San Luis Valley of south-central Colorado, U.S.A. allows for intensive agricultural production in desert conditions. The following information describes the natural setting as related to agriculture, and describes how resource management, primarily water management, allows for successful production with minimal environmental impacts.

Key words: San Luis Valley, Agricultural Production, Irrigation, Water Quality

1. Introduction

The San Luis Valley of south-central Colorado is a high mountain desert with numerous distinctions. Before the 1500s, early Native Americans utilized the plentiful resources this unique environment provides. In the 1850s, Hispanic settlers established the first water right and irrigation system that ushered in a new era of agricultural production.

2. Geography

The San Luis Valley extends about 100 miles from the northeast corner of Saguache County to about 16 miles south of the Colorado-New Mexico State line. East to west, it spans 60 miles between the Sangre de Cristo and the San Juan Mountains. The valley covers 3,125 square miles predominantly in Colorado. This area is one of the largest inter-mountain valleys in the world.

The Valley is nearly flat except for the San Luis Hills to the south. The average elevation of the Valley floor is 7,700 feet. Nine of the surrounding mountain peaks attain an elevation of 14,000 feet or more. A large north-trending structural depression that is down faulted on the eastern border and hinged on the western side makes up the Valley. As much as 19,000 feet of alluvium, volcanic debris, and inter-bedded volcanic tuffs underlie the San Luis Valley. To the east, the Sangre de Cristo Mountains are composed of igneous, metamorphic, and sedimentary rocks. They are one of the youngest ranges in the continental U.S. The San Juan Mountains to the west are composed mainly of volcanic flows, tuffs, and breccias. Many of the lava flows and tuffs from the San Juan Mountains dip eastward under the valley floor, and in the southwestern part of the Valley, restricting the vertical movement of groundwater.

Alluvial fans deposited by streams originating in the mountains border most of the Valley floor. The Valley's north half lies north of the Rio Grande with no natural surface or shallow groundwater outlet and is referred to as the closed basin. The lowest part of this area is known locally as the "sump." The Rio Grande headwaters and its tributaries drain the remainder of the Valley. Most of the streamflow is derived from snowmelt in the 4,700 square miles of watershed in the surrounding mountains.

3. Climate

Cold winters, moderate summers, and over 250 days of sunshine annually, are typical climatic conditions in the San Luis Valley. The average annual temperature is 42 degrees Fahrenheit. The average annual precipitation on the valley floor ranges from 7 to 10 inches. Precipitation in the San Juan Mountains can reach 50 inches annually. High winds can occur in the Valley especially from mid-March to May. Wind erosion of the soil is an annual concern.

---

* Water Quality/Agronomy Specialist and Project Coordinator, Colorado State University Cooperative Extension, San Luis Valley Water Quality Demonstration Project, 0881 N. U.S. 285, Monte Vista, CO, 81144.

4. Hydrogeology

An aquifer contains enough saturated permeable material to produce significant amounts of water for wells and springs. The San Luis Valley includes two types of aquifers as depicted in the cross sectional view. The aquifer system is commonly considered to be several thousand feet deep. The uppermost aquifer is called the unconfined aquifer and occurs almost everywhere in the Valley. The depth to this water for most of the valley is 15 feet or less. However, the depth can reach 300 feet along the edges and in most of Costilla County. The unconfined aquifer is 50 to 130 feet thick depending on the location. The lower aquifer is called the confined aquifer. Lenses of clay and lava beds confine and separate it from the unconfined aquifer. The clay lenses are not one continuous layer but are separate and overlapping in places. Water inflow below the clay lenses at higher elevations near the edge of the Valley gives the confined aquifer a greater pressure resulting in artesian flow.

5. Closed Basin Project

The closed basin encompasses 2,940 square miles of watershed north of the Rio Grande. Water flow in the basin does not flow out because of a natural surface and groundwater divide. The groundwater divide moves due to canal leakage and applied irrigation water. Groundwater south of the divide moves toward the Rio Grande and water north of the divide flows into the Closed Basin.

The Closed Basin Project was designed to reduce non-beneficial evapotranspiration and convey the resulting water to the Rio Grande. A series of wells pump water into pipeline laterals connected to a 42-mile conveyance channel that delivers the water to the Rio Grande. The salvaged water assists Colorado in meeting its obligation pursuant to the Rio Grande Compact with New Mexico, Texas and Mexico. The Project also delivers mitigation water to the Alamosa National Wildlife Refuge, Blanca Wetlands, and San Luis Lakes.

6. Water Quality

The Rio Grande water quality is considered the highest of the drainage's leaving Colorado. However, high levels of trace metals are found in some streams in the basin due to past mining activities and local geologic conditions. Streams affected include Willow Creek near Creede, the Alamosa River including some tributaries and Terrace Reservoir, and Kerber Creek and its tributaries. Salinity levels are low in all surface waters.

Groundwater quality is generally good with poorer quality toward the central part of the Valley near Center, Hooper, and Mosca. Mineral concentration increases toward the lower area of the closed basin due to geological formations and greater evaporation from shallow water table areas. High nitrate levels in the unconfined aquifer have been noted in various studies since the late 1960s. The suspected reason is leaching of inorganic fertilizer from intensive agriculture, as influenced by the short growing season, limited crop selection, coarse soils and shallow water tables.

Pesticides pose a similar threat to groundwater but integrated pest management efforts limit leaching potential. Recently, efforts by the agricultural community to monitor groundwater and improve efficiency of fertilizer and irrigation practices show promise in lowering nitrate concentrations.

7. Water Use

Total annual water supply to the Valley averages about 2,500,000 acre-feet. About 1,500,000 acre-feet is streamflow derived chiefly from snowmelt in the surrounding mountains and 1,000,000 acre-feet is from precipitation on the Valley floor. Water is important for various uses in the San Luis Valley including domestic, recreation, wildlife, and agriculture. Domestic use includes drinking water, small businesses, and lawn/garden watering for individuals and communities. Over 95 percent of domestic water use for the 45,000 residents depend on groundwater. The Valley has over 230,000 acres of wetlands, the most extensive system in the Southern Rocky Mountains. Numerous species of water birds breed, raise their young, and migrate through the Valley. Artesian and surface flows combined with high alkaline soils in some parts of the Valley result in unique wetlands. Wetland habitat on many managed wetlands in the Valley depends on irrigation and intensive water management. More than 40 geothermal artesian springs and wells exist in the Valley with temperatures ranging from 72 to 120 degrees Fahrenheit. Aquaculture has become a successful enterprise by utilizing warm geothermal water.

Ninety-seven percent of Valley water is used for agriculture, the major industry of the region. Over 500,000 acres are irrigated. Estimates in the mid-1980s reported groundwater withdrawal as 455,000 acre-feet and surface water use as 1,400,000 acre-feet. Over a million gallons (three acre-feet) of Valley water is consumed daily by approximately 90,000 head of livestock. Water discharge from the Valley averages about 2,100,000 acre-feet per year by evapotranspiration. Ground-water withdrawal primarily occurs as discharge from pumping wells. The annual streamflow at the state line averages 325,000 acre-feet and groundwater underground flow accounts for a small amount currently estimated as 55,000 acre-feet.

8. Agriculture

The Valley's natural resources and environmental conditions offer a great potential for a relatively sustainable, highly productive agricultural industry when managed with good stewardship. Desert conditions minimize pest impacts, but also create the need for irrigation for most of the local agricultural sectors.

8.1 Irrigation The principal source of water for irrigation in the San Luis Valley between 1880 and 1950 was surface water. A large network of canals was built in 1880-90. The area around Mosca and Hooper became unfarmable in 1915 due to the rising water table from irrigation. Drainage systems constructed between 1911 and 1921 to reclaim waterlogged lands alleviated some of the problems but created waterlogging in other low areas. Approximately 7000 miles of stream channels and ditches flow through the Valley.

Present irrigation practices in the Valley vary according to water source, soil conditions, topography, and types of crops grown. Traditional surface irrigation methods, as in flood or furrow irrigation, are used in areas that are supplied primarily by surface water. These areas include agricultural land near all stream systems in the Valley. Center-pivot sprinklers have been more prevalent since the early 1970s and rely upon a combination of surface and groundwater supplies. Approximately 4000 irrigation wells are used to supply over 2,130 sprinkler systems that are irrigating 257,000 acres.

The basis of irrigation management decisions can range from manually checking the soil water content to use of decision support software that utilizes local evapotranspiration data. Private consultants and government agencies often provide assistance in irrigation timing. Sprinkler and pump evaluations are also critical to maintaining higher levels of water delivery efficiency.

8.2 Soils Most soils are classified as deep. The soils range from 12-16 inches of gravelly sandy loams over cobbly sand parent material to loams and loamy sands. High water tables limit rooting depths in a few areas. Occasional calcium carbonate layers can occur limiting rooting depths. Saline-sodic soils occur in the fringes of the intensely cropped areas and impact plant growth.

8.3 Crop Management The short growing season of 90 to 130 days limits the typical crops to potatoes, small grains, alfalfa, meadow hay and pasture, carrots, lettuce spinach and similar hardy plants. However, marketing potential is probably a greater limit to crop choices than the growing season. Crop yields are very competitive with other regions. For example, potato yields can reach 550 hundred weight per acre and small grains can be over 170 bushels per acre. Cool nights and high solar radiation levels commonly increase crop quality. Producers are annually contracted to grow malting barley for brewing due to high yields and plumpness of the grain.

8.4 Agri-chemical Inputs Fertilizers are common production inputs needed to maintain crop yields and quality. Nitrogen and phosphorus are the nutrients applied for most crops. Naturally occurring potassium is usually sufficient for crop needs. Certain micro-nutrients, such as iron or zinc, are recommended depending on the conditions and crop being grown. Leaching potential and crop sensitivity to soil nutrient levels makes annual soil analysis a critical tool in soil fertility management. Groundwater analysis can also be important when a potential for elevated nitrate levels exists. Groundwater nitrate can be credited in nutrient planning for the current crop, avoiding leaching and further groundwater contamination.

Overall, an active integrated pest management (IPM) program is very effective in managing pests. The climatic conditions allow for fewer crop rotations and less pesticide use in managing pests. Scouting is a central factor in successful IPM and nutrient programs. Crop consultants are often contracted to assure scouting is thorough and systematic throughout the growing season. Potential crop pests are relatively low in most cases. However, if not controlled, weeds, diseases and insects can cause significant crop losses. Late blight in potato is currently the most troublesome pest. The Valley was virtually free of this disease up to 1998 when imported potatoes introduced the pathogen. Production costs have now increased 80 to 120 dollars per acre for the management program of this specific pest.

When a pest becomes well established, control options may be fewer, limiting management approaches due to the Valley's unique environment. For example, perennial pepperweed (*Lepidium latifolium*) has become a prevalent weed in non-cropland, pastures, hayfields, and wetlands. Management options are limited because of pesticide label restrictions to reduce potential of groundwater contamination.

8.5 Agriculture Related Issues Water quantity and quality are main agricultural concerns. Two significant attempts have been made by private entities to transfer water from the Rio Grande basin to another basin or to municipalities down river. This action has included years of litigation and two ballot issues recently taken to the state's electorate. To date, these efforts have not been successful.

High nitrate levels in the groundwater have been noted since the 1950s in the central area of the Valley. Nitrate monitoring and management efforts have intensified in recent decades. Irrigation water management and groundwater nitrogen crediting are the principal tools for remediation of this water issue. Soluble, persistent pesticides could pose a similar groundwater concern, but the incidence of detected pesticides has been very small due to effective management practices.

The source of the majority of this presentation is from an educational poster developed by the San Luis Valley Water Quality Demonstration Project with the dedicated cooperation of numerous individuals and government agencies providing good discussion and cross-references. Special acknowledgement for assisting in this presentation is offered to Debra Sarason, Davis Engineering; Kirk Thompson, Agro Engineering, Ronald Riggenbach, Natural Resources Conservation Service (NRCS); Dick Sparks, NRCS; Steve Russell, NRCS; Susie Thompson, Colorado State University; Rob Davidson, Colorado State University Cooperative Extension (CSUCE); Reagan Waskom, CSUCE; and, Dale Edwards, CSUCE. Special thanks to Julie Burt for formatting the orignal text to this journal article. Sincere thanks are given to Dr. James Young, USDA Agricultural Research Service, for his friendship and encouragement.

Instructions to Contributors

Journal of Arid Land Studies is a broad-based archival journal for the publication of significant research results in all areas concerning deserts, arid and semi-arid lands.

Papers will be published only when they are judged by the Editor to be characterized by some general significant conclusions or by experimental and field data having probable lasting value. It is understood that a paper submitted to this Journal has not been previously published, accepted for publication or submitted for review elsewhere.

Four copies of manuscript in English should be submitted to (hold original figures and diskette until acceptance):

The Editorial Office, The Japanese Association for Arid Land Studies
c/o Prof. T. Kojima Dept. Ind. Chem., Fac. Eng., Seikei Univ., 3-3-1 Kichijoji-Kitamachi
Musashino-shi, Tokyo 180-8633, Japan
Phone +81-422-37-3750, Fax +81-422-37-3871
e-mail kojima@ch.seikei.ac.jp

Submitted manuscripts will not be returned whether they are published or not. Original figures, tables and photos may be returned if authors desired.

Paper Categories

1. **Full-length Original Articles–** Formal presentation of significant and completed research projects. Enough originality is required. The length should be less than ten printed pages (about 7000 words, incl. Figs. etc.).
2. **Research Notes–** Brief reports with originality. Supplemental or intermediate reports. Reports which require prompt publication is also submitted. The length should be less than four printed pages (about 2800 words, incl. Figs. etc.).
3. **Others.–** Articles which are approved by the editorial committee. As to the details, please contact the editorial office.

Proofs and Charges

The authors are requested to correct only first proofs carefully. Some parts of publication and reprint charges may be imposed (see the last part of this instruction).

Copyright Transfer

Upon acceptance of an article by the Journal, the copyright of the article is transferred to The Japanese Association for Arid Land Studies.

Manuscript Preparation

All manuscript should be prepared on A4 (or 8.5 by 11 in.) paper in the order. The text has to be prepared on a diskette, using Word, WordPerfect or similarly well known word processing system, in double-spacing with 12 point or similar size typeface.

A) **Title Page** with the following items in this order.
- a) **Category** of paper.
- b) A descriptive and concise **title** of the paper.
- c) Authors' **names, affiliation(s), and address(es):** first names, middle initials, if any, and surnames followed by their affiliation(s) and address(es). The author to whom **correspondence** should be addressed is to be identified using superscript, * with **phone** and **fax numbers.**
- d) Five or less **Key words.**

B) **Abstract** is to be clear and concise. The **length** is around 250 words for full-length Original Articles 100 words for Research Notes.

C) **Main Body** should be prepared clearly and concisely. The precise arrangement of the text are left to the authors' discretion. (Each author may choose the format best suited to the paper.) **Figures and Tables** should not be included but be cited in the body. The **placement** of the Tables and Figures appearing first should be clearly identified by noting their numbers in the right hand margin. **Footnote** may not be used. Notes should appear at the end of the body, if necessary. SI (The system Internationale) unit should be used wherever possible. Standard abbreviation may be used.

Literature is to be cited in the text as Rognon (1994), or (Tucker *et al.*, 1981, 1985; Grove, 1986 a, b; Lean and Warrilow, 1989). The words "*et al.*" should be used for three or more authors. Lowercase letters following year may be used if necessary to identify. Cited pages from books should be identified as YOUNG and YOUNG (1992: 15-17).

D) **Literature** cited should appear at the end of each text in an alphabetical order. Give complete information as in following examples:

GROVE, A.T. (1986 a): The scale factor in relation to the processes involved in "desertification" in Europe. *In* FANTENCI, 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.

TUCKER, C.J., HOLBEN, B.N. ELGIN, J.H. and McMORTREY, J.E. (1981): Remote sensing of total drymatter accumulation in winter wheat. *Remote Sensing of Environment*, **11**: 171-189.

TUCKER, C.J., TOWNSHEND, J.R.G. and GOFF, T.E. (1985): African land-cover classification using satellite data. *Science*, **227**: 369-375.

YOUNG, J.A. and YOUNG, C.G. (1992): *Seeds of Woody Plants in North America*. Dioscorides Press, Oregon.

E) **Tables** should be typed on separate sheets and be prepared in order.

F) **Figure captions** should be typed on a separate sheet.

G) **Figures** should be drawn in black ink on a white background. The size of the lettering should be proportional to that of the drawing; it must be a minimum of 3 mm high when the illustration is reduced to 67 mm wide or 140 mm wide. First author's name and figure number should be written in pencil on the right corner of the sheet. **Photos** may be included as Figures. Three printed photos, or one original and two high quality reproductions, pasted on A4 paper should be submitted for reviewing process.

H) After the manuscript has been reviewed and accepted for publication, the author should not carry out any other corrections than that are requested. **The final version** of the text is then submitted to the Editorial Board together with **original figures**, and **a diskette** following the special instructions to be sent to the author. The diskette should include **an additional text** converted into an MS-DOS text file (ASCII file). The Editorial Board is responsible for the final arrangement and layout of the articles.

For domestic contributors

The authors are requested to prepare Japanese translations of the following items on a separate page; A-a) title, c) Author(s)' name(s), affiliation(s) and address(es), in the title page, and B) abstract.

To be a member of The Japanese Association for Arid Land Studies: Contact: Dr. T. YAMAGUCHI,

Inst. Agr. Forest Eng., Univ. Tsukuba, 1-1-1 Tennodai, Tsukuba, 305-8572, Japan
Phone + 81-298-53-6763, Fax + 61+298-55-2202
e-mail yamatomo@sakura.cc.tsukuba.ac.jp

Publication and reprint charges (valid for articles submitted after June 1, 1999)

Publication charge*: 50,000 Jp. Yen/article (free for members of The Japanese Association for Arid Land Studies)

Excess page charge*: 10,000 Jp. Yen/one excess printed page. Color page charge: 80,000 Jp. Yen/one color page.

Reprint charges (Should be ordered at the unit of 50 reprints. Domestic mailing cost is free)

paper categories	first 50 reprints* (with cover)	per additional 50 reprints	overseas shipping and handling
original articles	15,000 Jp. Yen (20,000Jp. Yen)	add 3,000 Jp. Yen	add 3,000 Jp. Yen/ 50 reprints
research notes	10,000 Jp. Yen (15,000Jp. Yen)	add 2,000 Jp. Yen	add 2,000 Jp. Yen/ 50 reprints

*Free for invited articles (incl. overseas shipping and handling charge for first 50 reprints)

Special Issue on "Desert Technology V"
Local Arrangement and Program Committee: James A. YOUNG (Chief), Debra E. PALMQUIST, Robert R. BLANK, Charlie D. CLEMENTS, William S. LONGLAND, John McLAIN, Wayne JOHNSON, Paul T. TUELLER, Robin TAUSCH, Watkins MILLER, Tom LUGASKI, Dawn RAFFERTY
Sponsors and Field Trip Cooperators: Engineering Foundation, USDA Agricultural Research Service, Empire Farmes, Desert Research Institute, Sierra Pacific Power, University of Nevada
Editorial Board of This Issue: Toshinori KOJIMA (Chief), James A. YOUNG, Yukuo ABE

日本沙漠学会編集委員会／〒180-8633　東京都武蔵野市吉祥寺北町3-3-1
成蹊大学工学部工業化学科　小島紀徳　気付
Tel: 0422-37-3750, Fax: 0422-37-3871, e-mail: kojima@ch.seikei.ac.jp
「おあしす」担当／〒422-8529　静岡県静岡市大谷836
静岡大学人文学部文化人類学研究室　嶋田義仁
Tel/Fax: 054-238-4499, e-mail: jsysima@hss.shizuoka.ac.jp

Editorial Office of The Japanese Association for Arid Land Studies
c/o Prof. Toshinori KOJIMA, Dept. of Industrial Chemistry, Faculty of Engineering, Seikei University
3-1 Kichijoji-kitamachi 3-chome, Musashino-shi, Tokyo 180-8633, JAPAN
Phone Int.+81-422-37-3750 (direct)　FAX Int.+81-422-37-3871　e-mail: kojima@ch.seikei.ac.jp

編　集：日本沙漠学会編集委員会／〒180-8633　東京都武蔵野市吉祥寺北町3-3-1
成蹊大学工学部工業化学科　小島紀徳　気付
Tel: 0422-37-3750, Fax: 0422-37-3871, e-mail: kojima@ch.seikei.ac.jp

発　行：日　本　沙　漠　学　会／〒305-8572　茨城県つくば市天王台1-1-1
筑波大学農林工学系乾燥地工学研究室　安部征雄　気付
Tel/Fax: 0298-53-4647, e-mail: abe@sakura.cc.tsukuba.ac.jp

定価　1,500円(Jpn. Yen, 消費税を含む)　　発行日2000年3月31日(March 31, 2000)

印刷：佐藤印刷 ㈱

VOL.10 S
March 2000
ISSN 0917-6985

JOURNAL OF ARID LAND STUDIES

CONTENTS

Special Issue: Proceedings of Desert Technology V
An Engineering Foundation Conference
Oct. 3-8, 1999, Reno, U.S.A.

THE JAPANESE ASSOCIATION FOR ARID LAND STUDIES