Journal of Global Environment Engineering, Vol. 5, pp. 27-36, 1999

DEMONSTRATION TEST ON GREENING IN THE UNITED ARAB EMIRATES

—GRASS GROWTH BY MOISTURE ABSORBENT TEXTILE AND EFFECT OF GREENING ON MICROCLIMATE—

Yasuhide Takano [1]
Teruyuki Fukuhara [2]

Abstract

A grass growth test using a Moisture Absorbent Textile (MAT) has been underway in the United Arab Emirates (U.A.E.) since 1996 to confirm the suitability of the MAT for greening in arid regions. Micro-meteorological data and sub-surface data concerning heat and moisture transfer were collected at grass-covered and bare soil sites to provide information on the differences in heat and moisture regimes for appropriate water management in arid regions. It was found that the grass growth rate and the vegetation density were increased because of the improved moisture retention of the soil resulting from the presence of the MAT.

In addition, a survey in the city of Dubai, U.A.E. in 1997 showed that a grass-covered park could potentially mitigate a severe urban microclimate in arid regions.

KEYWORDS: *greening in arid regions, Moisture Absorbent Textile, microclimatic mitigation, evapo-transpiration, heat and moisture transfer*

1. Introduction

Greening is a term coined to refer to processes intended to make vegetation grow in regions that are normally sterile. Recently, many greening procedures have been tried throughout the world to assist in the fight against global warming. In arid regions, greening is being tried in the hope of stabilizing farmland and roads against sandstorms, and even for fixing carbon dioxide from the atmosphere (e.g., Murai *et al.*, 1990; Toyama *et al.*, 1991; Al-Attar *et al.*, 1997). There have also been attempts to stabilize sand dunes in this way. Of course, water is a valuable resource in arid regions and water-saving irrigation technology is essential for the sustainable development of desert areas. In order to improve soil moisture retention, a Moisture Absorbent Textile (MAT) has been developed jointly by Fukui University, the Industrial Technology Center of Fukui Prefecture and local textile companies (Fukuhara *et al.*, 1993; Fukuhara *et al.*, 1995; Takano *et al.*, 1996).

Grass growth and sweet melon cultivation tests using this MAT have been carried out in the United Arab Emirates (U.A.E.) since 1996 to confirm the suitability of this approach for greening in

1 Student, Program for Doctor's Degree, Graduate School of Engineering, Fukui University, Fukui, JAPAN.
2 Dr.Eng, Professor, Department of Architecture and Civil Engineering, Fukui University, Fukui, JAPAN.

an extremely arid region (Nogami *et al.*, 1997; Nogami *et al.*, 1998). So far, it has been found that both the grass growth rate and the vegetation density were improved as a result of the presence of the MAT layer below the soil surface (Nogami *et al.*, 1997).

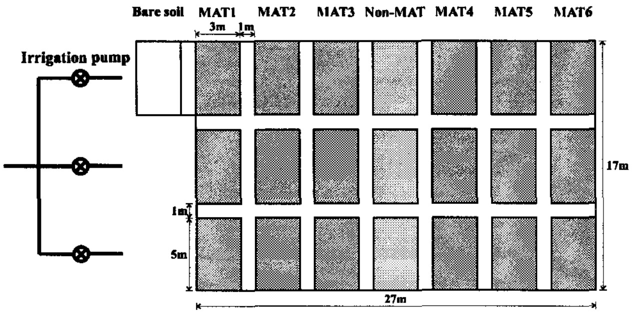


Figure 1. Plane view of experimental site

Greening can also be expected to lead to some mitigation of urban climate phenomena such as the "heat island" effect. Research on ways to improve urban environments affected by waste heat from buildings and street traffic has now become wide-spread in Japan, and greening in major cities has raised new hopes (e.g., Hoyano *et al.*, 1994). The connection between fractional vegetation cover and urban air temperatures has been well-studied in temperate and semi-tropical regions. Relations between cooling ratios and green coverage have been presented, for example, by Yamada (1993) and Pichakum *et al.* (1993). Although big cities in arid regions may be particularly sensitive to microclimatic mitigation by greening because of their severe climate, very few measurements have yet been made concerning regional hydrologic and climate response to greening in such regions. For this reason, a program of micro-meteorological observations and heat and moisture transfer measurements in the soil under bare and grass-covered surfaces was carried out at a special grass growth test site belonging to the Northern Agriculture Research Station of the Ministry of Agriculture and Fisheries of the U.A.E. in Ras Al Khaimah Emirate in 1996 and also at three locations in the city of Dubai, U.A.E. in 1997 (Takano *et al.*, 1997; Takano *et al.*, 1998).

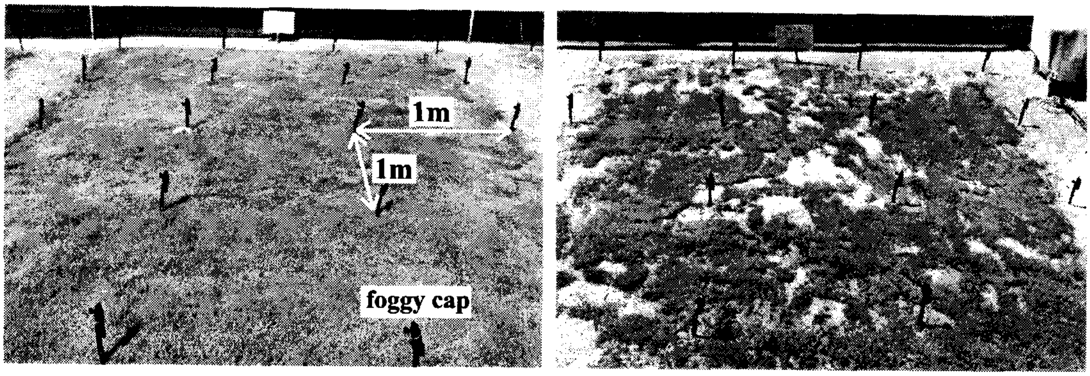
The purpose of this study is to describe the contribution of the MAT to plant growth and the effects of a grass-covered surface on microclimatic mitigation at these arid region sites in the U.A.E..

2. Grass growth test using a MAT

2.1 Outline of experiment and test site

The grass growth test using a MAT was carried out on an experimental site (area:600m^2) at the Northern Agriculture Research Station of the Ministry of Agriculture and Fisheries of the U.A.E. in February, 1996. This Station is in an arid region with annual precipitation about 100mm. For a discussion of meteorological conditions, see Takano *et al.* (1997). The soil at the experimental site is classified as sandy loam with a mean grain size of 0.08mm.

Figure 1 shows the schematic view and the experimental grass growth test site using Bermuda grass. The site was composed of 22 plots each having an area of 15m^2 (3$\times$5m). Six types of MAT were used in this test and these differed from each other as regards either texture or material. At all plots, except three Non-MAT plots and one bare soil plot, the MAT was laid at a depth of 0.1m below the ground surface (MAT plot). The grass was seeded in February 1996 using 60g on each plot. Irrigation water was sprayed on all plots at a rate of 21.5l/m^2 for a duration of one hour every day, to the extent possible, at the same time each day. The length of the grass was measured by a ruler and pictures were taken regularly to show the state of grass growth. For details of the growth tests, see



(a) MAT plot (b) Non-MAT plot

Photograph 1. Growth of grass at 35days after seeding

Table 1. Time change of average grass length

Elapsed days after seeding	MAT plot	Non-MAT plot
10 days	1.6 *cm*	1.0 *cm*
20 days	3.8 *cm*	3.1 *cm*
25 days	7.7 *cm*	6.7 *cm*

Nogami *et al.* (1997).

In addition, in order to evaluate the relationship between grass growth and soil moisture retention of the MAT plot, soil sampling was performed on those portions of the grass-covered plots where grass was absent, as well as the bare soil plot.

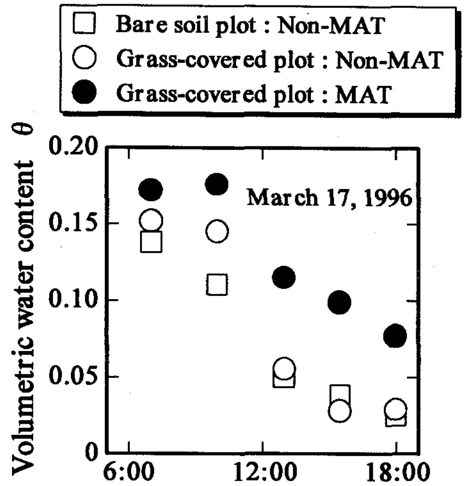


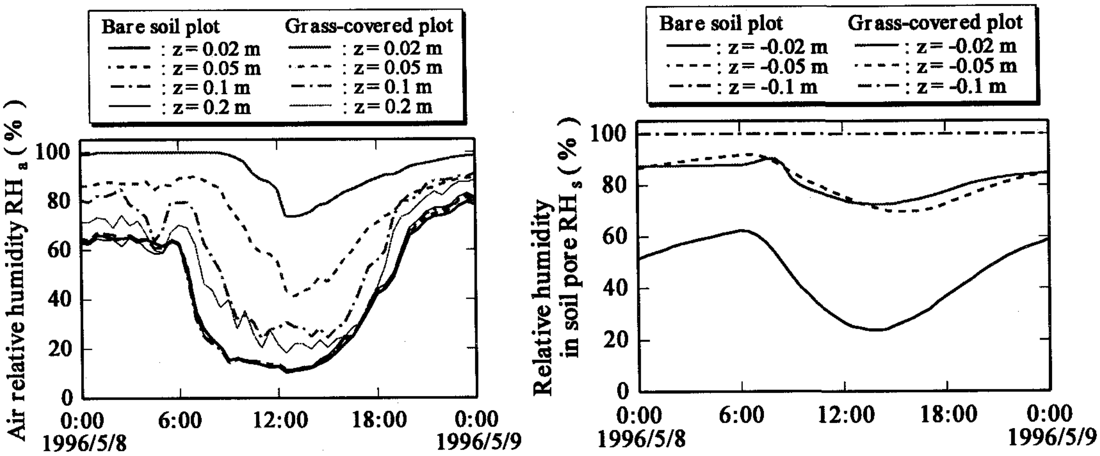
Figure 2. Time change of volumetric water content of soil surface

2.2 Results of grass growth tests

Photograph 1 shows a comparison of the grass growth for the MAT plot with that for the Non-MAT plot 35days after seeding. It is clear that the vegetation density in the MAT plot was higher than that in the Non-MAT plot.

Table 1 shows the change of the average grass length with elapsed days after seeding. There is an obvious difference in the grass length between the MAT and the Non-MAT plots. During the first month, the grass growth rate was significantly better for the MAT plots than for the Non-MAT plots. Subsequently there was little difference in grass length between the MAT and Non-MAT plots. The difference in the vegetation density, however, could still be seen even three months after seeding.

Figure 2 shows the time variation of the volumetric water content, θ, of the soil surface layer (defined as the first 0.02m below the surface), between 7:00 and 18:00 on March 17, 1996. Irrigation water was given to all plots the previous evening. By this date, a substantial difference in vegetation density between the MAT and Non-MAT plots was already evident. The values of θ for each plot were approximately 0.15 between 7:00 and 10:00 but, after that, θ decreased abruptly. For the



(a) Air relative humidity (b) Relative humidity in soil pores

Figure 3. Diurnal change of relative humidity above and below the surfaces of grass-covered and bare soil plots

MAT plots, however, θ remained at levels two to three times higher than for the Non-MAT and bare soil plots.

It is obvious that the moisture retention in the soil surface layer for the MAT plot was improved due to the presence of the MAT and this caused the difference in the grass growth rate and the vegetation density. A similar result was obtained from a melon cultivation test using the same type of MAT, carried out separately in 1996 and 1997 (Nogami *et al.*, 1998).

3. Considerations on changes to local environments as a result of greening

3.1 Micro-meteorological observations and measurements of heat and moisture transfer in sandy loam

It is useful to ask whether greening mitigation is practical as a means to change local environments in arid regions, particularly air temperature and humidity. Datum measurements at the bare soil and grass-covered plots were started in March, 1996. A Non-MAT plot was chosen a representative of grass-covered plot because of soil temperature and moisture content were not effected by the MAT. These measurements included continuous data on air temperature and relative humidity, short-wave radiation, long-wave sky radiation, albedo, and wind velocity, as well as soil temperature, relative humidity within the soil pores, volumetric water content and matric potential (pF). Air temperature, air relative humidity were measured with TESTO TERM Ltd. thermo-hygrometers while soil temperature and relative humidity in the soil pores were measured with VISALA Ltd. thermo-hygrometers. Soil matric potential was measured with a DAIKI RIKA Ltd. tensiometer. Albedo was measured by an albedo meter (EKO SEIKI Ltd.). For further details of the observation and measurement techniques used, see Takano *et al.* (1997).

3.2 Changes of relative humidity and soil matric potential by greening

Figure 3 (a) shows the diurnal change of the air relative humidity RH_a, above the surfaces of the grass-covered and bare soil plots on May 8, 1996. At that time, the mean grass height was 0.05m. As shown in Figure 3 (a), at all heights, the RH_a for the grass-covered plot was higher than that for the bare soil plot during the daytime (note that for the bare soil plot the RH_a curves nearly overlapped each other at all times, implying only a very slight gradient in RH_a for this case). Comparing, for example, at 13:00, it is seen that, at a height of 0.05m above the surface (z=0.05m), RH_a for the bare soil plot was 11%, while, for the grass-covered plot, it was 41%. At z=0.2m the RH_a for the bare soil plot was 12% while, for the grass-covered plot, it was RH_a=22%. At the grass-covered plot the grass enhances the availability and transfer of water vapor to the overlying atmosphere via evapo-transpiration.

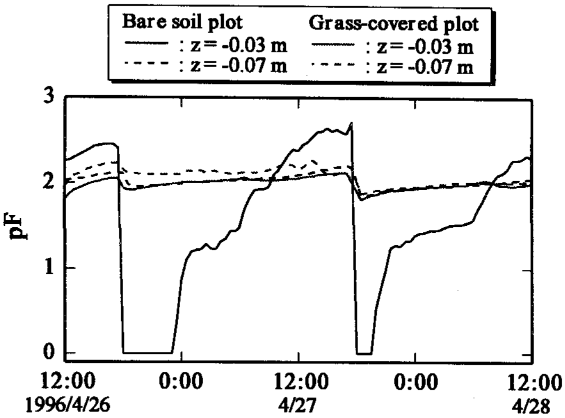


Figure 4. Variation with time of soil matric potential

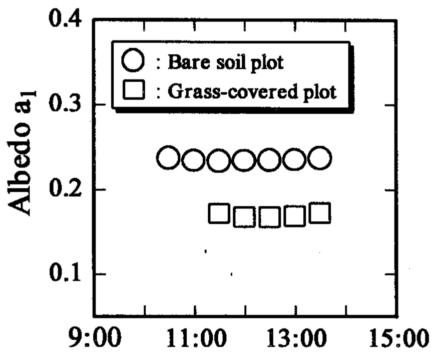


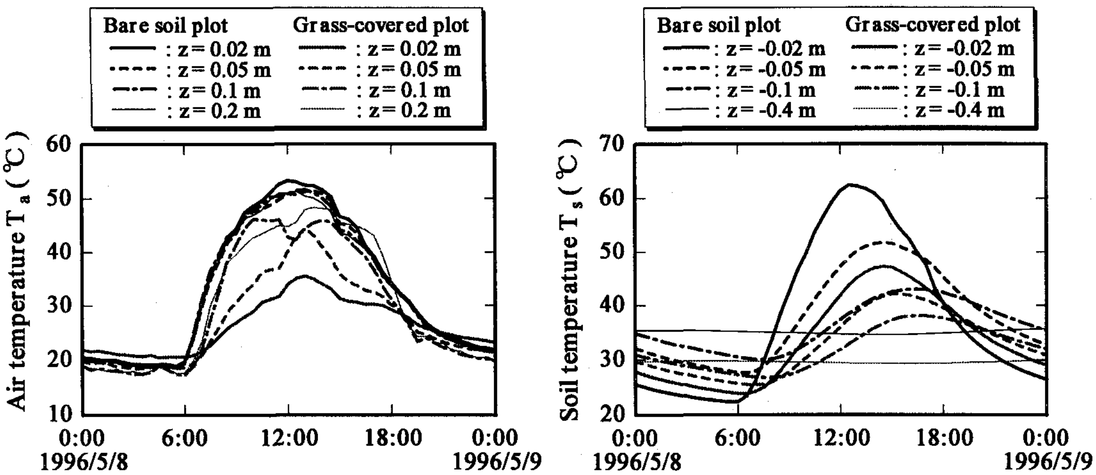
Figure 5. Ensemble-mean time variation of albedo

A similar picture emerged within the soil as well. Figure 3 (b) shows the diurnal change of the relative humidity in the soil pores, RH_s, just below the surfaces of the grass-covered and bare soil plots on May 8, 1996. For the grass-covered plot, just below the surface (z=-0.02m), RH_s was higher than that for the bare soil plot during the entire day. The maximum and minimum differences in RH_s were 48% (at 14:00) and 25% (at 6:00), respectively. Although not visible in the figure, RH_s was 100% for $z \leqq -0.1$m at the bare soil plot and for $z \leqq -0.05$m at the grass-covered plot, in spite of the diurnal weather change.

Figure 4 shows representative data concerning the diurnal variation of the soil matric potential, pF, during and following irrigation, for both bare soil surface and grass-covered plots. Irrigation water was sprayed at a rate of 20l/m^{2}hr for 20 minutes, commencing at 18:00, on both April 26 and 27, 1996. For the bare soil plot, at z=-0.03m, immediately after irrigation (18:00) the pF decreased to zero (i.e. the soil became saturated). Several hours later the pF began to increase rapidly and reached a plateau near 1.2. Subsequently, the rate of change of pF with time, became smaller, although there was again a temporary sharper increase after about 06:00. As the pF approached its maximum near 2.5 the rate of increase diminished, becoming negligible after about 15:00.

For the grass-covered plot, on the other hand, the pF decreased only slightly at both levels. The variation was much smaller than for the bare soil plot. At all times the values stayed within the narrow range 1.8 to 2.0.

From these results, it can be concluded that the grass cover served initially to block the



(a) Air temperature (b) Soil temperature

Figure 6. Diurnal change of temperature above and below the surfaces of grass-covered and bare soil plots

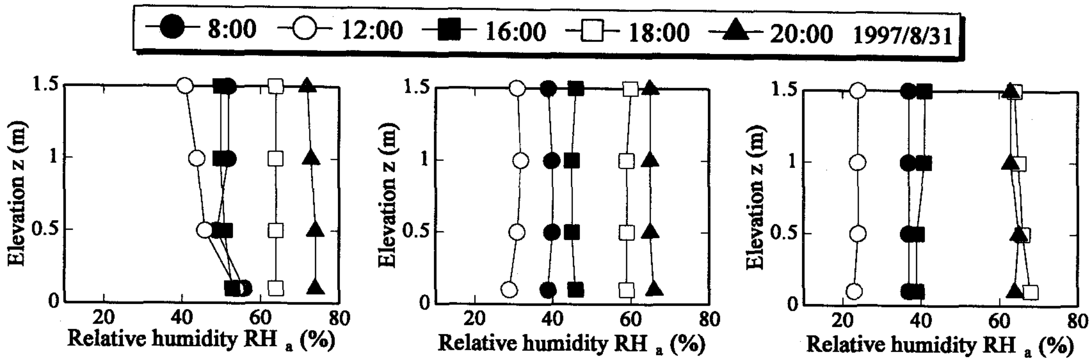
infiltration of the irrigation water and later to enhance transpiration. Moreover, the grass cover plays a significant role in protecting against the loss of soil moisture by evaporation.

3.3 Change of thermal environment by greening

Albedo, a_l, is one of factors that control the ground surface temperature and it is an essential parameter for micro-meteorological computations. Figure 5 shows the ensemble-mean time variation of albedo for the bare soil and grass-covered plots. Because only a single albedo meter was available, the measurement periods are different for the bare soil plot and for the grass-covered plot. Although this makes direct comparison of instantaneous values problematic, it should not affect mean values. The mean albedo for the bare soil plots was found to be 0.23, while at the grass-covered plots, it was 0.18. Consequently, the grass-covered surface can absorb slightly more short-wave radiation than the bare soil surface.

Figure 6 (a) shows the diurnal change of air temperature, T_a, above the surfaces of the grass-covered and bare soil plots on May 8, 1996. As Figure 6 (a) indicates, in the daytime, T_a for the grass-covered plot was lower than that for the bare soil plot at all heights. For example, at z=0.05m, T_a for the bare soil plot reached 52℃ at 13:00, while, it reached only 44℃ for the grass-covered plot. At the same time the difference in T_a at z=0.2m , the maximum height from which measurements are available, was still almost 5℃ (T_a=50℃ for the bare soil plot, T_a=45℃ for the grass-covered plot). Considering the data of both Figure 3 (a) and Figure 6 (a), it may be concluded that the absorption of latent heat associated with evapo-transpiration provides significant cooling and humidifying effects over the grass-covered plots.

Figure 6 (b) shows the corresponding diurnal change of the soil temperature, T_s, below the surfaces of the grass-covered and bare soil plots on May 8, 1996. Solid and dashed lines represent the soil temperatures at different depths below the surfaces of the bare soil and grass-covered plots, respectively. Significant time delays and diurnal amplitude variations are evident at depths near the surface, but the variations are no longer significant for z<-0.4m. These time lags arise because of heat



(a) Grass-covered park (b) Sidewalk (c) Asphalt surfaced parking lot

Figure 7. Time change of air relative humidity profiles

conduction in the soil and water vapor movement. At the level z=-0.02m, the maximum temperature of 56℃ was reached at 13:00 for the bare soil plots. For the grass-covered plots the maximum temperature at this level was 47℃, reached at 14:30. This difference is largely attributable to the cooling effect associated with evapo-transpiration from the grass-covered surface. An additional reason might be that the shading effects of the grass cover serve to lower T_s and delay the time when the maximum T_s appears.

Consequently, heat and moisture transfer between the grass cover and the atmosphere can play a vital role in the mitigation of microclimate in arid regions.

4. Verification of urban microclimatic mitigation by greening in Dubai

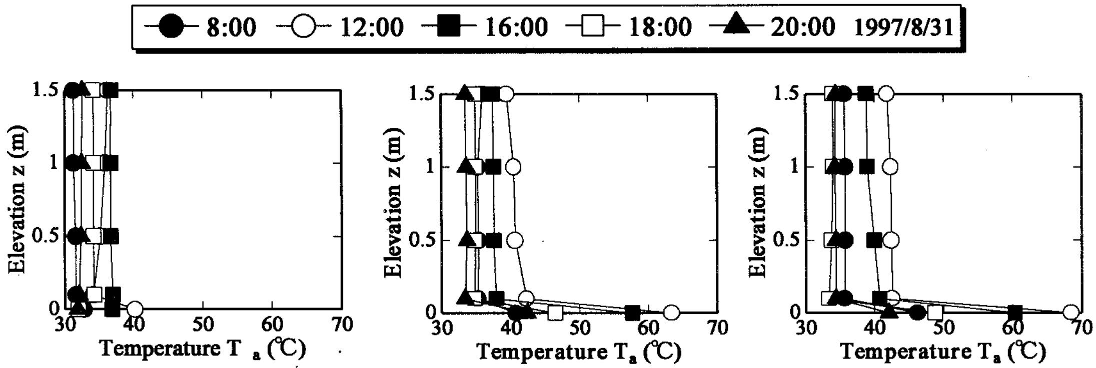
4.1 Measurement locations and experimental procedure

Microclimatic mitigation by greening was evaluated at the Agriculture Research Station, Ras Al Khaimah Emirate in 1996. In addition, measurements similar to those discussed in Section 3. were made in Dubai, August 31, 1997, in order to investigate urban microclimatic mitigation by greening a park within a big city in an arid region. Three locations were selected for comparison: (1) the middle of a big grass-covered park, (2) a sidewalk surrounding the park, (3) the middle of a large asphalt surfaced parking lot in a shopping center located about 500m from the park.

Using a thermo-hygrometer (SHINYEI Ltd.), air temperature, T_a, and relative humidity, RH_a, profiles (heights z=0.02, 0.1, 0.5, 1.0 and 1.5m) were measured at all three locations between 08:00 and 20:00 during one full day. Measurements were made at one-hour intervals during the morning and evening (times of most rapid change) and two-hour intervals near mid-day.

4.2 Change of air temperature and relative humidity as a result of greening

Figures 7 and 8 present results for air temperature and relative humidity profiles measured over (a) the grass-covered park, (b) the sidewalk, and (c) the parking lot. As seen in Figure 7, the grass-covered park almost always exhibited the highest RH_a among the three locations. This difference was



(a) Grass-covered park (b) Sidewalk (c) Asphalt surfaced parking lot

Figure 8. Time change of air temperature profiles

especially evident about 12:00.

From Figure 8 it is seen that, over the grass-covered park, T_a for all heights was consistently lower than at the other two locations. The difference was most marked near the surface. For example, at 12:00, and at a height of 0.02m, T_a was 40℃ over the grass-covered park but it was 63℃ over the sidewalk and 68℃ over the parking lot. Even at the 1.5m height, however, the effect was evident. At 12:00, T_a at 1.5m was 36℃ for the grass-covered park, 39℃ for the sidewalk and 42℃ for the asphalt surfaced parking lot. Since the wind was weak during the entire day, the sensible heat flux associated with air flow would have been small.

It is concluded that substantial cooling of the lower atmosphere can occur over a grass-covered area because of the latent heat associated with evapo-transpiration from the grass cover.

5. Conclusions

A demonstration greening test in a highly arid region using a synthetic geo-textile, referred to here as a "Moisture Absorbent Textile" (MAT), has been underway at the Agriculture Research Station in Ras Al Khaimah Emirate, U.A.E. since February 1996. As part of this investigation, microclimatic mitigation by greening was also studied at the Agriculture Research Station using micro-meteorological observations and measurements of heat and moisture transfer in the soil at test plots with bare and grass-covered surfaces. In addition, the effects of a grass-covered park on urban microclimatic mitigation were evaluated in the city of Dubai, U.A.E..

The measurements made so far in the U.A.E. have led to the following conclusions;

(1) The MAT material laid a short distance below the soil surface can improve the moisture retention of the soil and thereby improve the grass growth rate and vegetation density.

(2) Even in severe conditions such as those of the United Arab Emirates, a grass cover can potentially mitigate a microclimate by virtue of the cooling and humidifying effects associated with evapo-transpiration.

And in the future, the field data and experimental techniques, described in this study will be used as input to a climate model and to a hydrological model to compute energy and mass fluxes at bare soil and grass-covered surfaces in arid regions.

Acknowledgements:

We wish to express our gratitude to Mr. Hammad A. Al Mutawa, Acting Deputy Minister, Ministry of Agriculture and Fisheries, U.A.E., Mr. Rashid Khalfan Al Shareqi, Director of Reserch & Agriculture Production, Mr. Abdulla Khalfan Mohd. Al-Sharaiki, Director of the Northern Agriculture Region, and Mr. Mansool I. Mansool, Director of the Agriculture Research Station for offering us the opportunity to carry out this research. And special thanks are due to Dr. Laurel Everett Goodrich, professor of Fukui University, for reading the entire text in its original form and making a number of helpful suggestions.

References

Al-Attar, M.H., Al-Awadhi, N.M. and Taha, F.K. (1997): Treated wastewater use in aridland greenery with reference to Kuwait, Proc. of Japan-G.C.C. Water Resources and Greening in Desert, 4, pp.1-16.

Fukuhara, T., Kurokawa, K. and Takano, Y. (1993): A method for the contorl of evaporation and soil moisture by laying a Moisture Absorbent Textile, Proc. of the 48th Annual Conference of the JSCE, CS-79, pp.34-35 (in Japanese).

Fukuhara, T., Kurokawa, K. and Takano, Y. (1995): Control of evaporation in a sand layer by laying a Moisture Absorbent Textile and the mechanism involved, Annual Journal of Hydraulic Engineering, JSCE, Vol.39, pp.871-874 (in Japanese).

Hoyano, A., HE, J., Horiguchi, T. and Wang, G. (1994): Experimental study on heat budget for foliage layer of lawn-planting – Effect of rooftop lawn-planting on thermal environment. Part 1–, J. Archit. Plann. Environ. Eng., AIJ, No.462, pp.31-39 (in Japanese).

Murai, H., Alafifi, M.A., Yoshizaki, S., Itani, S.A. and Koto, A. (1990): Contribution of synthetic resin emulsion in sand dune stabilization and vegetation growth, Journal of the Japanese Society of Revegetation Technology, Vol.15, No.4, pp.1-11.

Nogami, Y., Fukuhara, T., Matsumoto, K., Sakata, S. and Kurokawa, K. (1997): Greening test in an arid region using MAT, Proc. of the 52nd Annual Conference of the JSCE, VII-24, pp.48-49 (in Japanese).

Nogami, Y., Fukuhara, T., Matsumoto, K. and Takano, Y. (1998): Melon cultivation and reduction of irrigation water consumption using Moisture Absorbent Textile in the United Arab Emirates, Proc. of the 53rd Annual Conference of the JSCE (in Japanese).

Pichakum, N., Maruta, Y. and Yanai, S. (1993): An Investigation on the distribution of air temperature and the effect of open space to the urban temperature in Minburi District, Bangkok, Jornal of the Japanese Institute of Landscape Architecture, Vol.56, No.5, pp.325-330 (In Japanese)

Takano, Y., Fukuhara, T. and Kurokawa, K. (1996): Experiment on grass growth resulting from use of a Moisture Absorbent Textile Layer, Proc. of the 51st Annual Conference of the JSCE, VII-258, pp.516-517 (in Japanese).

Takano, Y., Fukuhara, T. and Kurokawa, K. (1997): Heat and moisture transfer in soils and evaporation-drying processes in arid regions of the Middle East – Meteorological observations and measurement of heat and moisture in soils at U.A.E., Annual Journal of Hydraulic Engineering, JSCE, Vol.41, pp.221-226 (in Japanese).

Takano, Y. and Fukuhara, T. (1998): Hydrological and meteorological field observations in the United Arab Emirates – Evaluation of evaporation-drying processes in soil after irrigation using the "soil thermo-hygrometer" method, Annual Journal of Hydraulic Engineering, JSCE, Vol.42, pp.91-96 (in Japanese).

Toyama, M., Yamada, T., Tanigawa, J. and Okazaki, T. (1991): Problems on the agricultural development in Egyptian desert, Proc. of Annual Meeting of the Japanese Society of Revegetation Technology, No.22, pp.80-81 (in Japanese).

Yamada, H. (1993): Study on the distribution of air temperature In Kurihara, Saitama Pref. And the effect of open spaces on the urban climate in summer days, Jornal of the Japanese Institute of Landscape Architecture, Vol.56, No.5, pp.331-336 (in Japanese).