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# Radiation measurements from the Namib Desert

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ABSTRACT

Radiation measurements were performed at remote sites in the Namib Desert where ecological research projects are being undertaken. Since the radiation environment plays an important role in the ecology of desert plants and animals, the aim of this study was to make this information available to researchers working in the area. Incident short-wave radiant density, net radiant density, soil heat flux density and soil surface reflection coefficients were measured in the dunes and gravel plains along an east-west gradient, in the Namib Desert. Daily radiant density values ranged between 15 (June) and 26 MJ/m² (November). The annual radiant density for the Namib was 7 637 MJ/m² for 1982. Reflection coefficient values for bare sand (averaged between 10h00 and 15h00) show site differences. The highest recorded was on the plains. The soil heat flux density values were greatest near the coast (Rooibank) — typically 190 W/m² at local noon. The integrated value (for a 24 h period) was also greatest near the coast with negative values being experienced at Welwitschia Wash. However, net radiant flux density values were greatest for Welwitschia Wash due to its dark surface and the surrounding high walls of the wash.

CONTENTS



## 1 INTRODUCTION

Energy is radiatively transferred from the sun to the earth with resultant energy changes occurring within the earth's atmosphere. This radiant energy (short wave-lengths) may be reflected, transmitted, absorbed and then reradiated or it may be converted to stored chemical energy at the plant leaf surface (Savage, 1980). Some of the short-wave radiation entering the earth's atmosphere is absorbed by dust and gas components and converted into long-wave radiation.

The radiation environment of many plants and animals is of great importance in establishing their thermal equilibrium in their natural environment. Radiation can also play a role in seed germination, flowering, plant productivity and survival. Animals are mobile and can thus modify their radiative loads by their physiological characteristics and behaviour (Axtell, 1966; Cloudsley-Thomson, 1979).

Plants and animals existing in a desert environment are often exposed to large radiation loads. Their survival has been the subject of much research. In studying plant and animal survival mechanisms, it has been necessary to monitor their environmental conditions and the local microclimate. Many of the deserts of the world have available radiation data. McGinnies, Goldman and Palore (1968) reviewed the work done on radiation for all deserts, but their emphasis was on climatological rather than micrometeorological parameters. In the Namib Desert, extensive research is being undertaken on the diverse endemic fauna of the dunes and gravel plains. Detailed information has been collected on the climate and microclimate of the Namib excluding radiation measurements (Schulze, 1969; Seely & Stuart, 1976).

The objective of this study was to collect radiation data in the Namib at eight sites. Hopefully these data

500 mm apart. The voltage output was measured using a millivoltmeter and then converted to energy units using the appropriate calibration constants. These measurements were accurate to within 5% (calibration being performed against a unit traceable to national standard).

### 3.3 Net radiation

A Middleton net radiometer was used. This instrument has a sensing element consisting of 250 thermojunctions bounded by two blackened plates. The element is protected by two polythene hemispheres

TABLE 2: Radiation data for Gobabeb for 1981 (Desert Ecological Research Unit).

| | | Clear days | | Cloud corrected |
|---|---|---|---|---|
| Month | Week no. | Daily radiant density (MJ/m²) | Maximum solar RFD (W/m²) | Monthly total radiant density (MJ/m²) |
| January | 1 | 25,7 | 852 | |
| | 2 | 25,7 | 852 | |
| | 3 | 25,6 | 854 | |
| | 4 | 25,6 | 856 | |
| | 5 | 25,3 | 852 | 966 |
| February | 6 | 25,2 | 851 | |
| | 7 | 24,0 | 817 | |
| | 8 | 22,4 | 856 | |
| | 9 | 22,1 | 762 | 650 |
| March | 10 | — | — | |
| | 11 | 21,9 | 765 | |
| | 12 | 21,6 | 762 | |
| | 13 | 21,1 | 789 | 663 |
| April | 14 | 20,8 | 748 | |
| | 15 | 19,7 | 713 | |
| | 16 | 19,0 | 692 | |
| | 17 | 18,9 | 695 | |
| | 18 | 18,1 | 671 | 561 |
| May | 19 | 17,8 | 660 | |
| | 20 | 18,1 | 678 | |
| | 21 | 16,7 | 629 | |
| | 22 | 17,0 | 643 | 518 |
| June | 23 | 16,9 | 642 | |
| | 24 | 15,7 | 594 | |
| | 25 | 16,8 | 643 | |
| | 26 | 16,0 | 608 | 471 |
| July | 27 | 16,2 | 616 | |
| | 28 | 16,4 | 622 | |
| | 29 | 16,1 | 608 | |
| | 30 | 16,2 | 608 | |
| | 31 | 17,2 | 643 | 499 |
| August | 32 | 17,1 | 636 | |
| | 33 | 18,3 | 678 | |
| | 34 | 19,4 | 713 | |
| | 35 | 21,0 | 765 | 567 |
| September | 36 | 20,7 | 748 | |
| | 37 | 22,3 | 800 | |
| | 38 | 21,6 | 769 | |
| | 39 | 22,2 | 783 | 645 |
| October | 40 | 24,3 | 852 | |
| | 41 | 24,5 | 849 | |
| | 42 | 25,7 | 887 | |
| | 43 | 25,2 | 863 | |
| | 44 | 25,1 | 852 | 732 |
| November | 45 | 24,6 | 831 | |
| | 46 | 25,8 | 870 | |
| | 47 | 26,1 | 873 | |
| | 48 | 26,6 | 887 | 774 |
| December | 49 | 25,7 | 887 | |
| | 50 | 26,8 | 887 | |
| | 51 | 26,3 | 870 | |
| | 52 | 25,3 | 835 | 791 |
| TOTAL ANNUAL (MJ/m²) | | | | 7 637 |

TABLE 3: Reflection coefficients for different sites in the Namib Desert during March/April 1982.

| Site | Approximate distance from the coast (km) | Reflection coefficient (%) |
|---|---|---|
| Rooibank | 12 | 24 |
| Jumbo | 43 | 23 |
| Kahane | 53 | 20 |
| Noctivaga | 75 | 24 |
| Mniszechi's Vlei | 105 | 25 |
| Far East | 130 | 25 |
| Ganab | 100 | 26 |
| Welwitschia Wash | 68 | 19 |

Measurements were only taken between 10h00 and 15h00 on clear days due to the comparatively low sun angle before and after these times. All these measurements were averaged to obtain the reflection coefficient for a particular site. The reflection coefficients for different sites in the Namib are presented (Table 3).

For sandy surfaces in the dunes, the reflection coefficient varied from 20% at Kahane to 25 % in the Far East. The highest reflection coefficient measured was on the gravel plains at Ganab and the lowest at Welwitschia Wash. The low reflection coefficient at Welwitschia Wash may be due to the dark colour of the surface and surroundings. Along an east-west gradient in the dunes, the reflection coefficient decreases from east to west between the Far East and Kahane, but then increases again towards the coast.

### 4.3 Soil heat energy

During the daytime, energy is absorbed by the sand and the soil heat energy is positive. The maximum energy loss occurs shortly after sunset (Fig. 2). The loss of energy to the atmosphere decreases as the night progresses, due to the limited amount of available energy in the top sand layer (Fig. 2). The diurnal variation in soil heat energy for four sites is presented (Table 4) and the difference between two sites, Far East and Rooibank, is shown (Fig. 2).

The sand surface of the Far East absorbs less energy during the day than does that of Rooibank. The difference is probably partly due to the higher reflection coefficient of the sand surface. At night, the sand surface at Rooibank loses more energy than does that

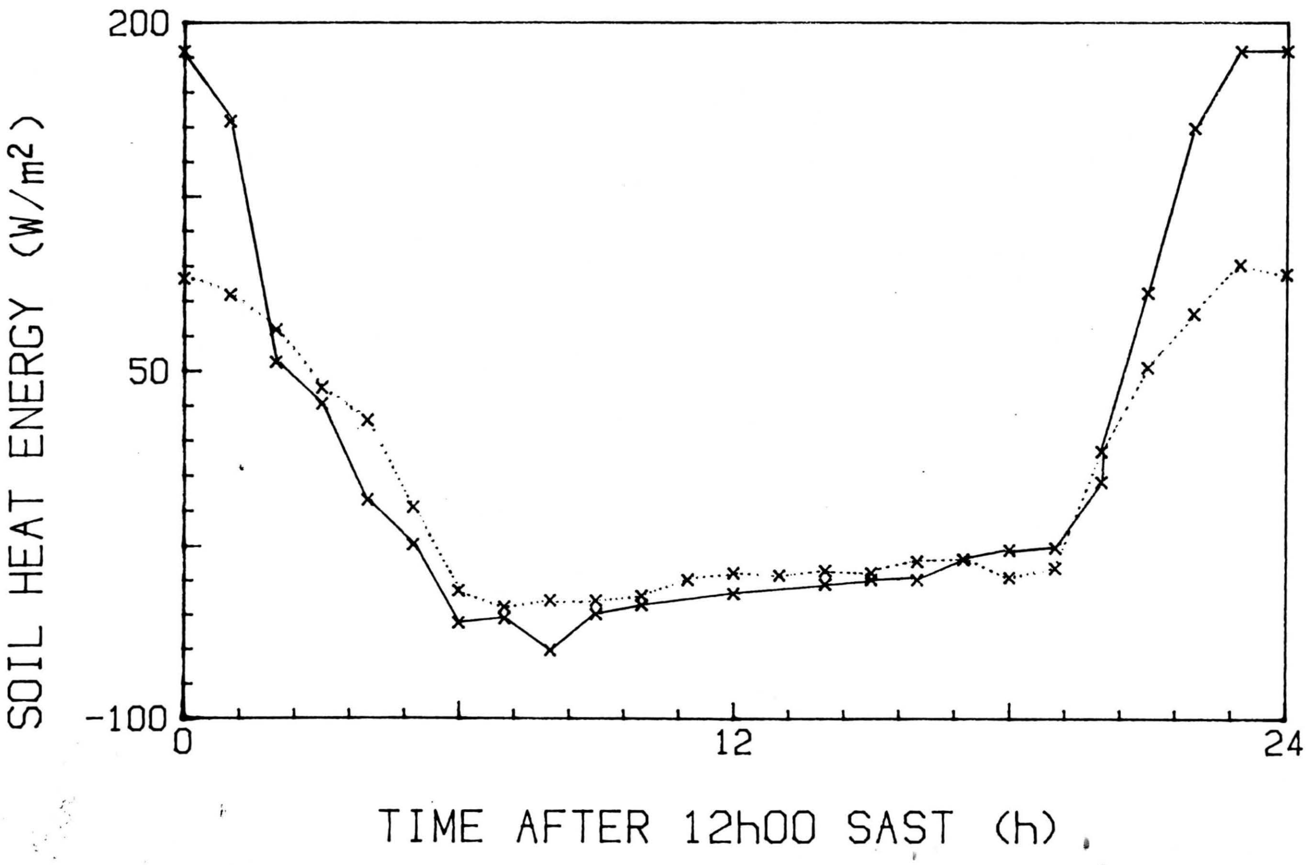


FIGURE 2: Diurnal variation in soil heat energy at Rooibank (—) and Far East (...) during March 1982.

at Far East, since a greater amount of energy has been stored in the upper layers during the day. Unlike the Far East, there is little vegetation on the Rooibank dunes to form an insulating layer.

During summer, there is a net surface energy input, but during winter there is a net loss. The net input or output of energy by the sand can be calculated by integrating the hourly soil heat energy values (Table 4). Since the measurements were taken in the transition period between summer and winter, the net values (Table 4) are near zero. The negative value for Welwitschia Wash is due to the site being in a deep wash where the sun reaches it for fewer hours each day compared to the other sites.

### 4.4 Net radiation

A desert is characterised by large radiant energy input and output. The large solar input is offset by the relatively high reflection coefficient of the surface as well as long-wave radiation losses. Low latitude deserts have a maximum net radiation value during summer of approximately 600 W/m² (Oke, 1978). The maximum value measured in the Namib during late summer varied between 435 W/m² and 600 W/m².

Net radiation values for eight sites for a period of 24 h are presented (Table 5). A 48 h net radiation curve is also shown (Fig. 3). At night, $I_{net}$ is negative becoming positive approximately two hours after sunrise. The maximum $I_{net}$ value at Welwitschia Wash occurred at 13h00 (South African Standard Time, SAST). Before sunset $I_{net}$ becomes negative and reaches a minimum value at 20h00. At this time, the maximum amount of radiation is being emitted by the sand surface. This amount decreases throughout the night due to the limited amount of available energy in the surface layers of the sand. During the 48 h of measurements at Welwitschia Wash, the first night of measurements was clear and the curve smooth. On the second night cloud was present for some time, followed by fog between 02h30 and 04h30. The peaks on the curve for the second night indicate the presence of cloud.

The integrated net radiation values show the net input or output of energy occurring above the sand surface (Table 5). This amount is positive for all sites under consideration, indicating that over a 24 h period there is a net energy input. The net input was greatest at Welwitschia Wash. This is possibly due to the lower reflectivity of the dark surface. The long-wave radiation emitted by the high sides of the wash could also have contributed to the energy input.

Assuming that $I_{net}$ is partitioned between the atmosphere and the soil and that there is negligible soil surface evaporation, it is possible to calculate the percentage energy entering the soil, $F_s/I_{net}$, and that entering the atmosphere, $I-F_s/I_{net}$ (Table 4). Of note is that for Rooibank and Welwitschia Wash in particular, the $F_s/I_{net}$ ratio generally decreases throughout the

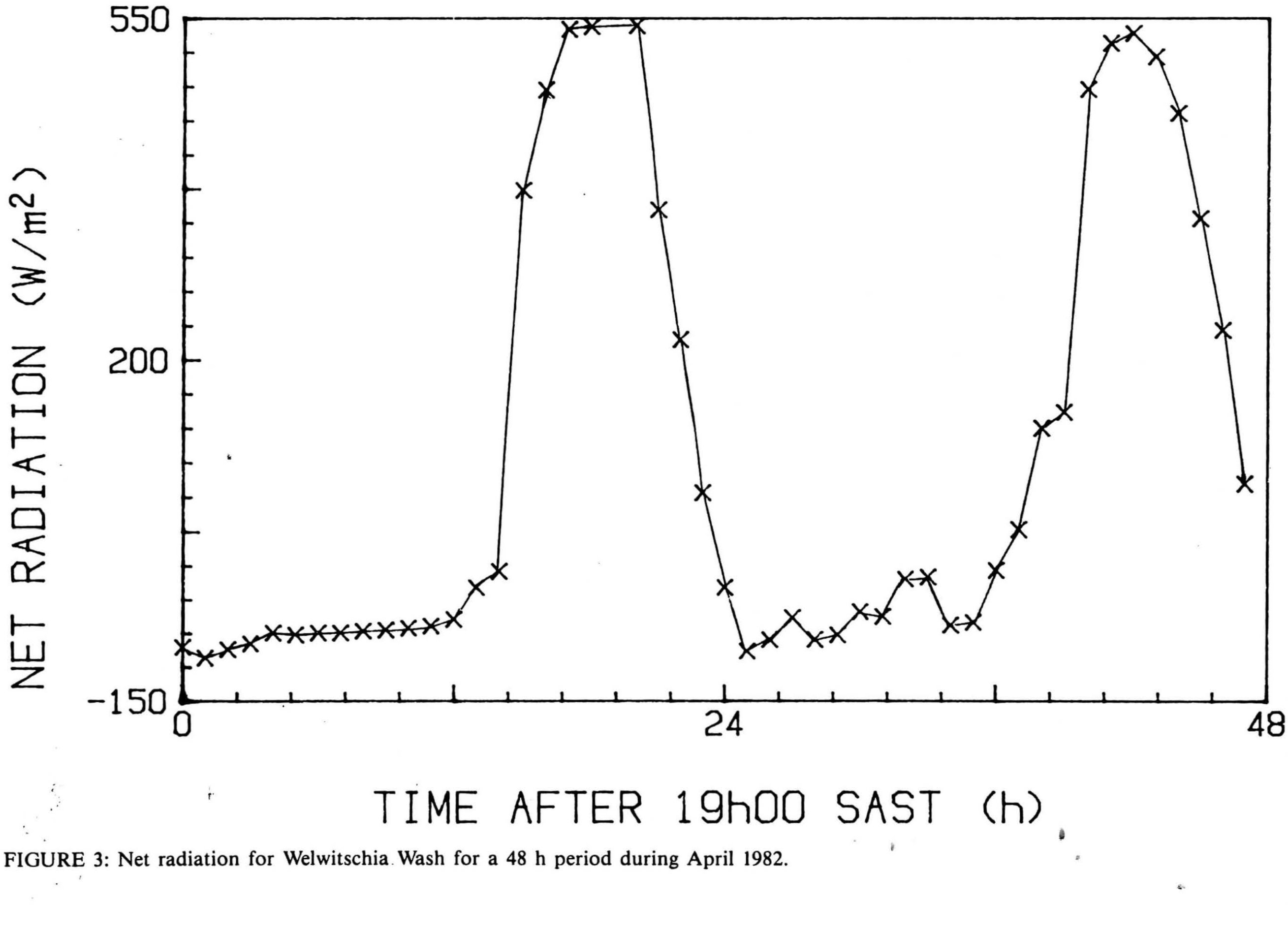


FIGURE 3: Net radiation for Welwitschia Wash for a 48 h period during April 1982.