Investigation of the Hydrophobicity of the Fairy circles of Namibia

We were interested in the soil in and around the "fairy circles" observed in some parts of Namibia. These are circular patches of soil with few plants living on them. They often take the form of circular depressions with long grass around their perimeter. Previous research on these circles suggests that grasses inside the circles show some signs of ill health and young plants germinating inside the circles tend to die during dry spells. The area is quite arid and plant growth seems to be limited by the availability of water; each plant is separated from its neighbour by a small distance.

Hypothesis

Our hypothesis is that the soil at the top of the patches is more hydrophobic than that in the surrounding area. The reason that we suspect this is that hydrophobic soil reduces the penetration of water, leading to the death of plants during dry spells. Hydrophobic soil is usually caused by the presence of organic material in the soil. We intend to measure the hydrophobicity of the soil and use this to determine if our theory is correct. This phenomenon is surprisingly common and has been found in many soil types, although sandy soils in dry climates are most likely to be affected.

Investigation

We visited the Namib Rand Nature Reserve on 9/5/2006 to 15/5/2006. Recent heavy rainfall had caused unusually good grass growth, obscuring most of the differences between the grass at the edges of the circles and in the matrix, but at the same time enhancing the contrast between the bare inner ring and the matrix. Our initial investigation revealed the following:

Although some claim that the rings are very long lasting local opinion is that they appear and disappear. At the time we were there some of the rings appeared to be expanding as they had a ring of dead grass at their edges, others appeared to be filling with grass. The rings occur in a broken band up the western edge of southern Africa just inside the desert.

Figure 1 Map of (most of) Namibia and the Namib Rand Nature Reserve

At the Namib Rand Reserve (map above) the circles are present in the entire area inside the red line (except on the Inselbergs). The rest of the habitat is steep or is desert. According to local sources the Kakaoland region of Namibia further north is less accessible and home to considerably greater quantities of the circles, they are also said to increase in size moving to the north of the country.

Inspecting the circles from ground level, they typically are 2-6m diameter. Some of them contain no plants, others grass seedlings, and some a type of plant called desert Edelweiss (*Helichrysum roseo-niveum*). Circles of different sizes are present near to each other and it is quite common for the circles to run into each other, leaving ragged edges. In some areas the barren "circles" are more circular than in others. They appear from the ground to be concentrated on the roads, but see below. A small number of circles appeared to be disappearing. In some areas grass seedlings were observed inside the circles, but they were smaller than any present outside. Circles were present on both sandy and rocky areas.

Figure 2 from top left, desert Edelweiss, circle with Edelweiss, grass seedling in circle, circle in rocky area

From above (up a hill) the circles are more impressive; there are a very large number distributed over the entire region with the gaps in between being of similar size to the diameter of the circles. The circles are not clustered into any distinctive pattern and are not distorted parallel or perpendicular to slope, they were found on slopes of all aspects up to 13 degrees of incline. Slopes greater than this were either rocky or were dunes and the plants present were different to those on the plains.

Figure 3 Circles viewed from on top of a hill

Hydrology Measurements

Three areas were chosen, with different growth densities, slope and type of ring. At all sites three species of grass were present, the main one being *Stipogrostis obtusa*, with *Stipogrostis ciliata* making up most of the rest of the grass, a third species, *Enneapogon desvauxii*, was also present.

Site 1 (S24 97.391 E 015.904780) was a large circle with a slope of 3 degrees to horizontal. All three grass types were present with both *Stipogrostis* species being

abundant. *S. ciliata* was slightly more common in the circle edges, giving them a slightly raised appearance. Edelweiss was present in many of the circles in this area. Measurements were made from the top to the bottom of the slope, from well outside to investigate any effects of the slope.

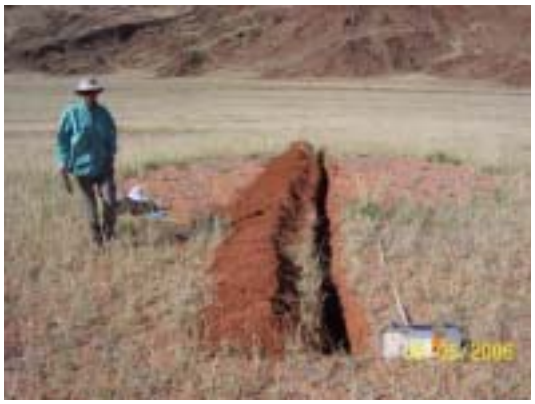

Figure 4 Site 1 with trench dug

Site 2 (S 24.92429 E 015.92045) was a smaller circle with mostly *S. obtusa* as the surrounding grass and *S. ciliata* in a ring around the circles, giving the appearance of enhanced growth at the ring edge. The grass around the circle was less dense and shorter than at site 1. Little Edelweiss was present in this area.

Figure 5 Site 2 showing what appears to be enhanced growth at the edge, but is actually *S. ciliata*

Site 3 (S24.87945 E 015.90672): In this area there was no apparent difference between the circles and their edges, all three grasses present with *S.obtusa* in far greater abundance than the other two. Grass density was also highest at this site.

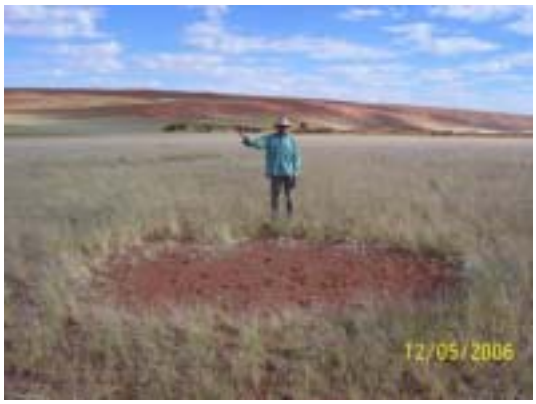

Figure 6 Site 3 showing circle with no obvious edge growth and high density of grass in surrounding area

Trenches were dug from the centre of each circle extending to about 1 radius into the outside vegetation. At site 1 this was repeated on the other side of the circle. The trenches were 60 cm deep and were aligned so that the excavated sand shaded them from the sun. Soil moisture was measured at 5, 15, 25, 35 and 45 cm depth at 10 cm intervals along the trenches using a delta T soil moisture probe. Further measurements were taken at greater depths at three points in the trench; in the centre of the circle, on the edge and well outside the circle. Samples were taken outside, inside and on the edge of the circles at 20 cm separation from each other at 0-5 cm depth and 10-15 cm as well as samples from each deep pit at 50 cm depth.

Figure 7 Photographs showing pit at centre of circle at site 3 and site 1 after refilling

Hydrophobicity

Drops of water were placed onto each sample after drying; the drops of water were absorbed almost instantly. Even soil taken from between the roots of grasses showed no hydrophobicity. To be hydrophobic a soil should not adsorb water for 5 seconds or more, this was clearly not the case here. Although soils commonly become more or less hydrophobic on drying these soils were hydrophilic all of the time. The soil could have been hydrophobic before the rain and have lost its hydrophobicity due to the intense rain, but this is unlikely; in this case hydrophobicity would normally return soon after drying.

Soil Water Distribution

When precipitation falls on a sandy soil such as this it infiltrates rapidly unless the soil is hydrophobic. As the area is arid it is expected that the water will not reach the water table except under rivers and lakes where long term seepage is possible. In most areas each rain event will wet the soil from the surface down to a certain depth, after this evaporation and transpiration will gradually remove the surface water leaving a wet zone at some depth that will gradually dry.

This profile was observed in all of the trenches. At sites 1 and 2, neat profiles in the matrix were observed with the maximum moisture level in the grassy part at around 20 cm depth at site 1 and 35 cm depth at site 2, the difference probably being due to the greater amount of vegetation at site 2 removing the water. The circles showed deeper penetration of water and faster increase in water level near the surface in both cases. Clear wetting fronts were observed inside the circles at less than 1 m depth. The soil below the edge of the circles showed less water than either the circle of the surrounding grassy area, probably due to the increased size of the plants there having greater water demands. At site 3 a layer of calcrete was evident at around the depth of the greatest concentration of water as well as several layers of gravel at different depths. These extended into the circle, but the calcrete and wetting front were deeper inside the circles than outside. This suggests that the circle chosen has been there for some time, and that the gravel has nothing to do with the formation of the circle. The gravel and calcrete made measurements more difficult in this circle, but the trend was exactly as with other circles except that some depths could not be accurately measured due to significant changes in structure (the method used is affected by soil structure).

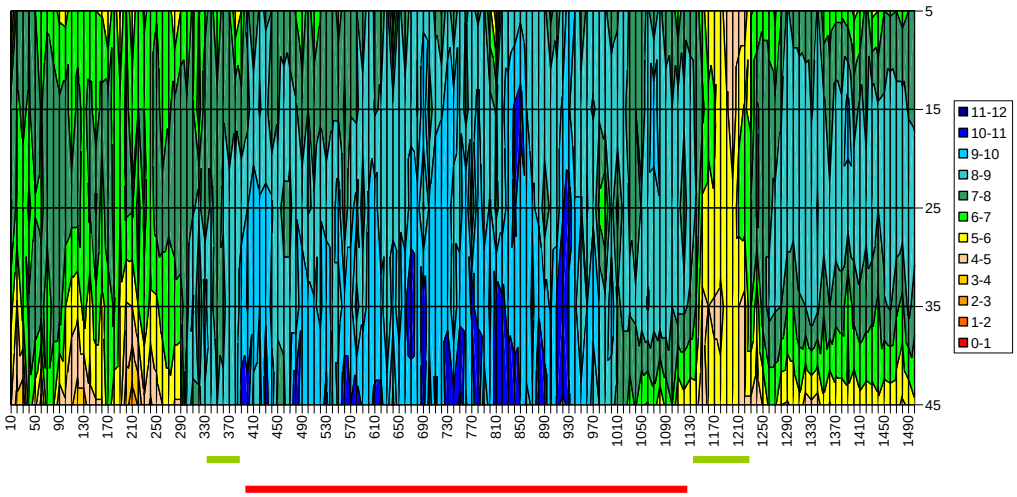

Figure 8 Spatial distribution of soil moisture along trench across circle at site 1 (depth and distance in cm) extent shown as red line, green lines show "enhanced growth region")

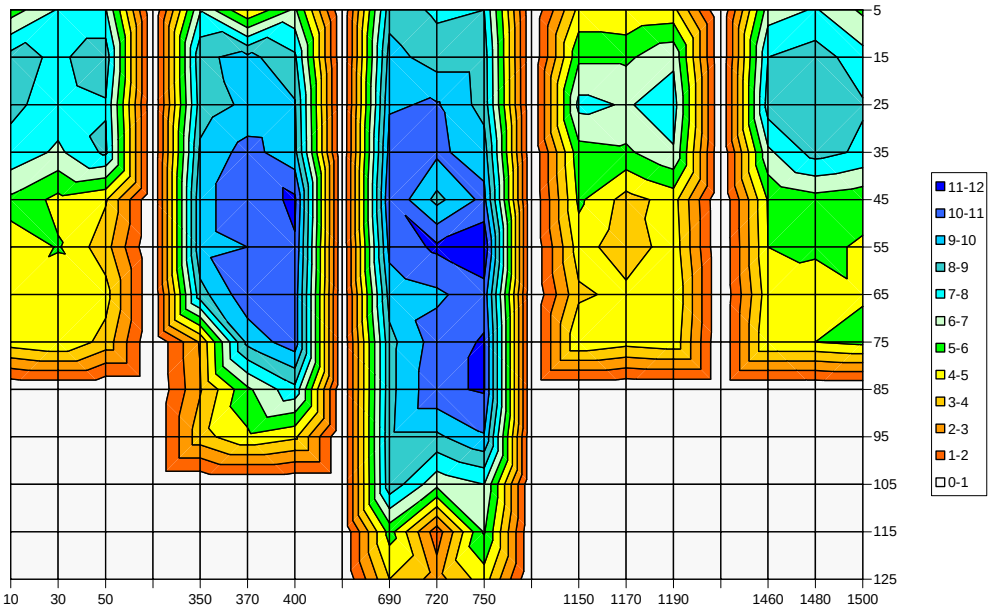

Figure 9 Soil moisture profiles in pits in grass (outside two), on the edge (next two in) and in the centre of circle (centre) at site 1

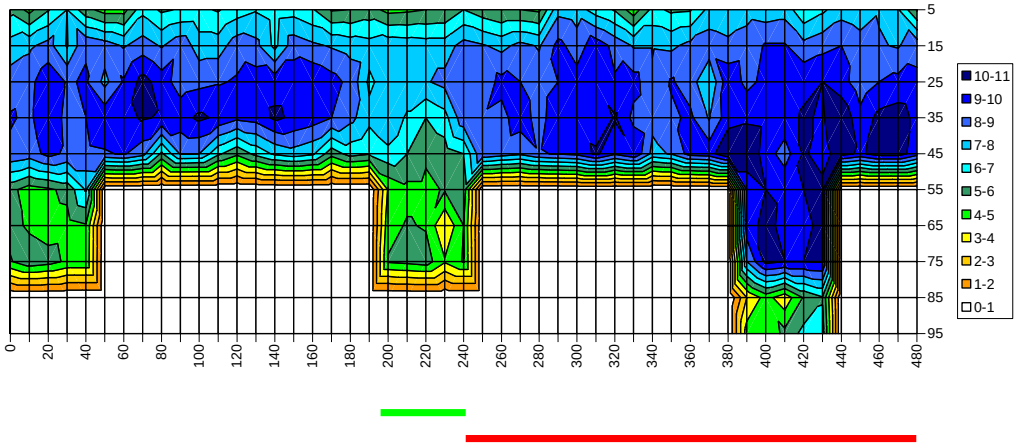

Figure 10 Soil moisture profiles from outside (left) to centre of circle at site 2 with deeper pits at the outside, edge and centre of circle (data that goes deeper) showing reduced moisture at edge and increased moisture in centre.

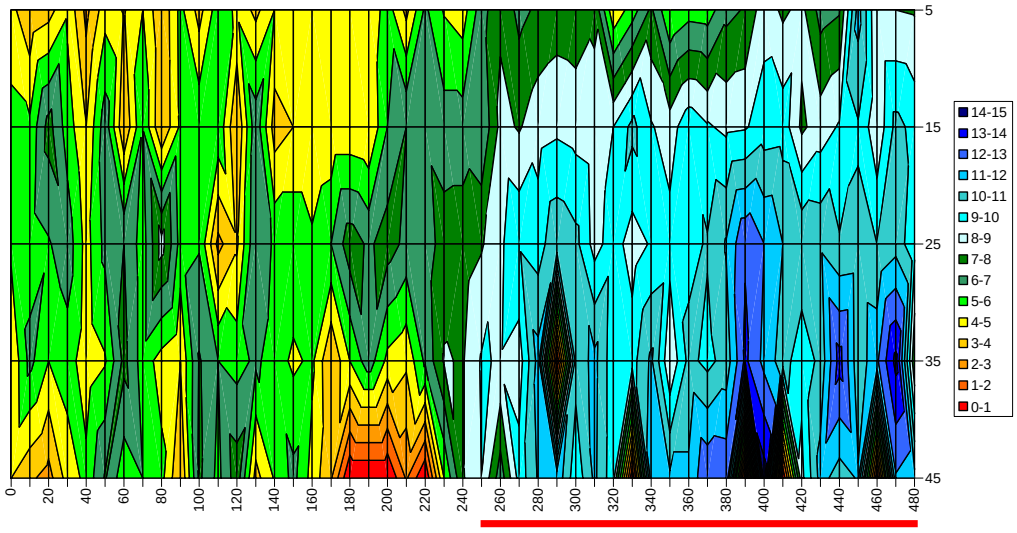

Figure 11 Soil moisture profiles at site 3 with the circle marked as a red line

These trends in soil moisture are entirely consistent with one-another and support the hydrophobicity measurements. We have therefore disproved our theory that the circles shed water and must therefore look at other possible mechanisms.

Animals

In addition to our digging we visited 50 circles during the day and 20 at night to look for animal activity that might create the circles. We also investigated which species were more common in the circles and what they were doing.

Termites
A popular theory is that termites cause the circles to form by foraging or poisoning, the longevity of some nests and the circles supports this. Termites were observed, but there was no correlation between their activity and the circles, more were found outside the circles than inside, although those seen were collecting grass seeds. No termites or burrows were found in any of the trenches. The central holes were 1.4 m deep, so tunnels should have been found if they were present.

Birds
A type of lark was observed landing only in the circles at site 1, however they were not very numerous. At site 2 they landed mostly outside the circles so were very unlikely to be responsible.

Ants
Two types of black ants and a type of red ant were associated with the circles, the larger black ants appeared to eat the Edelweiss seeds and were more numerous in areas where it occurred however the number and activity of all of the ant types could not be correlated with the circles, some cirles had barely any ants, some large quantities and we were not able to observe any of them attacking plants. Some ants were present in the trench at site 2, but these were not in the centre of the circle and were not seen in either of the other two trenches.

Beetles
A large number of beetles were present, but their burrows were not associated particularly with the circles. Scarabs were observed collecting grass seeds, but they can fly, so there is no reason for them to generate circular patterns. At site 3 there were a considerable number of burrowing beetles that fell into the trench, but these were confined to the part below the grass and were not any more numerous in the edge of the circle than elsewhere.

Others
Scorpions and lizards were also present but not associated with the circles.

Appearance of grasses
As with other researchers the seedlings inside the circles showed no sign of being nibbled or of any other obvious attack.

Although these observations do not preclude an animal causing the circles they do make it unlikely that this is the case.

Conclusions

So far this research has only provided negative evidence showing that there is no hydrological reason for the circles, as was thought at the outset. This also makes

explanations involving nutrients or radiation unlikely as no difference between soil outside and soil inside the circles was apparent, although the results of detailed tests on the samples will not be available for some time. We were unable to measure radiation on site, but again the lack of any difference in the soil makes it unlikely that radiation would be arranged in a pattern. In addition the local belief that the circles appear and disappear is not reconcilable with this theory. We also found some evidence against the theory that some kind of animal makes the circles, although such theories are difficult to disprove.

This leaves fungus as the most likely culprit. Supporting evidence is the number of fruiting bodies that were observed in the circles, probably due to the excessive rain that had fallen prior to our trip. Of the examples shown below only the last (bottom right) was observed outside a circle and it is obviously a different type to the others. A further type of fungus was found in the dunes and appeared to be living on the roots of a type of grass there.

Figure 12 Fungi photographed top left and right and bottom left inside circles near site 1 and bottom right outside circles near site 3

In addition to this rings (as opposed to circles) were observed in a different part of the country, near Solitare. As shown in the map in figure 1 these are inside the band where circles are found. All three grass species were present, but the density of grass, and therefore probably rainfall, was much greater. This shape is more typical of fungal growth in turfgrass with a ring expanding outward and the grass it passes filling in afterward. My current theory is that the low water availability in some parts of the country alters this growth pattern and creates circles instead of rings.

Figure 13 Barren rings observed at Solitare

Supporting evidence for this possibility is that living grasses of relatively large size taken from inside the edge of the circles showed evidence of roots having died back in the past but similar specimens from the grassy parts did not. Against this hypothesis is the fact that we looked for fungal hyphae in the root masses of the plants without

any success, but as we are not specialised in this field it is possible that we missed any indications that were present.