WEP Warwick Evans Publishing

Transactions on Environment, Energy and Earth Sciences
ISSN: 2960-1924, eISSN: 2960-2300 | Volume 3
GRET 2024

How Does The Change in Ratio of Vascular Plants to Biocrusts After Revegetation on Desert Soil Affect The Soil Hydrology?

Xinyan Wang [1], Yuanyue Ni [2]

[1] Hangzhou Foreign Languages School, Hangzhou, 310000, China

[2] Shanghai Yue Kong Pao Senior Secondary School, Shanghai, 201620, China

Abstract. Land desertification is one of the most serious challenges to the ecological environment in the world today, threatening the survival and development of mankind. China is one of the countries in the world with the most serious desertification problem, which causes land degradation, soil quality decline, reduced vegetation cover, sand and dust, and other catastrophic weather problems. Greening and afforestation is an effective measure to improve the local ecological environment of desertification, and different areas need to adopt different afforestation techniques, taking into account local climatic conditions and geological features. This study aims to rank the three basic types of sand-binding vegetation in terms of suitability to be cultivated in desert soil by evaluating their ability to absorb infiltrated water and find a suitable shrub/herb planting ratio to achieve sustainable development in the sand-controlled area.

Keywords: vascular plants; desert soil; soil hydrology; sand-binding vegetation.

1. Introduction

1.1 Background

The world's drylands, which make up about half of the planet and are inhabited by three billion people in 169 States, are seriously threatened by desertification, land degradation, and drought.(United Nations, 2023) About 400 million people are impacted by the 27.4% of China's land that has experienced desertification, according to research. (Browne, 2022) The topics of afforestation and reforestation received unprecedented attention as solutions to the drying world. This trend gave rise to another heated discussion concerning the type of plant with the most suitability to be cultivated in such projects.

Sand-binding vegetation can be categorized into shrubs, herbs, and microbiotic crusts. Different types of vegetation have different root depths, thus requiring water at different depths of the soil. (Jiang et al., 2023) However, the unique properties of sand soils—such as a high drainage capacity, a low water-holding capacity, and large amounts of air space(AHDB, 2024)—and their way of change with different vegetation cultivated indicate that requirements will not be fulfilled for all plant types. This study aims to rank the three basic types of sand-binding vegetation in terms of suitability to be cultivated in desert soil by evaluating their ability to absorb infiltrated water and find a suitable shrub/herb planting ratio to achieve sustainable development in the sand-controlled area. This will be achieved by studying the effect of the ratio of biomass of a certain type of vegetation among the others on the depth of infiltration in that area, and whether that depth corresponds with the ideal depth of water absorption for that vegetation type.

1.2 Literature review

Existing research on similar topics are reviewed.

Shi and others investigated the effect of typical plant communities on soil infiltration properties in their research. Their results indicated the highest infiltration rate at *Koeleria macrantha* communities and lowest at *Convolvulus ammannii* communities among the 6 typical plant communities of that desert that is compared. While they collected valid data, their findings on the effect of different plant communities on infiltration rate lacked an implication. An explanation on how the data can be utilized to manage degraded land more effectively is not included. While referring to the rigorous experimental design and methods of measuring infiltration properties of Shi and others' research, this study will be conducted with the more obvious purpose of determining the vegetation type of greatest suitability to be cultivated in deserts compared.

The research of Li and others investigated the effect of sand-binding vegetation on soil water content at different depths of desert soil. They correlated historical data on the relative coverages of shrubs and herbs on site and data of soil water content at different soil depths and made preliminary conclusions on the dominance of herbs in terms of fitness compared to shrubs in the desert environment. This study will build upon the research of Li and others by including the additional vegetation type of microbiotic crusts in the evaluation of the type(s) of vegetation most suitable for reforestation and afforestation.

1.3 Significance

The findings of this study on the vegetation type(s) of greater fitness in desert environments in terms of their ability to absorb infiltrated water can be applied in the management of areas of desertification. During the reforestation of such areas, project managers can utilize this study to select one or a few plant types of higher survival rate in deserts for reforestation projects to reduce cost and maximize the effect.

2. Methodology

Replace time with space is the special method used in this experiment. Originally what we can do to investigate the changes in areas revegetated in different times is to measure the moving sand dune first, and then plant with trees, shrubs, as well as herbs, and then investigate decades later. In turn, since the method explained above is too time-consuming, we chose three different areas where sand-preventing construction has been done at different times.

2.1 Research Site Description

Shapotou is 1,339 meters above sea level and is situated in the Ningxia Hui Autonomous Region in northern China, at 37˚330 N, 105˚020 E. This is the southeast edge of the Tengger Desert. It is categorized as a steppified desert zone, a region that lies between an oasis and a desert. (Li et al., 2004)

2.2 Sampling Method and Data Collection

Data used in this paper were collected from the database for desert ecosystem monitoring of the Chinese Ecological Research Network (CERN) at Shapotou Desert Experiment and Research Station, Chinese Academy of Sciences. Three research locations were used: one was a control site with shifting sand dunes, while the other two had sand binders planted at varying ages. While the other site was constructed in 1987, the first location was chosen in 1956, the year the Shapotou Desert Experiment and Research Station was initially created. Additionally, a moving sand dune served as the control group.

For control variables, since all of the plant species are planted in the same area, they have approximately the same amount of precipitation, evaporation, and the same temperature, weather, and time of measurement in a day.

For plant species, they are all planted in a 16-km long and 500-m wide planted vegetation area to the north of the railway. (Need more evidence to figure the real data out) The survey area of shrubs was 10*10 m, whereas that of herbs was 0.5*0.5 m. The plant species height, crown breadth, and coverage for each species in the sand stabilization areas were measured and recorded. Additionally, the thickness of microbiotic crusts was also measured.

The independent variable, in this case, is the vegetation coverage ratio of shrubs, herbs, and microbiotic crust on desert soil vegetated at three locations. Estimation has been done by one person, to make the data more accurate, and the approximate data of the percentage area of the plants' shadow is taken from the survey area. The ratio is calculated in two groups, including the ratio of vegetation coverage between shrubs and herbs, as well as the ratio of vegetation coverage between vascular plants and biocrust.

1% of the total amount of the shrubs, and 50% of the herbs, are picked from the selected area. The fresh weight is taken. The fresh weight has to be divided by the percentage that is picked from the plant in order to calculate the plant in that area as a whole. Finally, as the mass of all shrubs and herbs in that area was estimated, the data should divided by the area of the survey location, which is known to be the fresh biomass of that area.

The soil moisture content (S) at different soil depths is measured with the soil auger. The soil auger is hammered into the soil while remaining perpendicular to the ground surface at 6 depths of 5cm, 10cm, 30cm, 50cm, 70cm, and 100cm below the surface to collect soil between 0-5cm underground, 5-10cm underground, 10-30cm underground, 30-50cm underground, 50-70cm underground, and 70-100cm underground.

Each time the soil auger reaches the determined depth, it is lifted while being rotated so that the soil collected at the tip of the soil auger of the determined depth will not fall out. Only the soil at the tip of the soil auger should be collected for each depth.

The soil moisture content of each depth is calculated with the following equation,

$$S = \frac{W_{before} - W_{after}}{W_{after} - W_{container}}$$

with W_{before} representing the weight of the soil before it is dried in the oven as with the container, W_{after} representing the weight of the soil after it is dried in the oven as with the container, and $W_{container}$ representing the weight of the container.

The infiltration depth is measured by using a shovel to remove soil from the ground while remaining perpendicular to the surface. The section created by the shovel is examined for a line of change in color representing the border between the upper, wet soil and lower, dry soil. A ruler is used to measure the depth of the layer of wet soil, which reflects the depth to which the rain has infiltrated below the ground surface. This measurement is repeated in moving sand, the area revegetated in 1987, and the area revegetated in 1956.

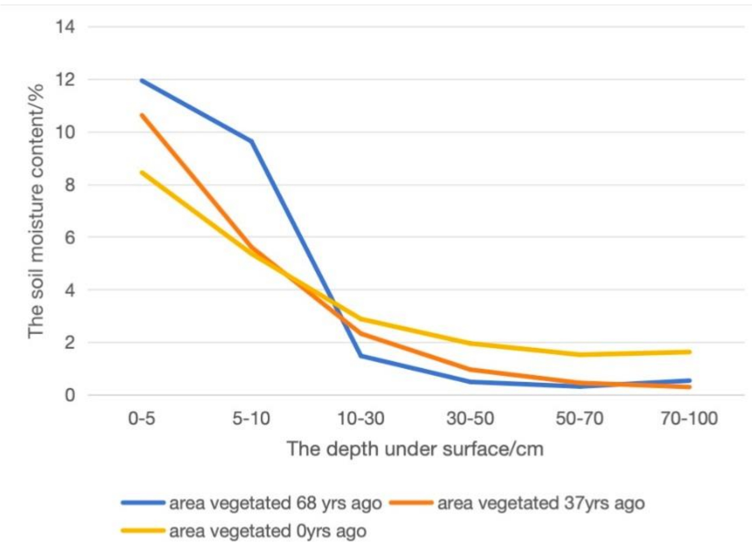

Figure 1. Change in soil moisture content as soil depth increases in areas revegetated in different years

3. Results

As soil depth increased, soil moisture content in all three sites demonstrated a decreasing trend, declining in values of 11.4%, 10.3%, and 6.82% respectively. As the time after the site is revegetated increased, the amount of decrease in soil moisture content along with soil depth also increased. Out of the three sites, the site revegetated 68 years ago exhibited the largest decline in soil moisture content from 11.9% to 0.535% as soil depth increased from 0-5cm to 70-100cm. The site revegetated 0 years ago exhibited the least decline from 8.44% to only 1.62% across the same depth. Out of the three sites, the site revegetated 68 years ago also exhibited the fastest rate of decline, especially between the depths of 5-30cm, followed by the site revegetated 37 years ago, and then the site revegetated 0 years ago.

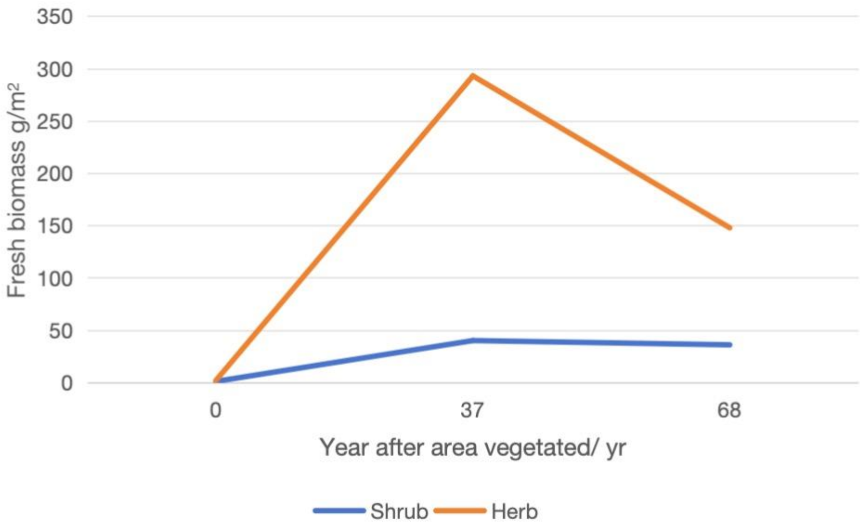

Figure 2. Change in fresh biomass of shrubs and herbs as time after revegetation increases.

The change in fresh biomass as the number of years the site has been revegetated increased does not exhibit a clear trend. Both the fresh biomass of shrubs and herbs peaked at 37 years after revegetation, at 40.0 g/m^2 and 292 g/m^2, respectively. Both biomass of shrubs and herbs were the lowest at 0 years after revegetation at 29.1 g/m^2 and 28.8 g/m^2. Both shrubs and herbs increase in fresh biomass from 0 to 37 years after revegetation and decrease in fresh biomass from 37 to 68 years after revegetation. Among the two, the fresh biomass of herbs was always higher than that of shrubs, with the largest difference of 253 g/m^2 at 37 years after revegetation.

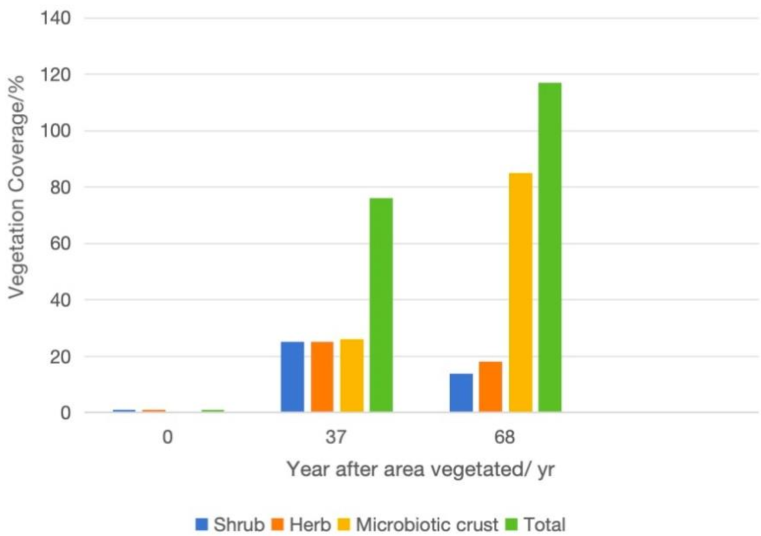

Figure 3. Change in shrub, herb, microbiotic crust, and total vegetation coverage as years after revegetation increases

The change in shrub and herb coverage as years after revegetation increases did not exhibit an obvious trend. Both shrub and herb coverage peaked at 25% during 37 years after revegetation and lowest at 0.5% during 0 years after revegetation. Both increased from 0 to 37 years after revegetation and decreased from 37 to 68 years after revegetation. The change in microbiotic crust and total coverage exhibited a general, increasing trend as the years after revegetation increased. Microbiotic crust coverage increased by 85% and total coverage increased by 116% from 0 to 68 years after revegetation. Among shrubs, herbs, and microbiotic crusts, their respective coverages fluctuated relative to each other and there was not 1 vegetation type that constantly has a lower or higher coverage than the other.

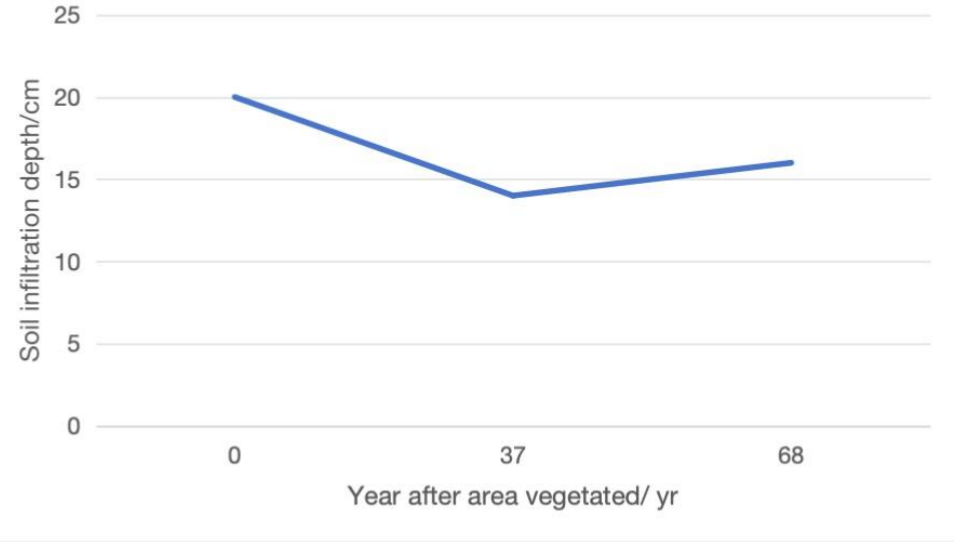

Figure 4. Change in infiltration depth as years after revegetation increases

Infiltration depth exhibited no general trend as the years after the sites were revegetated increased. From 0 to 37 years after revegetation, infiltration depth decreased by 6cm from 20cm to 14cm, then from 37 to 68 years after revegetation, infiltration depth increased by 2cm from 14cm to 16cm.

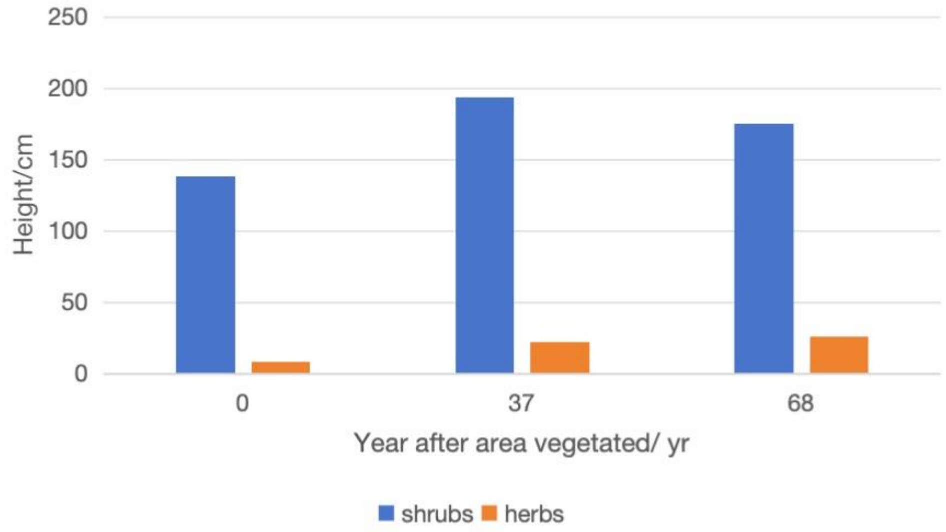

Figure 5. Change in average height of shrubs and herbs as time after the area is vegetated increases

While the height of herbs presented an increasing trend as it increased from 8cm to 25.5cm during 0 to 68 years after revegetation, the height of shrubs did not present a general trend. The height of shrubs was lowest at 138cm at 0 years after revegetation, peaked at 37 years after revegetation at 193cm, then reduced to 175cm at 68 years after revegetation. Among the two, the average height of shrubs was always higher than herbs, with a maximum difference of 172cm created at 37 years after revegetation.

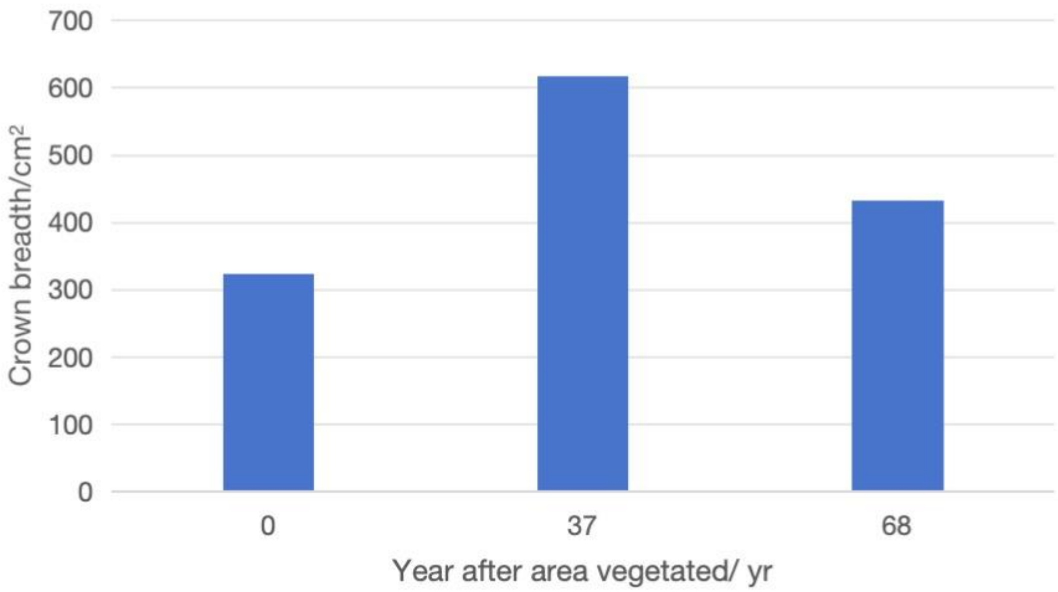

Figure 6. The change in average shrub crown breadth as time after the area is revegetated increases

The average crown breadth of shrubs did not present a general trend as the time after the area is vegetated increased. The average crown breadth was lowest at 323cm^2 at 0 years after revegetation, increased and peaked at 37 years at 616cm^2, and lowered again at 68 years.

4. Discussion

A few patterns can be observed from the results. Firstly, as the ratio of herb increases, or as that of shrub decreases, the ability of water to infiltrate and remain at greater soil depths is weakened. This is demonstrated via the faster rate of decrease in soil moisture content and the lower moisture content at great depths in the site revegetated in 1956 compared to the site revegetated in 1987 (see figure 1 and 4). Secondly, as more water concentrates at the shallow depths of the soil long after a site has been revegetated, the growth of shrub becomes increasingly limited relative to herb. This is demonstrated via the relatively lower crown breadth, biomass, and height of shrub in the site revegetated in 1987 (with less water at deeper soil layers) compared to the site revegetated in 1956 (with more water at deeper soil layers) (see figure 2, 5 and 6). Thirdly, as the ratio of microbiotic crust increases, the infiltration depth and moisture at great soil depths are both reduced. This is demonstrated via the gradually lowering soil moisture at depths below 10cm as the time after the site is revegetated and the ratio of microbiotic crust increases (see figure 1 and 3).

Our findings are in accordance with the findings of other researchers. The research of Li and others found that the moisture content of desert soil, especially in the deeper soil layers, will gradually decrease after 9-10 years of revegetation. Another research from Li and others also discovered the decrease in the number of species of shrub relative to herb as the time after revegetation increases (Li et al., 2007). They also discovered the ability of microbiotic crust to concentrate water content at shallow layers of desert soil.

The decrease of water in deep soil layers as shrub decreases and herb increases can be explained by the different root depth of the two plant types. Herb roots extract water from more shallow layers of soil compared to shrub roots (Li et al., 2004). Thus, as the ratio of herb increase and the ratio of shrub decrease, there will be more forces of extraction at the shallow soil layers and less at the deeper layers, leading to more water remaining at the shallow soil depths. As the moisture content at deep soil layers decrease, the growth of herb becomes more supported than shrub (Li et al., 2007), leading to a positive feedback cycle in which the outcome—an increase in the ratio of herb relative to shrub—is amplified. Microbiotic crust is located at the surface of the soil, trapping precipitation with itself at the surface (Li et al., 2000).

5. Conclusion

From this study, a few conclusions can be made. Firstly, as the length of time after an area has been revegetated increases, the ratio of herb increases relative to shrub, and the ratio of biocrust increases relative to vascular plants. Secondly, when the ratios of different plant types change as stated above, infiltration and moisture content at deeper layered soil both decreases. Thirdly, when soil hydrology changes as stated above, the growth of herb and biocrust becomes more supported relative to that of shrub, enhancing the changes in the ratios of plant types. Lastly, to maximize the effect of future revegetation projects, a larger ratio of herb should be cultivated and a larger ratio of biocrust should be implanted relative to shrub. This is so that plant types with more fitness to the desert environment—in terms of their better ability to absorb soil moisture—are cultivated, leading to higher survival rates and greater impact.

6. Acknowledgement

Thanks to Professor Jia and Ms.He for supporting us in collecting data, writing this paper, and renewing our understanding of the Tengger desert.

References

[1] Xin, Li. "Study on Soil Microbiotic Crust and Its Influences on Sand-Fixing Vegetation in Arid Desert Region." *Zhiwu Xuebao*, vol. 42, no. 9, 1 Jan. 2000. Accessed 7 Aug. 2024.

[2] LI, X. R., et al. "Association between Vegetation Patterns and Soil Properties in the Southeastern Tengger Desert, China." *Arid Land Research and Management*, vol. 18, no. 4, Oct. 2004, pp. 369–383, https://doi.org/10.1080/15324980490497429.

[3] Li, Xinrong. "Recovery of Topsoil Physiochemical Properties in Revegetated Sites in the Sand-Burial Ecosystems of the Tengger Desert, Northern China." *Geomorph*, vol. 88, no. 88, 2007.

[4] Li, X. R., et al. "Changes in Soil and Vegetation Following Stabilisation of Dunes in the Southeastern Fringe of the Tengger Desert, China." *Plant and Soil*, vol. 300, no. 1-2, 19 Sept. 2007, pp. 221–231, https://doi.org/10.1007/s11104-007-9407-1.

[5] Jiang, Peipei, et al. "Patterns of Deep Fine Root and Water Utilization amongst Trees, Shrubs and Herbs in Subtropical Pine Plantations with Seasonal Droughts." Frontiers in Plant Science, vol. 14, Frontiers Media, Sept. 2023, https://doi.org/10.3389/fpls.2023.1275464. Accessed 7 Aug. 2024.

[6] AHDB. "Characteristics of Different Soils | AHDB." Ahdb.org.uk, 2024, ahdb.org.uk/knowledge-library/characteristics-of-different-soils#:~:text=Sand%20Largest%20soil%20particle%20at%200.06. Accessed 7 Aug. 2024.

[7] Browne, Amelia. "Desertification in China: Causes, Impacts, and Solutions." Earth.org, 20 Dec. 2022, earth.org/desertification-in-china/#:~:text=Research%20shows%20that%20currently%2C%2027.4%25%20of%20land%20in. Accessed 7 Aug. 2024.

[8] United Nations. "UN Experts Call for Rights-Based Approach to Combat Desertification, Land Degradation and Drought." Https://Www.ohchr.org/En/Statements/2023/06/Un-Experts-Call-Rights-Based-Approach-Combat-Desertification-Land-Degradation, 16 June 2023, www.ohchr.org/en/statements/2023/06/un-experts-call-rights-based-approach-combat-desertification-land-degradation. Accessed 7 Aug. 2024.