ON THE MOUNTAIN-RIVER-DESERT RELATION

by

Ying MEI[a], Yu-Qi LIU[a], Ji-Huan HE[b,c,d*]

[a]Department of Environmental Science and Engineering, School of Energy and Power Engineering, Inner Mongolia University of Technology, Hohhot, China
[b]School of Mathematics and Information Science, Henan Polytechnic University, Jiaozuo, China
[c]National Engineering Laboratory for Modern Silk, College of Textile and Clothing Engineering, Soochow University, Suzhou, China
[d]School of Science, Xi'an University of Architecture and Technology, Xi'an, China

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When the Yellow River flows through Togtoh, north China, a puzzling phenomenon occurs, one side is the Hobq desert, and the other side of the river is a lush landscape of gardens. No theory can explain the desertification beside a river. Especially the river might be the main factor in the desertification. We address this challenge by establishing a mathematical model that can depict the different effects of the river and mountain on the river's both sides. The model herein takes into account the different meteorological parameters and soil parameters of the river's both sides and Earth surface's morphology. Moreover, though our focus is put on the Hobq desert, the present theory on mountain-river-desert relation can also be used for combating desertification. We anticipate that the mountain-river-desert relation is much more important than vegetation restoration and human activity.

Keywords: *Bernoulli potential, humidity, Darcy's law*

Introduction

There are many factors affecting desertification; the prevalent opinion is the heavy human activity. Overgrazing might lead to desertification, and vegetation restoration is the main effort to combat desertification. A flowing river has always been considered an effective tool for controlling the desert.

The Yellow River is the sixth-longest in the world. When it flows through Togtoh, north China, a puzzling phenomenon occurs, one side is the Hobq desert, and the other side of the river is a lush landscape of gardens[1-4], fig.1.

Drought is recognized as another main factor of desertification, however, the annual average rainfall is about 362 mm in the Hobq desert, and the average flow rate of the Yellow River is more than 1000 m^3/s. However, both the rainfall and the river cannot prevent Hobq from desertification.

It was recorded the Hobq area was densely forested, lush with water and grass, and was populated by herds of cattle and sheep. The area was gradually turned to desert, and now

*Corresponding author, e-mail: hejihuan@suda.edu.cn

it has a history of more than 3000 years. The dry climate, abundant sand sources, and excessive use by human beings were recognized as the main factors for the desert development from land with lush grass. Herein we address this challenge by giving a new opinion on desertification, and the mountain-river-desert relation is proposed for the first time.

(a) (b)

Figure 1. The desert-river phenomenon in Togtoh, north China; (a) the whole Yellow River and (b) Hobq desert adjacent to the Yellow River

In situ experiment

Before the development of a new theory, we designed an in-situ experiment on October 9, 2021. The research area was located at 111° 2 'E and 40° 18' N in Togtoh, north China with an average altitude of about 1000 m, on the eastern boundary of the Hobq Desert.

Mobile dunes of the Hobq desert account for about 61% of the total dune with heights from 10 m to 60 m. Aeolian sandy soil is the main soil, and the vegetation is dominated by *Agriophyllum sguarrosum*, *Artemisia desertorum*, *Hedysarum fruticosum, and Caragana korshinski*. The annual average temperature is about 7.3 ℃.

In our experiment, 12 sample points were designed for the experimental study, distributed on both sides of the Yellow River, as shown in fig. 2. Sample Points 1~6 were designed on the east bank of the Yellow River, the distance between the two adjacent samples was 50 m, and the other samples were on the west bank of the Yellow River. The width of the river at the study area is about 200 m.

Figure 2. Sample locations on both sides of the Yellow River

The Kestrel Weather Meters Model Numbers 1000-3500 was used to measure the sample points' wind velocity and direction, temperature, relative humidity, air pressure above 1.2 m of each sample point. The altitude of each sample point was measured using a mobile phone. Soil samples were collected below 30 cm of the soil surface.

Soil density and soil porosity were calculated by:

$$\text{Soil density } = \frac{W}{V} \tag{1}$$

$$\text{Soil porosity } = \frac{W' - W}{V} \times 100\% \tag{2}$$

where W is the soil's weight, V – the volume, and W' – the soil's saturation weight. The measured data are given in tab. 1.

Table 1. In-situ experimental data

Sample No.	Altitude [m]	Wind speed [ms^{-1}]	Wind direction	Temperature [°C]	Relative humidity [%]	Air pressure [100mmHg]	Soil density [gcm^{-3}]	Soil porosity [%]
1	–	–	–	–	–	–	1.43	41.06
2	994.20	1.1	NW324°	12.6	31.8	30.35	1.27	46.72
3	994.20	1.1	NW312°	12.1	34.4	30.35	1.34	37.76
4	994.20	0.9	NW293°	13.4	33.4	30.35	1.14	34.05
5	994.30	1.4	NW302°	11.6	43.2	30.36	1.17	36.76
6	995.60	0.9	W271°	11.5	34.4	30.36	1.30	42.57
7	998.70	2.1	NW337°	13.9	37.0	30.27	1.41	47.17
8	998.30	1.3	NW316°	13.6	37.9	30.27	1.52	36.10
9	1001.21	1.5	N10°	13.4	41.7	30.26	1.55	38.88
10	990.70	1.7	N4°	14.3	39.1	30.29	1.35	40.19
11	995.90	2.0	NW331°	11.1	41.4	30.28	1.51	38.39
12	998.90	3.2	NW330°	11.4	41.5	30.26	1.51	36.87

Experimental data analysis

The Hobq desert is the seventh-largest desert in China. It is located north of the Ordos Plateau and in the south of the Yellow River. To the north is the Lang Mountains area, in the western part is the Seertang Mountains, as shown in fig. 1. The desert has 400 km long from east to west, 15-20 km wide in the east, and 50 km wide in the west, covering an area of about 1.45 million hectares.

As shown in tab. 2, the soil porosity of the two sides of the river changes little, the average porosity of samples No.1~No.6 is 39.82%, while the value is 39.6% for samples No.7~No.12. That means that the river affects little on soil porosity. So we focus ourselves on meteorological parameters.

Table 2 Average values of both sides of the Yellow River

Sample No.	Wind Velocity [ms^{-1}]	Temperature [°C]	Humidity [%]	Soil Porosity [%]
1-6	1.08	12.24	35.44	39.82
7-12	1.97	12.95	39.77	39.60

According to Bernoulli equation [5], we have:

$$\frac{1}{2}u_{\text{west}}^2+\frac{P_{\text{west}}}{\rho_{\text{west}}}=B_{\text{west}} \tag{3}$$

$$\frac{1}{2}u_{\text{east}}^2+\frac{P_{\text{east}}}{\rho_{\text{east}}}=B_{\text{east}} \tag{4}$$

where u is the wind velocity, P – the air pressure, ρ – the air density, B – the Bernoulli potential, and the subscripts west and east imply, respectively, the west and east parts of the river.

According to the state equation of moist air [6], we have:

$$P_{\text{west}}=R(1+0.61\varphi_{\text{west}})\rho_{\text{west}}T_{\text{west}} \tag{5}$$

$$P_{\text{east}}=R(1+0.61\varphi_{\text{east}})\rho_{\text{east}}T_{\text{east}} \tag{6}$$

where R is the dry air constant, T – the temperature, and φ – the specific humidity. In view of eqs. (5) and (6), we re-write eqs. (3) and (4) in the forms:

$$\frac{1}{2}u_{\text{west}}^2+R(1+0.61\varphi_{\text{west}})T_{\text{west}}=B_{\text{west}} \tag{7}$$

$$\frac{1}{2}u_{\text{east}}^2+R(1+0.61\varphi_{\text{east}})T_{\text{east}}=B_{\text{east}} \tag{8}$$

According to the experimental data given in tab. 2, we had:

$$u_{\text{west}}>u_{\text{east}},\ T_{\text{west}}>T_{\text{east}},\ P_{\text{west}}>P_{\text{east}},\ \varphi_{\text{west}}>\varphi_{\text{east}} \tag{9}$$

Our experimental data revealed that:

$$B_{\text{west}}>B_{\text{east}} \tag{10}$$

We, therefore, can conclude that the Bernoulli potential in the Hobq desert was much higher than that in the opposite area of the Yellow River. This difference makes the water molecules in air spread from the high potential area to the low potential area, that is, from the Hobq desert to the opposite of the Yellow River. The moisture transmission from the riverside to the other side is the inherent factor of desertification. We can use Darcy's law to explain the moisture transmission.

Darcy's law is to model the moisture permeability in a porous medium. The air can be considered as a porous medium, and the water molecules are diffused from the high pressure area to the low pressure area. The permeability velocity can be expressed as [7]:

$$w=k\frac{\mathrm{d}P}{\mathrm{d}x} \tag{11}$$

where w is the permeability velocity and k – the permeability parameter. Equation (11) is valid only for the motionless air. For moving air, we modify eq. (11) as:

$$w=k\frac{\mathrm{d}B}{\mathrm{d}x} \tag{12}$$

Equation (12) implies that moisture transmission happens from the high Bernoulli potential area to the low Bernoulli potential area. Equation (12) can be expressed in a difference form:

$$w = k\frac{B_{\text{west}} - B_{\text{east}}}{H} \tag{13}$$

where H is the width of the river.

Our experimental data revealed that the desertification process is caused by the difference of Bernoulli potentials on both sides of the river. But what is the main factor affecting this difference?

The mountain-river-desert relation

To answer the previous question, we have to consider the Earth's surface morphology. Figure 3 shows the change of wind velocity due to the Lang Mountains and Seertang Mountains. The mountains are considered the boundary of the air-flow, and the wind velocity on the boundary is assumed to be zero. By this simple analysis, we conclude that the Hetao Plain has a smaller wind velocity than the Hobq desert. So the Hobq area has higher Bernoulli potential. But why is the river the boundary of the desert?

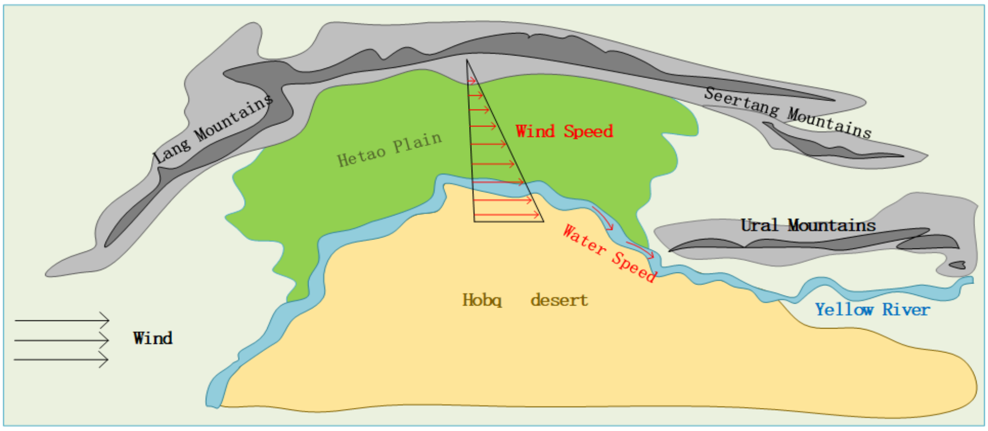

Figure 3. The mountain-river-desert relation

The river must play an essential role in the desertification process. We assume that the water moves at a velocity of uriver, and Bernoulli equation about the river is:

$$\frac{1}{2}(u_{\text{river}}^2 + u_{\text{air}}^2) + R(1 + 0.61\varphi_{\text{river}})T_{\text{river}} = B_{\text{river}} \tag{14}$$

where uair is the air velocity above the river, and φriver and Triver are, respectively, specific humidity and temperature above the river surface. It is obvious that:

$$\varphi_{\text{river}} > \varphi_{\text{west}} > \varphi_{\text{east}} \tag{15}$$

$$B_{\text{river}} > B_{\text{west}} > B_{\text{east}} \tag{16}$$

According to eq. (16), the area above the river surface has the highest Bernoulli potential, so the most moisture will spread to the Hetao Plain, and the moisture transmitted to the Hobq area will finally move to the river's opposite area.

Discussion and Conclusion

Our theoretical analysis shows that the area between the mountains and a river will not become a desert, and the river's opposite area has an inherent trend to lose moisture, which might cause desertification. Though this paper focuses on the Hobq desert, the maintain-river-desert relation is also helpful to combat desertification. This paper sheds a bright light on the mechanism of desertification development, and we anticipate that our maintain-river-desert model can be modified and applied to other deserts.

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References

[1] Liang, X., *et al*., Desertification Direction of the Northern Margin of Hobq Desert, *Acta Geological Sinica-English Edition, 89* (2015), 3, pp. 1055-1056
[2] Fan, Y. X., *et al*., Sedimentary and OSL Dating Evidence for the Development of the Present Hobq Desert Landscape, Northern China, *Science China-Earth Sciences, 56* (2013), 12, pp. 2037-2044
[3] Yang, H., *et al*., Characteristics of Aeolian Dune, Wind Regime and Sand Transport in Hobq Desert, *China, Applied Sciences-Basel, 9* (2019), 24, 5543
[4] Pan, B. T., *et al*., Analysis of Channel Evolution Characteristics in the Hobq Desert Reach of the Yellow River (1962-2000), *Global and Planetary Change, 135* (2015), Dec., pp. 148-158
[5] Schafle, C., Kautz, C., Student Reasoning in Hydrodynamics: Bernoulli's Principle versus the Continuity Equation, *Physical Review Physics Education Research, 17* (2021), 1, 010147
[6] Liu, F. J., Dou, H., A Modified Young-Laplace Equation for the Bubble Electrospinning Considering the Effect of Humidity, *Thermal Science, 17* (2013), 2 , pp. 629-630
[7] Yang, Z. P., Filtration Efficiency of a Cigarette Filter with X- or Y-Shaped Fibers, *Thermal Science, 23* (2019), 4 , pp. 2517-2522

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