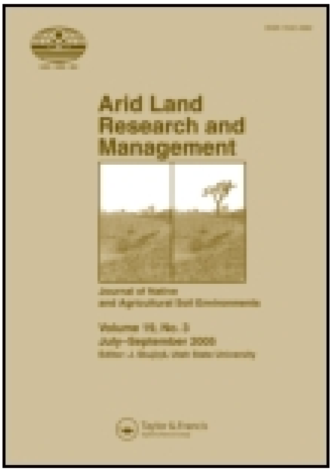

Arid Land Research and Management
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/uasr20

Effects of Vegetation Reclamation on Temperature and Humidity Properties of a Dumpsite: A Case Study in the Open Pit Coal Mine of Heidaigou

Yang Zhao[a], Xin-rong Li[a], Peng Zhang[a], Yi-gang Hu[a] & Lei Huang[a]
[a] Shapotou Desert Research and Experiment Station, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou, China
Published online: 08 Jan 2015.

Arid Land Research and Management, 29:375–381, 2015

ISSN: 1532-4982 print/1532-4990 online
DOI: 10.1080/15324982.2014.962192

Research Note

Effects of Vegetation Reclamation on Temperature and Humidity Properties of a Dumpsite: A Case Study in the Open Pit Coal Mine of Heidaigou

Yang Zhao, Xin-rong Li, Peng Zhang, Yi-gang Hu, and Lei Huang

Shapotou Desert Research and Experiment Station, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou, China

Vegetation cover greatly influences the microclimate of a landscape, which plays an important role in ecosystem function and health. The following study examines the influence of different vegetation types on the microclimate of a surface mine reclamation site. Average soil and air temperatures are significantly lower, while relative humidity is significantly higher in re-vegetated areas of a surface mine dumpsite in the Heidaigou. Vegetation recovery, particularly an increase in herbaceous vegetation cover, is expected to significantly reduce temperature and increase relative air humidity, improving the microclimate of the dumpsite in arid and semi-arid regions.

Keywords herbaceous vegetation, microclimate, relative air humidity, soil temperature

Microclimate is a crucial determinant of ecological patterns, directly influencing ecological processes, changes in ecosystem function, and landscape structure. Bare land covered by vegetation can reduce daytime air and soil temperatures, increase relative air humidity, and stabilize the temperature and moisture regimes of a territory (McPherson, 2007; Brom and Pokorný, 2009). Vegetation produces ecologically important microclimates in arid and semi-arid ecosystems, which greatly impact ground level biological processes including soil seed banks, seedling establishment, seed germination, and seedlings survival and growth (Griffith, 2010).

During the course of surface mining, vegetation cover is disturbed over large areas (Brom et al., 2012). In China, roughly 2200 m^2 of soil were damaged during the surface mining of ten thousand tons of coal, and an additional 1000 m^2 were damaged in the

Received 28 December 2013; accepted 2 September 2014.
Address correspondence to Yang Zhao, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, 320 Donggang West Road, 730000, Lanzhou, China. E-mail: zhaoyang66@126.com
Color versions of one or more of the figures in the article can be found online at www.tandfonline.com/uasr.

associated dumpsite (Sun, 2000). Due to the removal of vegetation cover, the hydrology and microclimate of the region have been completely altered. These changes could result in altered ecosystem structure and function, such as increased soil temperature, decreased abundance of understory vegetation, and low relative humidity resulting in reduced plant transpiration, photosynthesis, and production (Brom et al., 2012; Parker et al., 2012). Moreover, it could impact the species distribution and the structure of plant communities (Lendzion and Leuschner, 2009). Microclimate information is vital for empirical field studies, theoretical modeling exercises, and management decision-making. However, little attention has been paid to the microclimate conditions after vegetation reclamation at dumpsites in surface mining areas (Brom et al., 2012). In the following study, air and soil temperatures, and relative humidity were measured in re-vegetated dumpsite areas to answer a question: Is the effect of different vegetation cover on temperature and humidity properties significantly different?

This study was conducted at the north dumpsite (197 km^2) of the Heidaigou opencast coal mine (39°43′-39°49′ N, 111°13′-111°20′ E, average elevation is 1163 m), Junggar Banner, Inner Mongolia Autonomous Region, China. The annual average temperature, rainfall and the relative humidity are 7.2°C, 426.3 mm and 58%, respectively. Temperature parameters and humidity were measured for five different vegetation types: Tree + Herbaceous (TH), Tree + Shrub (TS), Tree + Shrub + Herbaceous (TSH), Herbaceous (H) and Bare Land (BL) re-vegetation types (specific descriptions of sites and soil physical properties are shown in Table 1 and Table 2). The measurements were done on three clear dry summer days with 5 days of preceding clear and dry weather (July 30, August 10 and 18, 2013). The three days were used as replicate measurements. Air (at 1.0 m), soil surface temperature and relative humidity (at 0.1, 1.0 and 2.0 m) were measured with DT616CT temperature and humidity data loggers (Hong Kong CEM company, Hong Kong), with an accuracy of ±0.2°C in temperature and ±2% in humidity. Soil temperature at 0.1 m depth was measured with a rectangular geo-thermometer (Hebei Wuqiang Shengtong Instrument and Meters Factory, Hebei Province, China), with an accuracy of ±0.5°C. Observation interval was set to 2 hours from 08:00 to 18:00 local time. All measurements were completed within 20 minutes at each interval. For each re-vegetation type, 3 plots (10 m × 10 m) were randomly chosen, and height and cover (vertical projection area of vegetation, measurement by the digital photography method) of woody species were measured on the same days during the summer as the temperature and humidity measurements. An additional three plots (1 m × 1 m) were randomly set up within each 10 m × 10 m plots to quantify species and cover of herbaceous plants. To compare the difference temperature and humidity properties between re-vegetation types, Tukey HSD ($p < 0.05$) were used. To describe the relationship between herbaceous vegetation cover, woody vegetation cover, and total vegetation cover and air temperature at 1.0 m, soil surface temperature, soil temperature at 0.1 m depth, and relative air humidity at 0.1 m, 1.0 m, and 2.0 m, a linear-regression analysis was used. SPSS 16.0 software was used for statistical analyses.

There were significant differences in diurnal average air and soil surface temperatures between re-vegetation types ($p < 0.05$). BL had the greatest air temperature value (32.12 ± 0.48°C) which were significantly higher than the other re-vegetation types ($p = 0.048$, $F = 6.866$, $df = 4$); BL also had the greatest soil surface temperature value (31.64 ± 0.72°C), which were significantly higher than TSH and H re-vegetation types ($p = 0.023$, $F = 10.235$, $df = 4$) (Figure 1 A–C). The

Table 1. Year of re-vegetation, total vegetation cover, main re-vegetation species, and average height of woody vegetation in the re-vegetation types of Tree + Herbaceous (TH), Tree + Shrub (TS), Tree + Shrub + Herbaceous (TSH), Herbaceous (H), and Bare Land (BL), respectively

Re-vegetation types	Year of Re-vegetation	Coverage %	Main Re-vegetation species	Average height of woody vegetation m
TH	1995	43.46	*Populus alba* var. *pyramidalis* Bunge, *Pinus tabulaeformis* Carr., *Melilotus suaveolens* Ledeb, *Leymus secalinus* (Georgi) Tzvel.	3.94
TS	1995	38.02	*Populus alba* var. *pyramidalis* Bunge, *Hippophae rhamnoides* Linn.	3.74
TSH	1995	48.17	*Populus alba* var. *pyramidalis* Bunge, *Hippophae rhamnoides* Linn., *Leymus secalinus* (Georgi) Tzvel., *Medicago sativa* L.	3.22
H	1995	82.67	*Medicago sativa* L.	
BL	–	–	–	

Table 2. Soil volumetric moisture content in July 30, August 10 and August 18, soil texture and bulk density in the re-vegetation types of Tree + Herbaceous (TH), Tree + Shrub (TS), Tree + Shrub + Herbaceous (TSH), Herbaceous (H), and Bare Land (BL), respectively

Re-vegetation types	Soil volumetric moisture content %			Soil texture	Bulk density (0–20 cm) g cm^{-3}
	Jul 30	Aug 10	Aug 18		
TH	5.61	5.63	5.44	Loam	1.44
TS	5.73	5.95	5.85	Loam	1.25
TSH	8.82	8.86	8.79	Loam	1.33
H	9.45	9.48	9.53	Loam	1.20
BL	3.31	3.30	3.39	Loam	1.52

differences in the diurnal mean air, soil surface, and 0.1 m soil depth temperatures between the re-vegetation types and BL were 1.4°C, 5.3°C and 4.5°C, respectively.

The differences in temperature between the re-vegetation types are likely due to the differences in vegetation cover (see Table 1) and the resulting water content held in the vegetation. Our study showed a negative relationship between soil surface temperature and temperature at 0.1 m soil depth and total vegetation cover ($p = 0.007$, $F = 10.175$ and $p = 0.046$, $F = 4.820$; $df = 13$), respectively (Figure 2a and b).

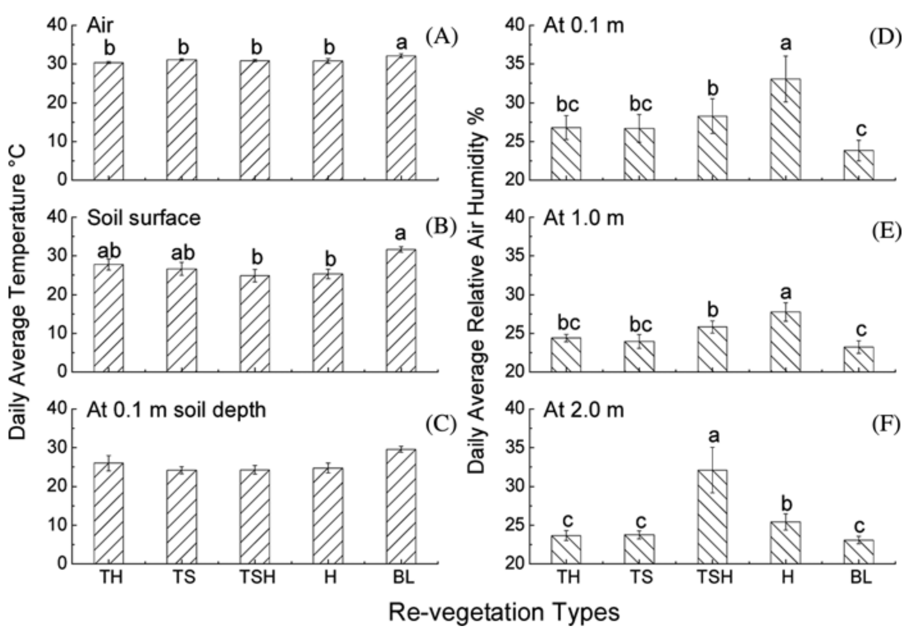

Figure 1. Comparison of the diurnal average air temperature at 1.0 m, soil surface temperature, soil temperature at 0.1 m depth (°C; Mean ± SE; A–C), and relative air humidity at 0.1 m, 1.0 m, and 2.0 m (%; Mean ± SE; D–F) in the re-vegetation types of Tree + Herbaceous (TH), Tree + Shrub (TS), Tree + Shrub + Herbaceous (TSH), Herbaceous (H), and Bare Land (BL), respectively. Values with different letters are significantly different at $p < 0.05$.

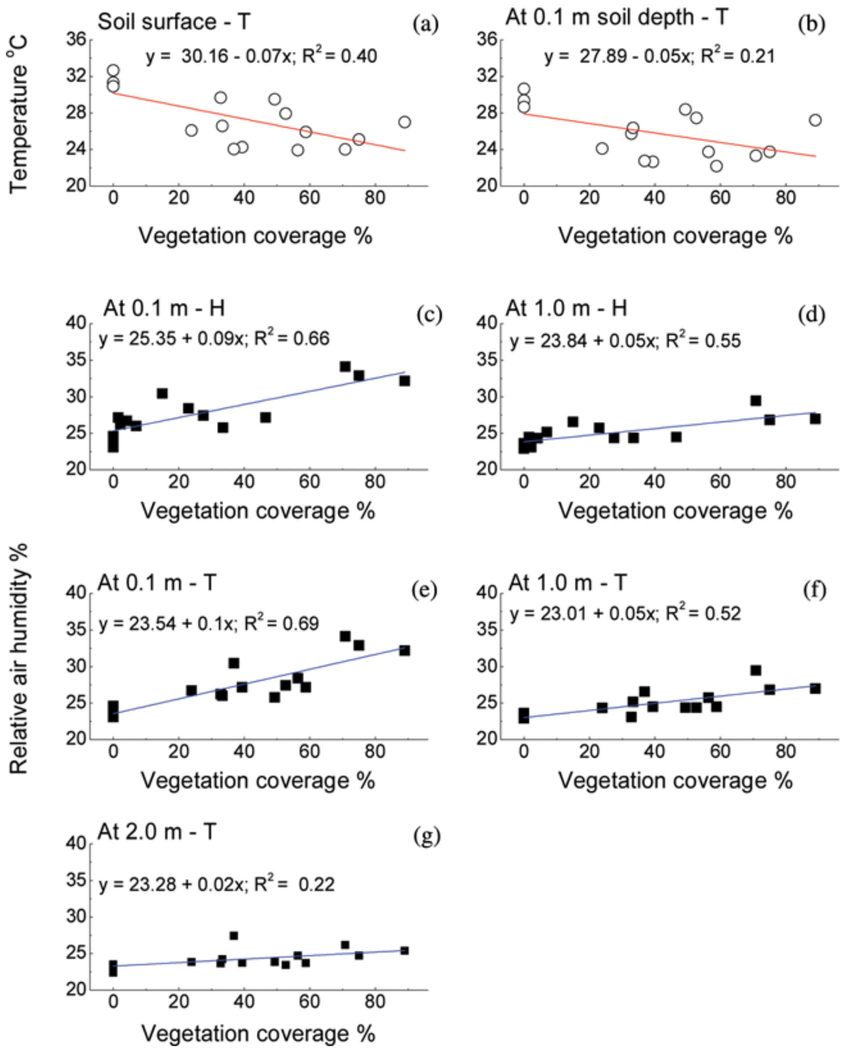

Figure 2. Regression analyses of herbaceous vegetation cover (H), woody vegetation cover (W), and total (T) vegetation cover and air temperature at 1.0 m, soil surface temperature, soil temperature at 0.1 m depth (a and b), and relative air humidity at 0.1 m, 1.0 m, and 2.0 m (c–g), respectively.

The reduction in temperature is achieved by the conductance of heat into air and soil. Solar energy is a main heat source to the landscape. Vegetation cover attenuates the amount of solar radiation reaching the air and soil surface (Kidron, 2009). This interdependence indicates that vegetation cover has an ability to retain and release water through transpiration, consuming heat and cooling down the surrounding temperatures (McPherson, 2007). Our results are similar to those obtained by a previous study carried out in a brown coal dumpsite with different reclamation types (Brom et al., 2012).

There were significant differences in diurnal average relative air humidity at 0.1, 1.0, and 2.0 m between re-vegetation types ($p < 0.05$). H had higher values at 0.1 and 1.0 m and TSH had higher values at 2.0 m than the rest (Figure 1 D–F). There was a significantly positive correlation between humidity at 0.1, 1.0, and 2.0 m and total vegetation cover (vertical projection area of all vegetation in plot) ($p < 0.001$, $F = 32.032$; $p = 0.001$, $F = 16.496$ and $p = 0.045$, $F = 4.912$; $df = 13$; Figure 2 c–e). This suggests that re-vegetation significantly increased relative air humidity in the daytime. Vegetation increased the rates of evaporation and transpiration through leaf cover, and therefore increased the humidity. The greater the vegetation cover, the greater the amount of water held in vegetation (Huang et al., 1987). Overall, differences in vegetation cover lead to humidity differences among re-vegetation types.

Effective vegetation management (changes in vegetation cover) improved microclimate conditions in the ecosystem. Woody vegetation can modify the microclimate, particularly the temperature regime within the canopy. Parker et al. (2012) highlighted the role of herbaceous vegetation in the improvement of near-ground microclimate, as it significantly changed the amount of solar radiation received and thus, water availability (González-Alday et al., 2008). In the present study herbaceous vegetation impacted ground-level microclimate conditions significantly more than woody vegetation (Figure 2a and b). Conversely, Brom and Pokorný (2009) reported that woody vegetation, instead of herbaceous vegetation, decreased temperatures in a wetland ecosystem. Low survival rates of trees are a problem under rainfed conditions for re-vegetation in our study area. Herbaceous vegetation is dominant in the undisturbed vegetation near the study areas; it can adapt to the local climatic conditions and had a high survival rate (Jiang et al., 2013). Therefore, we should consider the role of herbaceous vegetation in modifying the microclimate in dumpsite re-vegetation in arid and semi-arid regions.

In the dumpsite, re-vegetation can significantly reduce air and soil temperatures and increase relative air humidity. Our results emphasize that different vegetation types, that is, herbaceous vegetation type, ameliorate microclimatic conditions in dumpsites in comparison with open spaces. Therefore, re-vegetation techniques could be an option to reduce the harsh microclimatic conditions of dumpsites in open pit coal mines in arid and semiarid regions.

Funding

This work was sponsored by the CAS Action-Plan for Western Development (KZCX2-XB3-13-03), the National Natural Scientific Foundation of China (41201086, 41101081), and Foundation for Excellent Youth Scholars of CAREERI, Chinese Academy of Sciences.

References

Brom, J., and J. Pokorný. 2009. Temperature and humidity characteristics of two willow stands, a peaty meadow and a drained pasture and their impact on landscape functioning. *Boreal Environment Research* 14: 389–403.

Brom, J., V. Nedbal, J. Procházka, and E. Pecharová. 2012. Changes in vegetation cover, moisture properties and surface temperature of a brown coal dump from 1984 to 2009 using satellite data analysis. *Ecological Engineering* 43: 45–52.

Griffith, A. B. 2010. Positive effects of native shrubs on *Bromus tectorum* demography. *Ecology* 91: 141–154.

González-Alday, J., R. H. Marrs, and C. Martínez-Ruiz. 2008. The influence of aspect on the early growth dynamics of hydroseeded species in coal reclamation areas. *Applied Vegetation Science* 11: 405–412.

Huang, Y. J., H. Akbari, H. Taha, and A. H. Rosenfeld. 1987. The potential of vegetation in reducing summer cooling loads in residential buildings. *Journal of Applied Meteorology* 26: 1103–1116.

Jiang, W., Y. Cheng, X. Yang, and S. Yang. 2013. Chinese Loess Plateau vegetation since the Last Glacial Maximum and its implications for vegetation restoration. *Journal of Applied Ecology* 50: 440–448.

Kidron, G. J. 2009. The effect of shrub canopy upon surface temperatures and evaporation in the Negev Desert. *Earth Surface Processes and Landforms* 34: 123–132.

Lendzion, J., and C. Leuschner. 2009. Temperate forest herbs are adapted to high air humidity-evidence from climate chamber and humidity manipulation experiments in the field. *Canadian Journal of Forest Research* 39: 2332–2342.

McPherson, R. A. 2007. A review of vegetation-atmosphere interactions and their influences on mesoscale phenomena. *Progress in Physical Geography* 31: 261–285.

Parker, W. C., D. G. Pitt, and A. E. Morneault. 2012. Influence of herbaceous and woody vegetation control on seedling microclimate, leaf gas exchange, water status, and nutrient relations of *Pinus strobus* L. seedlings planted in a shelterwood. *Forest Ecology and Management* 271: 104–114.

Sun, S. G. 2000. Influence of ecoenvironment and the problem to be solved due to open pit excavation. *Coal Mine Environmental Protection* 14: 53–54. (In Chinese)