Potential Application of Hugelkultur to Increase Water Holding Capacity of Karst Rocky Desertified Lands

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Globally, desertification has been identified as one of the most pressing environmental problems due to its impact on agricultural productivity and water availability (Conceição and Mendoza 2008). Desertification is defined as "land degradation… resulting from various factors, including climatic variations and human activities" (Reynold *et al.* 2007). As a result of erosion and vegetation loss, the ability of these areas to sustain life is degraded. Although climate change has been shown to influence rates of land degradation, there is a stronger correlation with human activities (Harriman 2014). While the majority of desertification takes place in arid and semi-arid environments, this is not always the case. *Karst Rocky Desertification* (KRD) refers to areas where the soil loss has created extensive surface exposures of limestone bedrock, particularly widespread through the vast karst area of rural southwest China (Yuan, 1997)

In undisturbed karst systems, the epikarstic zone in the vicinity of the soil/bedrock interface can provide significant storage of shallow water resources. When the soil is lost, precipitation can immediately percolate through the bedrock into deeper, less accessible areas of the aquifer. Without the soil to hold water at the surface, plants and in turn human populations can face desert-like conditions even as groundwater flows beneath.

The Southwest China Karst, once well known for areas of old growth forest, covers 540,000 km^2 of land with several provinces in southwestern China, principally Sichuan, Chongqing, Guangxi, Guizhou, Hunan and Yunnan. Large-scale deforestation and slash and burn cultivation transformed the rural countryside, leaving it vulnerable to degradation (Yuan, 1997). As a consequence, extensive areas have developed KRD and the impact of human activity is indicated as the primary driving force (Wang et al., 2004; Xu *et al.* 2013).

Poverty is widespread in KRD affected areas. Increasing environmental pressure due to population growth and poor agricultural practices on vulnerable soil on karst slopes exacerbates the cycle: poverty to population growth to environmental degradation (Tang and Xia, 2001). Current research efforts focus on breaking the cycle of degradation.

A conjunction of the words "permanent" and "agriculture," the term "permaculture" first originated in a collaborative effort between David Holmgren and Bill Madison to describe an "integrated, evolving system of perennial or self-perpetuating plant and animal species useful to man" and as integrated design science (Mollison and Holmgren 1978). In essence, permaculture is intentionally designed through species selection and overall structure to mimic natural environmental relationships in order to sustain a community.

In the current study, we examined one variation within the permaculture system called *hugelkultur,* an etymologically German word meaning "mound culture." In his book, *Sepp Hotlzer's Permaculture,* Holtzer first describes these raised beds. Hugelkultur beds are made to imitate natural nutrient cycling found in wood decomposition and the high water holding capacities of organic detritus, while also improving bed structure and drainage properties. The beds are, in essence, large, layered piles of woody debris or other detritus under a layer of soil (Holtzer 2011).

We propose that the high organic matter content of the hugel beds will demonstrate a higher water holding capacity (WHC), and enhance soil development, in a way that may show promise as a potential method to help alleviate problems of KRD.

Methods

Soil samples were taken from hugels at three different locations in Bowling Green Kentucky, which has a karst landscape in ways similar to that of parts of Southwest China, beginning in April 2015. We sampled biweekly with a 1.5 cm diameter soil corer. Hugel cores, unless halted by wood, were taken to 30 cm. To determine the amount of water held in a water saturated plot of desertified land, samples were taken on land with similar characteristics to KRD sites i.e. an area dominated by exposed bedrock in Bowling Green, Kentucky.

Soil cores were placed in Whirl-Pak sampling bags and weighed on an electric balance, and then transferred into a paper bag. The samples were then prepared to be oven dried overnight at 120 ^{o}C. The samples were then reweighed to determine changes in soil moisture.

We used a modified formula for the volume of a cylinder to determine the volume of each hugel. Using the wet and dry weights to ascertain grams of water present per volume of sample core, we multiplied the volume of the hugel of origin by the amount of water per volume of soil core to estimate the amount of water present in each hugel.

To project the amount of water that could be held in a 1 hectare field with hugels, if hugels were built to widths corresponding to each test hugel and a footpath of equivalent width was left in between each hugel, the water present per volume of soil core sample was multiplied by the volume of a hypothetical 100 meter long hugel and the number of such hugels that could be built in a hectare. A similar formula was applied to the desertified samples.

Precipitation data was obtained through Kentucky Mesonet (http://www.kymesonet.org).

Results

Over the course of three months, the water levels in the hugels stayed consistently high; the fluctuation in moisture reflected precipitation levels (Figure 1). The saturated sample taken on KRD land showed M = 7.74 ± 2.5 *SD* cm of soil depth and was estimated to hold 154,000 kg/Ha. When compared to the mock desertified area, the hugeled plot demonstrated a much higher WHC M = 955,084 ± 51,038 *SE* kg/Ha. Even through the dry weather periods, hugels contained more water than that held in a water saturated KRD plot.

Discussion

Although hugels required a large amount of initial input of organic material (soil, compost, logs), they can be used for years afterward as a lower maintenance agricultural system. This study suggests that hugel construction could greatly increase water stored on KRD lands (Figure 1). One Ha of hugels con-

Location (Lat/Long)	Sample Name	Date Established	Source Material
36.972450, -86.462412	UUH1	May 2013	Onsite trees and soil, hay and leaves
	UUH2	May 2014	
36.979561, -86.416342	EBH1	March 2014	Nearby trees, aged firewood, onsite soil

Table 1: Hugel location and details

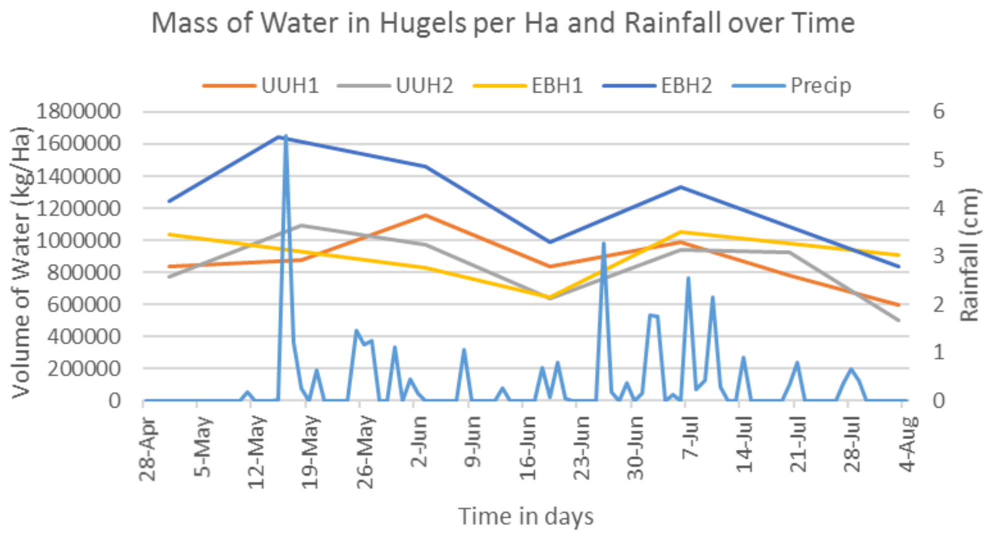

Figure 1:Mass of Water in Hugels per Ha and Rainfall over Time

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Samples from December 2013 provide a better demonstration of the benefits of hugelkultur using building methods of the sampled hugels more closing mimic the conditions in China. Those hugels were constructed using wood, mulch and limited soil obtained on site. Even with minimal treatment, samples taken from the hugels contained an average of 59% water by gram while the samples from the control, flat land plots, contained 33% water per gram. Unfortunately these hugels were transferred to another owner and destroyed.

In order to be applied in the KRD areas in southwestern China, hugelkultur needs to be effective in several arenas: practical building methods, agricultural yield, and WHC. This study demonstrates its effectiveness in WHC, and research on the yield qualities of hugels is currently being studied. As for construction practicality, flexibility in building materials and the possibility of self-propagation through on-hugel tree cultivation increase the accessibility of productive hugelkultur systems. These systems could be established on the outskirt of rural villages impacted by KRD using available soil in combination with assorted organic matter. Trees could be planted into these hugels along with other indigenous edible or economically valuable plants to create a sustainable, profitable system.

References

Conceição, P. and Mendoza, R. U. 2008. Anatomy of the Global Food Crisis. Third World Quaterly 30: 1159-1182

Harriman, L. 2014. The future of the Aral Sea lies intransboundaryco–operation. UNEP Global Environmental Alert Service

Holtzer, S. 2011 Sepp Holzer's Permaculture: A Practical Guide to Small-Scale, Integrative Farming and Gardening. Chelsea Green Publishing

Mollison, B., Holmgren, D. 1978. Permaculture One: A Perennial Agriculture for Human Settlements. International Tree Crop Institute USA

Reynold, J. F., Smith, D. M. S.,Lambin, E. F., Turner, B. L.,Mortimore, M.,Batterbury, S. P. J., Downing, T. E.,Dowlatabadi, H., Fernandez, R. J., Herrick, J. E., Huber-Sannwald, E., Jiang, H.,Leemans, R.,Lynam, T.,Maestre, F. T.,Atarza, M., Walker, B. 2007. Global Desertification: Building a Science for Dryland Development. Science 316: 847-851

Tang, J., Xia, R., 2001.Characteristics of water and land resources and remedy measures of ecological environment in karst mountain areas of south China. Carsologica Sinica, 20(2): 140-148. (in Chinese)

Wang, S. J., Liu, Q. M., & Zhang, D. F. (2004). Karst rocky desertification in southwestern China: geomorphology, landuse, impact and rehabilitation. *Land degradation & development*, *15*(2), 115-121.

Xu,E., Zhang,H., Li,M.. 2013 Mining spatial information to investigate the evolution of karst rocky desertification and its human driving forces in Changshun, China. *Science of the Total Environment* 458-460: 419-426.

Yuan, D., 1997, Rock desertification in the subtropical karst of south China. *Zeitschrift für Geomorphologie.* 108: 81-90.