Urban Food Systems Symposium

# Establishing hügelkultur for season extension research, specialty crop production, and permaculture education

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## Abstract

Hügelkultur is a system of tall, windrowed beds comprised of layers of buried wood, soil, and organic matter. No peer-reviewed research has been identified on production of vegetable crops in hügelkultur systems. This study utilizes pumpkin (*Cucurbita pepo* L. 'Cinnamon Girl'), a warm-season crop, and lettuce (*Lactuca sativa* L. 'Muir'), a cool-season crop, to evaluate whether the shady north side, or sunny south side of east-to-west oriented hügel beds offers a viable season extension strategy for specialty crops. Data collection includes total yield, marketable yield, soil temperature and moisture, light intensity, air temperature, and relative humidity. The experiment began on June 11, 2020 and data collection continues into the fall of 2020. Preliminary observations suggest that the south-facing hügel slopes dry out faster than slopes on the north side. Differences in soil moisture and temperature between the three aspects seems to vary at different parts of the year. Data analysis will be conducted during the winter of 2020-21.

## Keywords

pumpkin, lettuce, aspect, raised bed, microclimate

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**INTRODUCTION**

Hügelkultur, German for "hill culture," is a system of raised beds comprised of layers of wood, soil, compost, and various types of organic matter to create windrowed mounds. Permaculture practitioners around the world utilize hügelkultur, or hügel beds. Permaculture is an ethical design system that seeks to mimic the complexity of natural ecosystems in the human environment. No peer-reviewed studies on using hügel beds for specialty crop production has been identified in the literature, thus this project is the first of its kind. Due to the lack of research on this topic, commonly purported benefits of hügelkultur will be discussed briefly.

Purported benefits of hügelkultur include reduced inputs, specifically irrigation and fertilizer, especially in well-established beds that are in the process of decomposing. As wood begins to decompose in the beds, the wood is thought to act like a sponge storing water that becomes available to plants during dry conditions. Likewise, as wood decomposes completely, the C:N ratio declines so that less nitrogen is tied up by soil microbes. It is purported that plants have lower fertilizer requirements in well-established hügel beds due to advancing decomposition of wood in the profile.

Evaluating some of these purported benefits, specifically the evolution of soil nutrients and soil moisture retention over time, requires long-term evaluation. Although these aren't the objectives of the present study, data relevant to these questions is being collected since it is relevant to the research questions of this project. In the short term, with recently constructed hügel beds, this project explores hügelkultur for its potential as a season extension practice. Considering there is no research in academic literature specifically about hügelkultur, a review of relevant topics primarily related to shady and sunny aspects and their influence on soil temperature, soil physical and chemical properties, and plant biomass is used to build evidence for our hypothesis

Hügel beds, when oriented east and west, create shady and sunny aspects that could provide a new strategy for season extension. Most of the available research on shady and sunny aspects focuses on the comparison of chemical, physical, biochemical, and biophysical properties of soils in natural landscapes. Although there is somewhat extensive research on microclimates created from diverse topography, there is minimal research on how these microclimates could be applied to agricultural production systems. Some available research supports the idea that microclimates, created by north- and south-facing slopes, could offer season extension potential by providing evidence that soil temperatures are warmer on south-facing slopes than on north-facing slopes.

A common trend among current research related to shady and sunny aspects, is that north-facing slopes tend to have greater soil carbon and nitrogen levels than do south-facing slopes, which in natural ecosystems is associated with greater plant diversity and biomass on north-facing slopes (Begum et al., 2010; Rezaei and Gilkes, 2005). In relation to soil physical properties, Rezaei and Gilkes (2005) found that comparing north-, south-, east-, and west-facing lands had no influence on soil water holding capacity in semi-arid regions of Iran. In contrast, Begum et al. (2010), who compared north- and south-facing aspects of rural parts of the Himalayan region of Nepal, found that the most drastic differences between north- and south-facing slopes was the moisture content. These findings are more applicable to long-term research questions related to the purported benefits that hügelkultur can lead to reduced irrigation and fertilizer needs over time. Simultaneously, they may be relevant to crop selection when growing on hügel beds, in that south-facing slopes on hügel beds may be better-suited for plants that prefer dry or quickly draining soils.

Soil moisture and fertility are important in relation to crop success, but have less impact on season extension when compared to soil temperature differences created by shady and sunny aspects. Burnett et al. (2008) found that differences in temperatures between north- and south-facing aspects are more substantial in subsurface measurements than is found in air temperatures. Additionally, they found that the greatest difference in subsurface temperatures between north- and south-facing aspects occur in winter months, with south-facing aspects reaching “as much as 8°C higher” than north-facing slopes (Burnett et al., 2008). The subsurface temperature differences between the aspects were smaller in late-spring and summer months, though the south-facing aspect remained consistently warmer by about 4°C (Burnett et al., 2008).

These findings suggest that the shady and sunny aspects of east-west facing hügel beds could create microclimates that could be applied as a system of season extension in agriculture. On south-facing slopes, warmer temperatures may allow for longer seasons in late fall and early spring months, than might be possible in traditional flat bed agriculture. On north-facing slopes, cool-season crops planted in the spring may have a longer growing season that extends into the hot, summer months; and, fall-planted crops may be planted earlier when compared to traditional flat beds.

There is limited research comparing north-facing and south-facing slopes with flat beds, and this study could offer insight on hügelkultur as a season extension strategy. Xu et al. (2019) evaluate the differences in soybean (*Glycine max* (L.) Merr) production and biomass between north- and south-facing slopes. Although they focus primarily on plant growth, including the vigor of soybeans at various life stages, some of their findings apply to season extension potential. They found a “declining trend [in soybean plant biomass] from the sunny, top, and shady slopes to the bottom of the slope in June” (Xu et al., 2019). As summer months progress, the difference in biomass between shady and sunny slopes was minimal, supporting the findings of Burnett et al. (2008) that soil temperature differences between the two aspects is smaller in the summer and increases during winter months.

Since soybeans are warm-season crops it is expected that they will thrive in warmer soils. Xu et al. (2019) reported the plant biomass was highest for the south-facing slope than the top of the hill in June. Additionally, they found that plant “biomass varies with the slope aspect and position and over a growing season" (Xu et al., 2019). These findings support the hypothesis that shady and sunny aspects created by hügelkultur may allow for season extension throughout the growing season, depending on the crop and the regional climate and topography. Given that the study by Xu et al. (2019) focused on soybean production, their study provides no commentary on seasonality of production.

Most of the research relevant to season extension focuses on one crop, for instance soybeans. This provides scholars with crop-related trends but fails to compare more than one crop at a time, for instance cool- and warm-season crop comparisons. Additionally, most research on this topic utilizes natural topographical landscapes that lead to unique soil physical and chemical properties. Considering soil properties will vary due to factors including parent material and climate, in addition to topography (Rezaei and Gilkes, 2005), there is a need to isolate the influence of shady and sunny aspects and their influence on season extension.

There is research to support the hypothesis that the shady and sunny aspects, created by hügel beds oriented east-to- west, could offer a new season extension practice for growers. Unfortunately, aside from the study by Xu et al. (2019), no other research has been identified that evaluates season extension due to aspect in an agricultural context. This project is unique as it compares man-made raised beds, hügel beds, each comprised of soil from one site, similar wood species, and single-source compost in hopes of more closely isolating the influence of sunny and shady aspects on season extension compared to traditional flat- or [minimally] raised-bed agriculture. This research aims to find out if microclimates, created by sunny and shady aspects of an east- and west-facing hügel bed, extend the growing season for pumpkin and lettuce.

## MATERIALS AND METHODS

### Experimental design

The hügelkultur research plots were installed to facilitate two concurrent experiments with randomized complete block, split-plot experimental designs with four blocks and four replications per main plot. The main plot treatments are north-facing aspect (hügel), south-facing aspect (hügel), and flat beds as a control. Each main plot is divided into four 7.3 m long subplots (which can be analyzed as a second blocking factor [east-to-west]). Each subplot has three 2.4 m long sub-subplots randomly assigned to 1) pumpkin (*Curcubita pepo* L. 'Cinnamon Girl') experiment, 2) lettuce (*Lactuca sativa* L. 'Muir') experiment, and 3) a refuge/buffer planting of Kansas-native wildflowers.

### Hügel bed construction

The hügelkultur experiment was started in June 2020 and installed at Kansas State University's (KSU's) Willow Lake Student Farm in Manhattan, KS. Hügel and flat plots are oriented east-to-west to create a shady (north) and sunny (south) aspect. Each hügel bed is 29.3 m long, 2.4 m wide, and approximately 1.1 m high. Flat beds were established 29.3 m long and 0.8 m wide. Within each block, main plots were randomly assigned in the north or south half of the block, and shady and sunny aspects of each hügel bed were necessarily adjacent to each other. In permaculture, hügelkultur is a design system that is utilized to fit the landscape and surrounding ecosystems. There is no 'correct' way to build a hügel bed. This could be a topic of future research, but for the purposes of this project, the beds are designed in a way that both serve the needs of the study and that can be easily replicated for future research.

Using a mini-excavator, four 30.5 m long, 2.1 m wide, and roughly 0.3 m deep trenches were dug to begin the construction of each hügel bed. Hügel bed construction does not always incorporate a trench, but this project utilized a trench to ensure enough soil was available for all layers of the beds, as the team did not want to bring in soil from another location. Each layer within the hügel bed is comprised of wood, soil, and compost. Wood came from KSU's Tuttle Forestry Research Center, on which KSU's WLSF is situated. Wood used in the bed is primarily Eastern Cottonwood, *Populus deltoides* W. Bartram ex Marhsall. The compost was obtained from KSU Department of Agronomy's North Farm. Compost at this facility incorporates waste from KSU dining halls and greenhouses.

Once all the trenches were dug, the layering of the hügel beds began. For the purposes of explaining the construction process, each 'layer' consists of wood, soil, and compost. Each layer included a combination of approximately equal portions of soil and compost. With each additional layer of wood, the size of the woody material used became progressively smaller.

The base layer of each hügel bed began with the placement of wood, primarily trunks of trees with diameters of around 30 - 45 cm. Logs wrapped in chain were transported using tractors to a staging area near the research plot. A mini excavator was used to pick up and place the large logs into the trenches. Following the placement of the first layer of wood, compost and soil were added. The compost and soil were raked by hand into an evenly distributed layer. Walking on the beds during the raking process increased compaction and pushed compost and soil into the gaps between the wood to create a densely filled hügel bed.

The second layer began with the placement of more wood, with logs in diameter of up to around 30 cm. Logs were not measured, but consistency was maintained throughout the construction process. Once again, soil and compost were placed on top of the wood, compacted, and raked until smooth and evenly distributed.

The third layer included wood with diameters up to about 15 cm. For this third layer, a mixture of soil and compost was again placed on top of the wood. The combination of soil and compost were hand-raked until smooth and evenly distributed. The final layer utilizes twig-sized wood, with diameters no larger than about 5 cm, though most of the wood used included diameters that were much smaller.

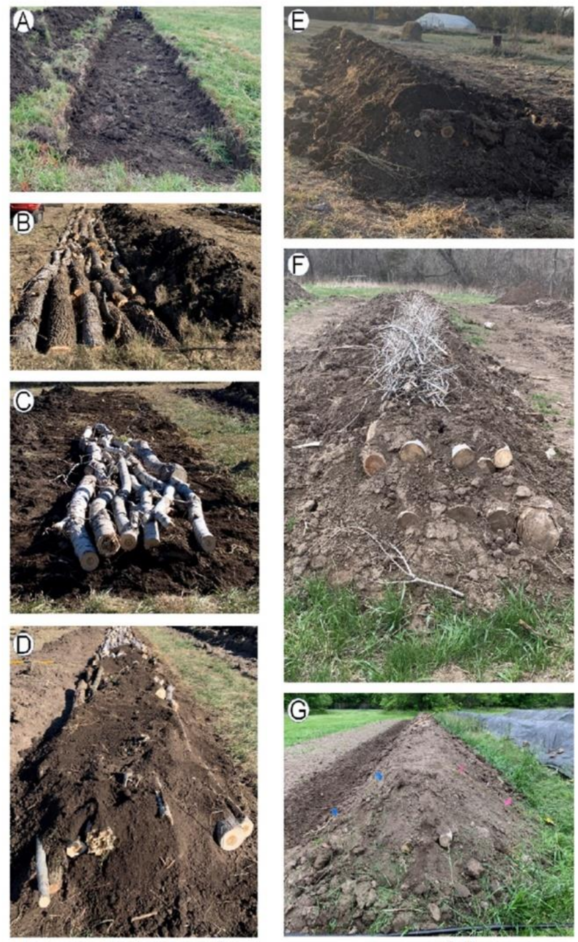


Figure 1. A visual representation of the hügelkultur construction process: A) Completed trench B) Base layer of large wood fills the trench C) Second layer of wood on top of raked compost D)Second layer partially covered with soil E) Third layer of wood topped with combination of soil and compost, after raking F) Final layer of twig-sized wood G) A completed hügel bed

Using a skid steer, the final additions of soil and compost were placed on each bed. The same process for hand raking and walking was used to create a flat top to each hügel bed. Some finesse was used to ensure that slopes of both sides of all hügel beds were roughly the same. Completed beds stand roughly 1.1 m tall. The length of the beds varied a bit, so the experimental plots were adjusted so that the total usable length of each hügel bed is 29.3 m. The width of each hügel bed is approximately 2.4 m. The usable width of each face of the hügel beds average approximately 1.3 m.

Figure 2. Panorama of the research plot as of July 3, 2020

**Data collection**

Data collection is currently underway, so analysis is not complete. Pumpkin harvests began on August 11th and the last harvest was completed on September 18, 2020. Data related to pumpkin harvests included total yield, total marketable yield, days to first harvest, and length of harvest. Testing for °Brix will no longer take place, as sufficient marketable yield would not support the measurement during this study. Lettuce plants are currently in the ground and will be harvested in late fall.

In addition to data related to yield, environmental conditions are being monitored and collected using a HOBOnet basic weather station. Environmental monitoring sensors are located midway up the face of the north and south faces of the hügel bed and in the center of the flat bed, between the 11th and 12th plot of the second block from the north. Soil moisture/temperature probes are installed at depths of 5.1cm and 30.5 cm. There is a single sensor measuring PAR (light intensity) 30.5 cm above the soil surface; and, near-surface air temperature and relative humidity are being measured 8.9 cm above the soil surface. A full complement of these sensors is located in each aspect (north/south/flat).

**RESULTS AND DISCUSSION**

**Preliminary observations**

Since data analysis is not complete, [anecdotal] observations will be presented. From an observational standpoint, there are no noticeable differences between the south- and north-facing hügel slopes in pumpkin plant size or number. However, there are obvious differences in plant size, including vine length and density, between plants in hügel beds and flat beds. Hügel beds have substantially larger plants. This may be a result of the larger amount of organic matter in the hügel beds. Organic matter, usually compost and woody material, is an intrinsic part of hügel bed construction. A post-emergent granular fertilizer 8-2-4) was applied to all flat beds on 17 June 2020 at a rate of of 89.7 kg N/ha. An identical fertilizer application was spread over the hügel beds on 18 June 2020. Soil samples were taken on 15 July 2020. In order to equalize soil nutrients, Alaskan liquid fish emulsion (5-1-1) was applied at a rate of 48.2 kg N/ha on 28 July 2020. A subsequent application of Alaskan liquid fish emulsion, at a rate of 11.2 kg N/ha, was applied to the flat beds on 7 August 2020. Fertilizer applications stimulated the plant growth of those on flat beds, but they never caught up or came to comparable sizes of the hügel beds. Based on yield data, which has not been analyzed, the hügel plots appear to perform better than the ground plots with greater total and marketable yields.

Figure 3. Juxtaposition of a south-facing hügel plot (background) and a flatbed (foreground) as of August 25, 2020.

Without the benefit of complete environmental data, there appeared to be noticeable trends in soil moisture during the summer months. Specifically, the flat beds dried out faster than hügel plots. Sunny aspects dried out faster than shady aspects. This trend began to change in mid-fall during the lettuce planting. The south-facing hügel slopes started drying out quicker than flat beds as the ambient air temperature began to decrease. During the late fall months, the ground plots, which have good drainage, retained moisture longer than south-facing and possibly the north-facing plots as well. A review of the environmental data will allow us to assess the trends from the past two growing seasons.

**Permaculture education**

KSU co-hosted a Permaculture Design Course (PDC) with Kansas Permaculture Institute (KPI) at WLSF. The PDC was a 10-day, intensive course taking place August 14-23, 2020. Participants included KSU students and community members from northeastern Kansas.

During the PDC, students learned about many permaculture design principles and took part in activities to increase their knowledge of site assessment, design, and maintenance. The hügel beds provided PDC students a hands-on learning environment working with hügelkultur. Participants weeded hügel beds and transplanted lettuce. All participants were able to spend time working in each of the aspects. Participants actually made comments that the south-side was visibly drier than north-facing slope and ground plots.

Figure 4. PDC participants planting lettuce in the hügel beds and flat beds on August 21, 2020

**CONCLUSION**

Hügelkultur may offer a novel season extension strategy. By experimenting with both warm- and cool-season crops, researchers will utilize yield and environmental data to improve our overall understanding of a hügelkultur system. Data analysis will take place in winter 2020-2021. In addition to research, the hügel beds will continue to serve as an educational tool for future PDCs, workshops, and field days.

**ACKNOLWEDGEMENTS**

Funding from KSU'S Center for Sustainable and Alternative Crops allowed us to extend WLSF's environmental monitoring capability to the hügelkultur research plots. Data collected from this system expansion will play a pivotal role in our ongoing assessment of hügelkultur as a season extension strategy. This project would not be possible without the assistance of the WLSF's Farm Manager, Regan Hale. Regan plays an essential role, assisting with numerous aspects of this project including plot construction, irrigation access and troubleshooting, harvesting, and fertilizing. Dr. Charlie Barden, Director of Geyer Forestry Center, made this project possible by providing cottonwood trees for the construction of the hügel beds. Finally, I'd like to acknowledge Amber Lehrman and Carol Barta of KPI for bringing PDC participants to WLSF.

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