K-STATE Research and Extension | Wildcat District

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Using the Heat Capacity of Soil and Water

Soil, along with vast many other uses, acts as a powerful moderator of temperature and climate. We call this volumetric heat capacity and it's the energy it takes to change the temperature of something. Soil and water have fairly high heat capacities. While engineers commonly use soil heat capacity calculations to design looped geothermal HVAC systems for houses and buildings, farmers use the soil's heat capacity and insulation to protect crops and cattle. Anyone can use the heat capacity of soil and water in our homes and greenhouses to 'regulate' temperatures from day to day and from season to season.

Soil is fairly insulative if enough is used, having an R-value between 0.25 to 0.5 per inch according to some publications. The soil temperature of the soil three feet deep anywhere in Kansas will be around 55 to 60 degrees at any point during the year, as the seasonal temperature change never reaches that far down. Even at shallow depths of just four inches, the soil can be 20 degrees warmer in the winter or cooler in the summer. The volumetric heat capacity of soil varies by how much water it currently holds, and our clay soils likely range from 1.4 to 3.0 MJ per cubic meter per degree C (MJ/m^3 C). This means it takes 3 MJ (~2800 BTUs) to increase one cubic meter of soil to one degree C. Water is 4.18 MJ/m^3 C.

While 3 MJ/m^3 C might not seem like much, it ends up being a powerful energy storage. Increasing 100 cubic yards of soil from 55F to 80F would take around 1,900 MJ of energy. It would take all the energy the average Kansas household uses in a year to heat half an acre of soil, three feet deep, the same 55F to 80F. A closed loop vertical HVAC system, the one where a plastic pipe is laid in a 5- to 6-foot-deep trench, needs to be 100 feet long per ton of cooling needed according to some publications. This means most systems could technically fit a backyard.

The heat capacity of soil is commonly used in greenhouses as most are built directly on top of the soil. In some places in the world, largely in Asian countries, huge greenhouses are built into the sides of hills. The back wall of the greenhouse collects heat during the day and then radiates that heat back out during the night. At times the greenhouse can be blanketed in a canvas to keep the heat from radiating out into the night sky. In other parts of the world, including this one, some greenhouses are built underground with only the roof above the soil surface. In both cases, care must be taken in the design to keep the walls from collapsing or water from flooding the greenhouse floor. However, this practice nearly eliminates, or at least greatly reduces, the need for supplemental heat in the places where they are built.

In Kansas, we are more likely to use soil's heat capacity and insulation when we build houses on hillsides. In above-ground houses, not so much soil, but the use of rock walls and brick chimneys is more common for some heat capacity effects. To some degree, nearly every house wall, being made of gypsum, has a heat capacity similar to air-dry clay. Of course, we prefer to keep our houses nearly the same temperature through the day and night, so there aren't big daily transfers of energy. The heat capacity of both underground houses and aboveground houses can be well complemented with good usage of solar gain through windows.

In many ways, water is easier to increase the heat capacity of a room because it is easier to move around and has a high volumetric heat capacity. A greenhouse can be lined with filled water barrels, often with boards on top to use as a table for plants. One gallon of water takes 8.33 BTUs to change one degree F, so a greenhouse with ten, 55-gallon barrels heated to 80 degrees during the day, would release 137,000 BTUs to reach 50 degrees F. That's equivalent to one and a half gallons of propane. The actual heat transfer wouldn't be perfect, but it would help considerably in moderating day-to-night temperatures.

If you have any questions about using heat capacity factors to design a house or greenhouse, it would be best to call an architect or engineer. If have any questions about soil chemistry or basic soil questions, contact me at the Crawford County Extension Office located in Girard by calling 620-724-8233.

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