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Using the Heat Capacity of Soil and Water

Soil, along with many other uses, acts as a powerful moderator of temperature and climate. Volumetric heat capacity is the energy required to change the temperature of a substance. Soil and water have fairly high heat capacities. While engineers commonly use soil heat capacity calculations to design looped geothermal HVAC systems for homes and buildings, farmers utilize 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 in our greenhouses to 'regulate' temperatures from day to day and from season to season.

Soil is fairly insulative if enough is used, with an R-value between 0.25 and 0.5 per inch, according to some publications. The soil temperature three feet deep anywhere in Kansas will be around 55 to 60 degrees at any point during the year, as the seasonal temperature change rarely reaches that depth. The soil can be 20 degrees warmer in the winter or cooler in summer, even at shallow depths of just 4 to 5 inches. 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 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 plastic pipes are laid in a 5 to 6 foot deep trench, needs to be 100 feet long for each ton of cooling needed, according to some publications. This means most systems could technically fit in a backyard.

The heat capacity of soil is commonly used in greenhouses, as most are built directly on top of 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 covered with a canvas to prevent 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 prevent the walls from collapsing and to prevent water from flooding the greenhouse floor. However, this practice nearly eliminates or can greatly reduce the need for supplemental heat in the places where they are built.

In Kansas, we are more likely to utilize the soil's heat capacity and insulation when building houses on hillsides. In aboveground houses, rather than soil, the use of rock walls and brick chimneys is more common due to their 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 above-ground houses can be well complemented with the effective use of solar gain through windows. This can be complemented with solar energy heating cement or stone walls and floors to retain that heat into the night (thermal lag). The heat capacity of cement is 1.2 to 2.2 MJ/m^3 °C, depending on the water content of the cement, and around 1.5 MJ/m3 °C for brick.

In many ways, water is easier to increase the heat capacity of a room because it is more easily moved 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 near that 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 you have any questions about soil chemistry or basic soil questions, I'd be more able to help. Reach me at the Girard Extension Office at 620-724-8233.

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