What is variable rate irrigation?
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What is the problem?
The adoption of irrigation in South Carolina has increased considerably in recent years, mostly in response to recent drought periods, combined with relatively high commodity prices. This is at a time when public concerns and legal requirements about water resource conservation are also increasing. Farmers are under increasing pressure to produce more crop with less water, while protecting the environment, to meet the needs of an ever increasing population. Farmers need new technologies to minimize farm inputs, like water and fertilizers, while sustaining or increasing crop yields and quality. Precision application of farm inputs where, when, and in the amount needed is critical to achieve sustainable agricultural systems.

For row crop production, sprinkler irrigation systems, usually with center pivots (CP), are the most common systems in the state, accounting for around 89% of irrigated acres. However, CP systems usually apply a relatively uniform amount of water to inherently variable fields. Variable irrigation application may be required to address variable soil types, topographies and crops, in addition to addressing other issues like irregularly shaped fields, overlapping CP systems, farm roads and canals, etc. Soils in South Carolina are particularly variable and although they are grouped into 13 general soil types, there is a total of 159 soil associations (Fig. 1). Therefore, it is common to find multiple soil types under a center pivot. Figure 2 shows an electro-conductivity (EC) map of a soil irrigated by a center pivot in South Carolina, with lighter areas representing sandier soils and darker areas, heavier soils. In this case, at least three distinct soil types are shown under the pivot. Applying uniform irrigation with this pivot would mean that some areas may be over irrigated while others may be under irrigated, which could result in lower overall yields and waste of water by runoff and deep drainage.

What is the solution?
The solution to this problem lies in matching field variability with an equally variable irrigation application. The technology to do this is known as Variable Rate Irrigation (VRI). VRI technology works by applying irrigation water based on specific water needs of individual management zones, rather than applying a uniform rate across an entire field. By optimizing water application, the use of VRI can potentially save millions of gallons of irrigation water while increasing both crop yield and quality. To do this, VRI systems are capable of controlling the amount of water applied through individual or through a group of sprinkler heads along the length of the pivot. The area under the pivot can then be divided into irrigation management zones, based on soil texture, soil topography, or any other relevant property as shown in Fig. 3. If zones are based on soil texture, this can be done by using existing soil maps or more precisely by
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Mapping the field using a VERIS machine (Fig. 4). This machine measures EC, which relates to soil texture.

What are the components of a VRI systems?

A VRI system may include the following components: (1) pivot control panel, (2) VRI control panel, (3) Solenoid valves, (4) Control nodes, (5) GPS system, (6) variable frequency drive, and (7) remote control system.

Similar to a pivot without VRI capabilities, the Pivot Control Panel controls the start/stop of the pivot and the travelling speed. The VRI control panel, on the other hand, controls operations inherent of the VRI system itself, including controlling irrigation application rate in response to a stored irrigation management map and the current pivot location (Fig. 5). Solenoid valves are used to control flow to the sprinkler heads. The Solenoids are controlled by the Control Nodes, which determine what percent of the time the valves are open/close. There are many Control Nodes along the length of the center pivot, with each Control Node controlling several valves. The Control Nodes receive commands from the VRI control panel. Inputs from a GPS system located near the end of the center pivot allows the VRI control panel to determine the position of the pivot in the field.

Since water flow to some (or all) of the sprinkler heads at a given time may be reduced or totally cut off, the instantaneous flow rate required by the center pivot would be correspondingly reduced. If the pump is supplying a nearly constant flow rate, excess water flow and pressure could result, which would need to be released, which could result in potential waste of water and/or energy. An alternative, is to install a Variable Frequency Drive
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Figure 8. Variable Frequency Drive (VFD). (VFD) at the pump (Fig. 8) to automatically adjust the pumping flowrate and pressure by controlling the rotation speed of the pump impeller. The VFD receives input from a pressure switch installed on the pump outlet pipe and keeps the water pressure stable within pre-set maximum and minimum thresholds, saving water and energy.

An optional component of a VRI system is to install a Remote Control System, which allows viewing and controlling the operation of the center pivot and the pump using the Internet, via a smart phone or a computer. For this, different systems based on radio, cell phone, or satellite communication are currently available. Additional hardware, like antennas and radio receivers, would need to be installed at the pivot and pump to allow remote communication (Fig. 10).

The VRI system described above represents a system with electrically activated solenoid valves. However, there are systems that activate the solenoid valves using pneumatic (air) pressure instead of electricity. In addition to the components described above, the pneumatic systems typically require an air compressor and small-diameter tubing to provide compressed air to activate each of the solenoid valves (Fig. 11).
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Different commercial VRI systems are available from center pivot manufacturers and other suppliers (i.e., Valley, Reinke, Zimmatic). The cost can be significant and varies widely depending on each particular situation. For example, in 2004, a total of 32 systems were installed in Georgia, South Carolina, Florida, and Arkansas to demonstrate VRI technology. The average pivot size was 1463 ft, covering 155 acres, with 138 of those acres cropped and 17 acres non-cropped. The average installation cost at that time was $21,379.

Farmers should consider that the economic viability of VRI technology depends on the size and variability of the field and the potential energy and water savings and yield increases that can realistically be achieved. Some fields are sufficiently uniform that investing in VRI would not pay off, while others can take full advantage of this technology and achieve significant water and energy savings and increases in overall yields and profits. They should also be aware that VRI technology is one of the practices supported by NRCS-EQIP. Therefore, eligible farmers could obtain cost share money to pay for part of the cost of the system.

The mission of the Irrigation Water Management program at Clemson University is to develop advanced irrigation technologies and educate farmers on how to improve irrigation water management to increase farm profitability and environmental sustainability in South Carolina.

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Figure 11. VRI system with pneumatic solenoid valves, showing the air compressor and tubing.