New Satellites for Soil Moisture: Good for Iowans!

Brian K. Hornbuckle
Department of Agronomy
Iowa State University of Science and Technology
bkh@iastate.edu

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My wife recently asked “Do we still need rain?” Unfortunately we don’t really know the answer to this question here in Iowa! We can compare the year-to-date amount of precipitation with Iowa climate, but it won’t tell us how much of that water was captured by the soil and thus the current amount of soil moisture available to support the row-crop agriculture that dominates our state.

Take 2013 as an example. After a record-setting wet spring was followed by another dry summer, we may be at near-normal levels of annual precipitation, but we do not know the fraction of water that actually infiltrated into the ground and was not lost as run-off into rivers, lakes, and streams.

In addition to providing crops with water, soil moisture also plays a large role in the timing and amount of precipitation through its influence on the water and energy budget at Earth’s surface (e.g. Findell and Eltahir, 2003). Water evaporated from the soil and transpired by plants transfers energy from Earth’s surface to the atmosphere, increases the humidity, and subsequently influences the likelihood of precipitation.

Currently we enter each growing season “blind” as to whether or not there will be enough soil moisture and precipitation to support productive crops. If we could keep a running inventory of the water stored in Iowa soils, and if we had better weather forecasts that extended farther into the growing season, farmers could make decisions on what to plant (a drought-tolerant hybrid?), crop management (increase plant-density?), nutrient management (when to apply nitrogen?), and soil management (reduce tillage to keep as much water in the soil as possible?) in order to maximize yield. Public and private entities that support farmers would also benefit.

The ability to keep track of soil moisture will likely become more important in the future. Wetter springs are expected to become more common in Iowa, but so is the occurrence and severity of drought (Hatfield and Takle, 2014). Despite increases in mean temperatures, water availability will continue to be the most important factor in crop production (Hatfield et al., 2011).

Besides allowing us to better predict crop productivity and make improved forecasts of weather, knowing the current state of soil water would also help address two other issues that are important to our state. When its moisture content is high the soil cannot absorb much more water. Run-off causes flooding and often carries with it eroded soil and chemicals that pollute our bodies of water. If we knew more about soil moisture, it would be good for Iowans!
Figure 1: At left, the European Space Agency’s Soil Moisture and Ocean Salinity (SMOS) satellite mission. At right, data from a single pass of the SMOS satellite over the Midwest U.S. Wet soils are marked by cool colors, dry soils by warm colors.

Fortunately we are at the beginning of a new era of soil moisture observations that will be obtained by satellites orbiting Earth. The first global maps of near-surface soil moisture are now being produced about every-other day by the European Space Agency’s Soil Moisture and Ocean Salinity (SMOS) mission (Kerr et al., 2010). An artist’s rendition of the SMOS satellite and an example of SMOS soil moisture is shown in Figure 1. Launched on November 1, 2009, the SMOS satellite is a giant step forward from previous satellites because of its ability to “see through” vegetation and observe the soil, even under the tall corn of Iowa.

Soil moisture can be defined as the water stored in soil that is available to plants and hence exchanged between the land surface and the atmosphere via evaporation, transpiration, and precipitation. This water resides in the root–zone of plants, about the first 1 to 2 m of the soil. Near-surface soil moisture is the water held in the first 3 to 5 cm of the soil that can be sensed via satellite. Soil moisture can be estimated from frequent observations of near-surface soil moisture through the use of models (e.g. Calvet and Noilhan, 2000).

The SMOS satellite carries an instrument which is essentially a special type of camera that is able to record the microwave radiation (and not the visible radiation that our eyes can see) naturally emitted by Earth’s surface. This is an example of passive remote sensing, which contrasts with active remote sensing techniques like weather radars that produce their own radiation and record the radiation scattered back. The microwave radiation emitted by land surfaces changes depending on their moisture content. Wet soils emit less microwave radiation than dry soils. Models that relate the microwave radiation measured by satellites to near-surface soil moisture have been developed (e.g. Wigneron et al., 2007).

An example of the quality of SMOS soil moisture is shown in Figure 2. Focus on
Case study: soil moisture change in 2012.

Figure 2: A change in near-surface soil moisture observed by the SMOS satellite following a significant rain event during the summer drought of 2012.

Page County in Southwest Iowa (the second county from the western border in the bottom row of counties). According to SMOS, near-surface soil moisture was very low, about 5% by volume, at 7 pm local time on August 24, 2012, consistent with drought conditions in this area.

Between 7 pm on August 24 and 7 am the next morning, August 25, a significant amount of rain fell in this region. The National Weather Service reported 68 mm at a maximum rate of 14 mm per hour at one location within Page County. If initial near-surface soil moisture was indeed 5% and if all of this rain infiltrated into the first 20 cm of the soil, then a simple water balance gives a resulting soil water content at 7 am of about 40%. The SMOS soil moisture product at 7 am on August 25 has a value between 40 and 45%, as expected.

My research group has tested SMOS data in other ways and found that it is performing as expected. Google “Iowa SMOS data” if you would like to look at the data yourself.

In the coming year an additional soil moisture satellite will begin orbiting Earth. NASA’s Soil Moisture Active Passive (SMAP) mission is scheduled to be launched on November 5, 2014. A picture of the SMAP satellite is shown in Figure 3. SMAP will use both passive and active microwave remote sensing to improve the spatial resolution of near-surface soil moisture observations from about an Iowa county for SMOS (≈ 40 km), to about an Iowa township (≈ 10 km), the scale at which future global circulation models will be used to make weather and climate predictions (Entekhabi et al., 2010).

What work is left to do? Quite a bit. In order to maximize the benefit of these new satellite missions, the products that they deliver must be validated: that is, the near-surface soil moisture observations must be compared to a “standard.” The simple analysis performed with Figure 2 is not rigorous enough. Validation will be conducted using instruments that directly sample near-surface soil moisture in carefully designed field experiments.

We also believe that the current algorithms used by SMOS and SMAP to translate observed microwave radiation into near-surface soil moisture must be modified in order to account for changes in the roughness of the soil surface caused by tillage that can “confuse” the satellites (Patton and Hornbuckle, 2013).

Once satellite algorithms have been improved and validation is accomplished, I believe that regional water balance models consisting of atmospheric and land surface mod-
els, along with schemes that incorporate real-time information regarding soil moisture, river levels, precipitation, and atmospheric conditions, will be created within the next decade. Such a system would be able to give estimates of current and future land surface water conditions, including soil moisture. Then it would be up to us to use this information to make decisions, and as a tool to test actions that Iowans could take to ameliorate the impact of future droughts, floods, and other types of climate variability.

*It will be good for Iowans!*

**References**

Calvet, J.-C., and J. Noilhan (2000), From near-surface to root-zone soil moisture us-


