

## INTRODUCTION

The ability to make more water available for domestic, agricultural, industrial and environmental uses will depend on better management of water resources, watersheds, and storm water runoff. To determine the quantity of runoff from a given watershed, several key pieces of information such as the soil moisture or antecedent moisture condition and surface storage must be accurately known. Recently NASA scientists have developed a new technique (modified GPS Delay Mapping Receiver -- DMR) which operates by recording the GPS signal reflected from the earth's surface and can be used to estimate the surface soil moisture. The DMR tracks and measures both direct Right-Hand\_Circularly Polarized (RHCP) GPS signal and reflected Left-Hand\_Circularly Polarized (LHCP) GPS signal at 1.575 GHz frequency (Figure 1).

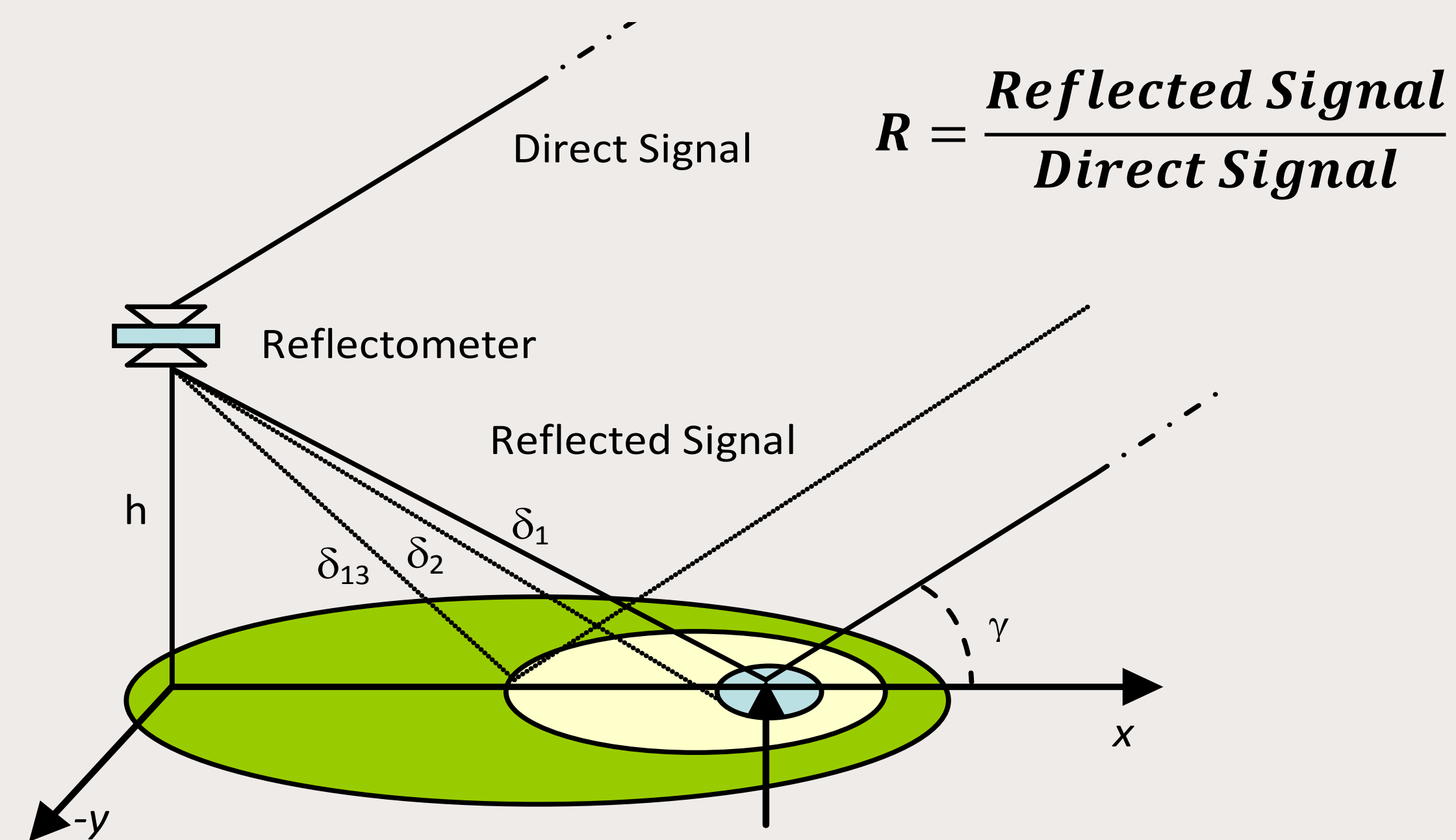


Figure 1. GPS signals transmitted from a satellite, scattered from the land surface, and then received by DMR.

The DMR system have been tested by NASA scientists at several different locations. Masters et al. (2004) has used this technique to detect surface soil moisture changes 12 hours and 10 days after rainfall, as shown in Figure 2 (yellow indicates high reflectivity, red indicated low reflectivity.)

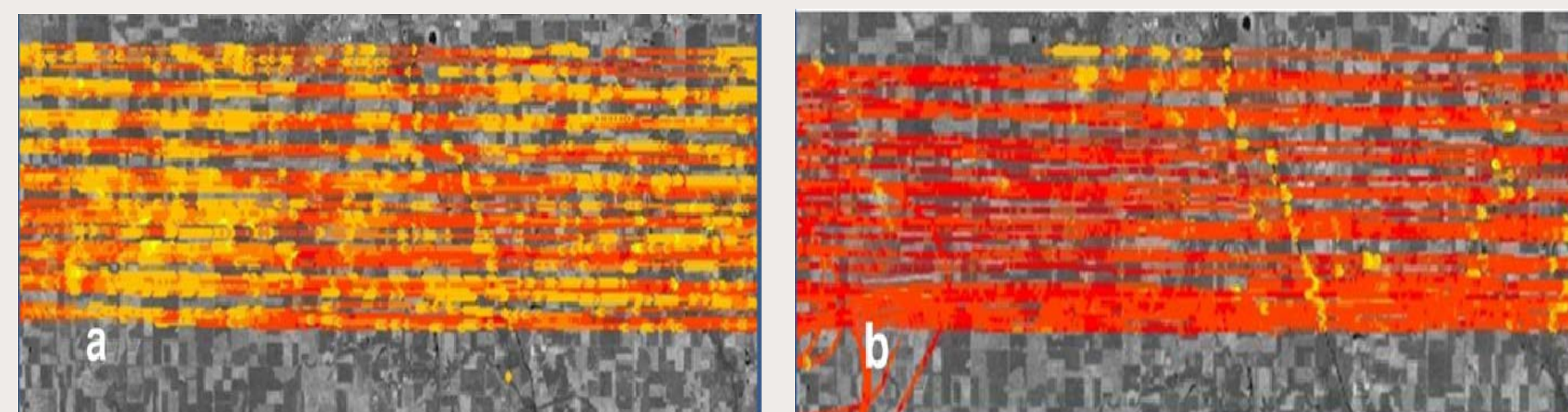


Figure 2. Reflectivity collected 12 hours (left) and 10 days after rainfall (right).

Our overall objective was to investigate the feasibility of utilizing reflected GPS satellite signal to determine soil moisture content. Replicated tests have been conducted in the last four years at Edisto Research & Education Center to determine correlations between measured soil moisture contents and GPS reflectivity values under various soil textures and ground cover conditions. Our results have shown that this space-based technology has great potential for determining soil moisture contents.

## FIELD EXPERIMENTS

Tests were conducted in a field with three different soil types -- Faceville, Fuquay, and Lakeland (Figure 3). DMR was mounted on a hi-boy sprayer for collecting GPS reflectivity data (Figure 4). Soil samples were collected at different depths in all plots to determine soil moisture contents. Also, plant samples were collected and oven dried to determine plant water contents and biomass. Correlations between soil moisture contents and GPS reflectivity values as affected by soil type and ground cover were determined.

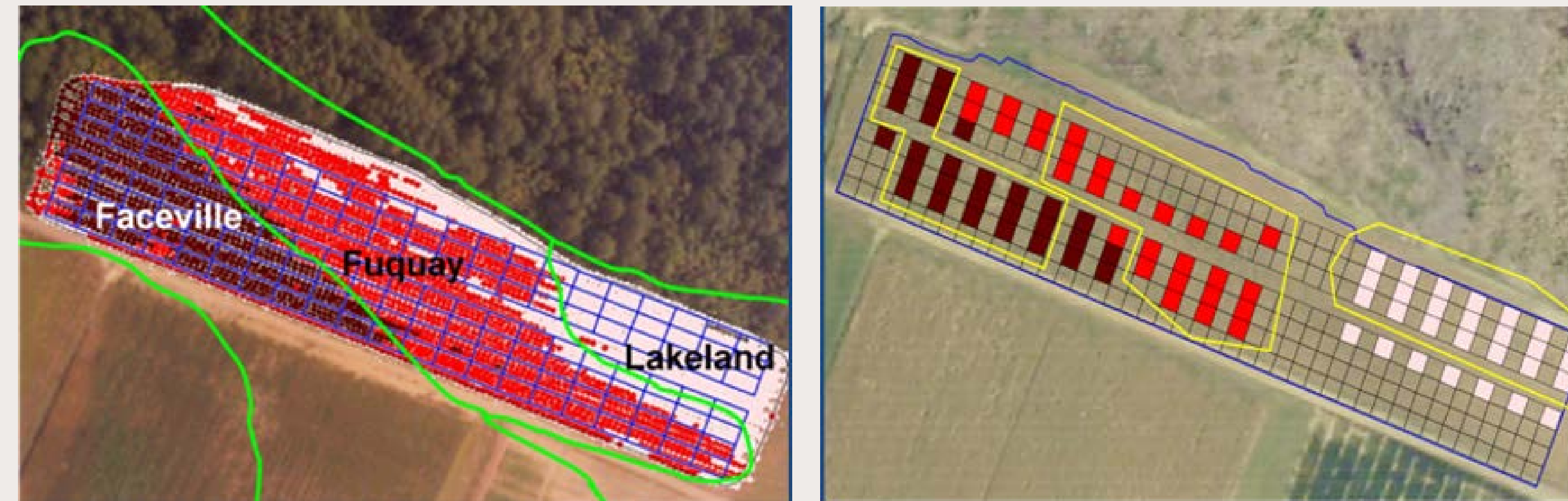


Figure 3. Test field with three soil types (left) and actual plot design (right).



Figure 4. Hi-boy mounted DMR collecting data from bare soil (left) and cotton field (right).

## RESULTS

As shown in Figure 5, GPS reflectivity values could correlate with soil moisture contents at all depths. However, R<sup>2</sup> decreased as the sampling depth increased, possibly due to less GPS signal penetration at deeper depths.

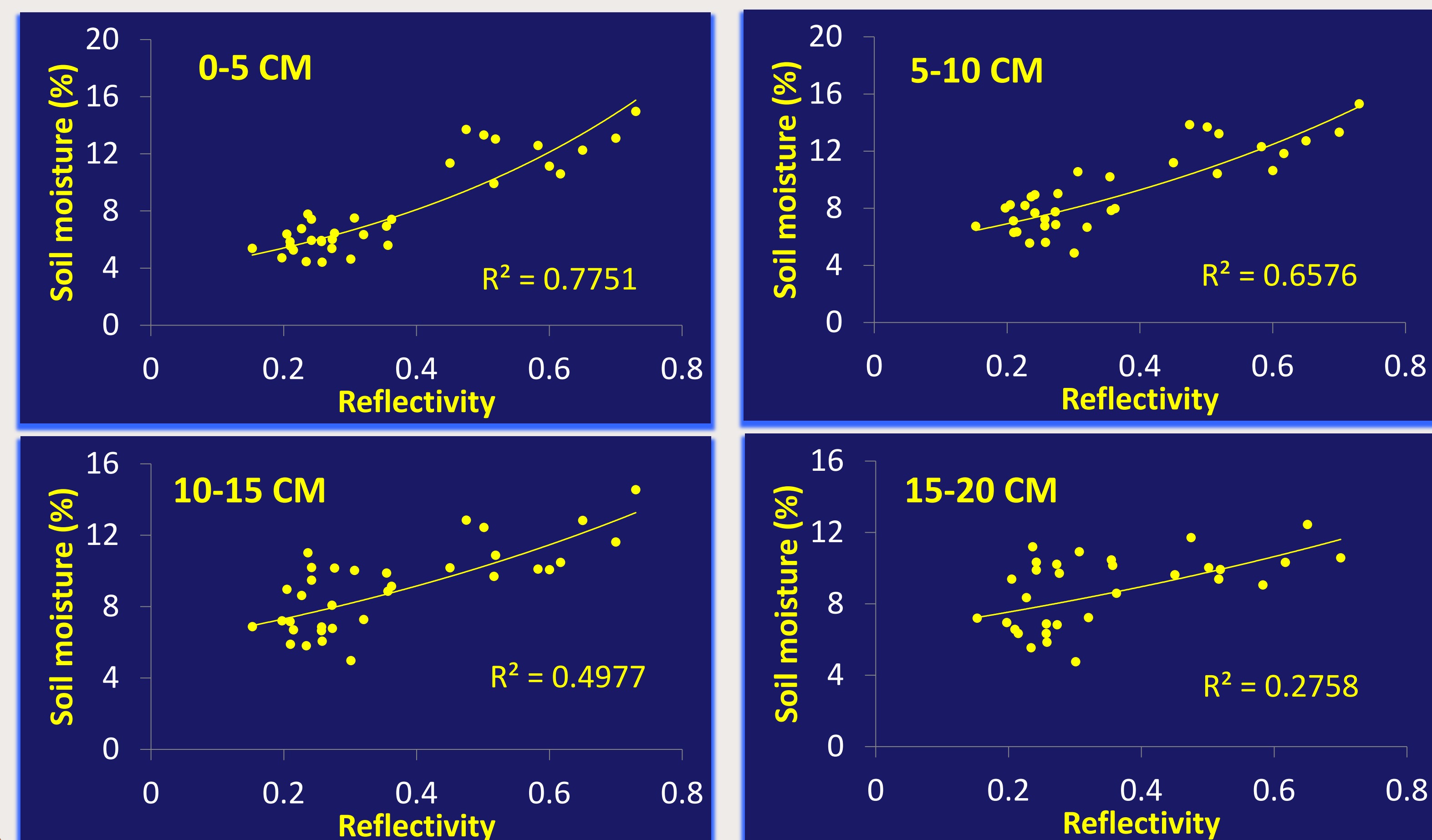


Figure 5. GPS reflectivity values versus soil moisture contents at different depths.

## RESULTS CONTINUED

There were strong positive correlations between GPS reflectivity values and soil moisture contents in all three soil types (Figure 6). However, soil type did not affect GPS reflectivity values. It was also found that ground cover could attenuate GPS signals, as shown in Figure 7.

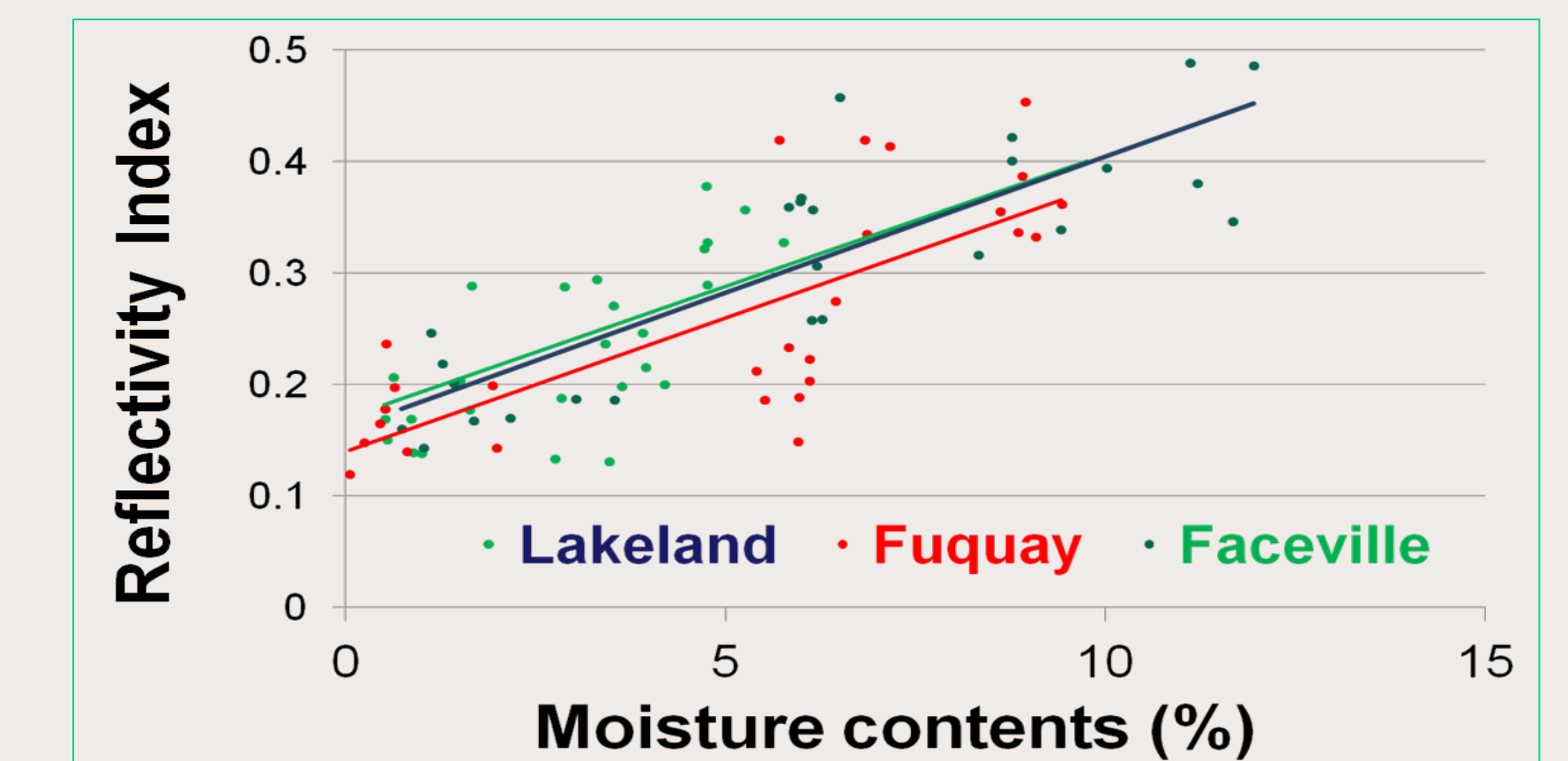


Figure 6. Relationship of reflectivity values and soil moisture contents as affected by soil type: Lakeland, Fuquay, and Faceville.

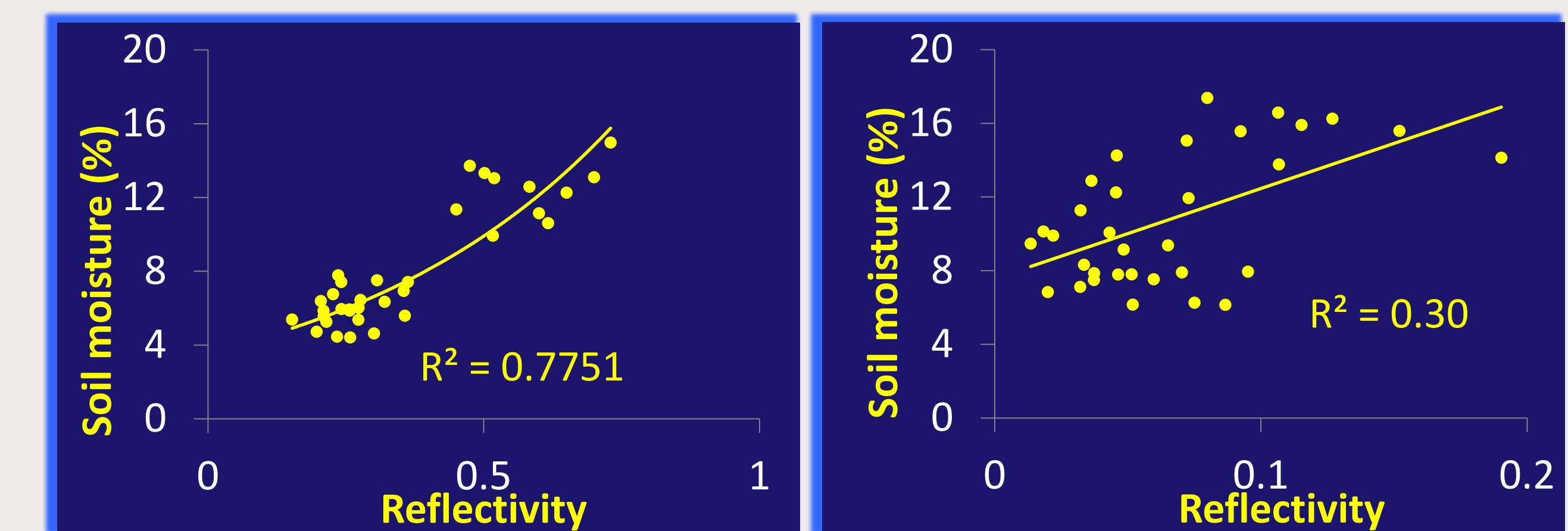


Figure 7. Soil moisture versus GPS reflectivity values under bare soil (left) and cotton field (right)

## CONCLUSION

- ❖ GPS reflectivity could be used to detect soil moisture contents at different depth. However, the relationship decays with increasing depth.
- ❖ GPS reflectivity was not significantly affected by soil type.
- ❖ Plants could attenuate GPS signals, which needs to be further studied.

## REFERENCES

Masters, D., Axelrad, P., & Katzberg, S. (2004). Initial results of land-reflected GPS Bistatic radar measurements in SMEX02. *Remote Sensing Environ.* 92 (4): 507-520.

## ACKNOWLEDGEMENTS

The authors acknowledge the support of the NASA Langley Research Center.