基于多频 SAR 数据探测中国山西省玉米成熟期的植株含水量

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玉米是世界上种植最广泛的农作物之一，在农业生产中占据着重要的地位。监测成熟期玉米的水分和干物质重量非常必要，不仅可以掌握玉米最佳产量的收获时间，而且可以改善收获期农业机械的管理，特别是通过种植户间共享农机资源提高收获效率。由于对植被含水量敏感，SAR 遥感可以为其大范围监测植被水分含量提供一种经济有效的方法。本研究旨在评估利用多频（C 和 X 波段）SAR 反向散射数据反演成熟期玉米植株水分含量方法的可行性。基于如上目标，2023 年夏末在中国山西省进行了为期 5 周的田间调查，每周 1 次实施了 4-5 次的数据采集，观测了 5 个地块的玉米鲜重、植物含水量、播种密度、BBCH（生育期）和株高，获得了 22 项观测数据。利用线性回归分析评估 SAR 反向散射对植物水分含量（玉米穗、茎叶和整体）的敏感性。结果表明，在生长季末期 TerraSAR-X 和 Sentinel-1 监测玉米植株含水量的能力较弱，但 C 波段交叉极化 VH 数据表现出最高相关性（玉米穗 R=-0.55，植株 R=-0.53）。利用随机森林算法回归分析 SAR 数据和原位观测数据之间的非线性关系，但一折交叉验证结果 (R^2=0.24)较差，表明该方法并不适用于植物水分含量的反演。分析此结果的原因可能包括以下两点。首先，由于该区域的地块较小，雷达数据的斑点噪声影响了雷达测量的代表性。其次，随着观测期间植物含水量逐渐降低，C 和 X 波段的 SAR 在高生物量条件下穿透能力下降，导致了信号饱和。

Monitoring the Plant Water Content in Senescent Maize using Multifrequency SAR Data, in Shanxi Province, China

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Maize is one of the most widely grown crops in the world, and plays a major role in farming operations. Monitoring the water and dry matter content of maize crops reaching their final stage of development is essential not only to ensure optimum crop yields, but also to improve harvest logistics by facilitating the sharing of mechanical resources between multiple small landowners. SAR remote sensing, thanks to its sensitivity to vegetation water content, can provide a cost-effective approach to its large-scale monitoring.

The present study aims to evaluate the feasability of a plant water content retrieval method in senescent maize crops from multi-frequency (C- and X-band) SAR backscatter data. To accomplish the stated objective, a 5-week field campaign was conducted in the Shanxi province, China, at the end of the summer of 2023. Wet biomass, plant water content, sowing density, BBCH, and plant height were measured in five maize parcels. Fields were visited four to five times, around one-week apart, resulting in 22 observations.

A linear regression analysis was used to assess the sensitivity of SAR backscatter to the plant water content (in cobs, plants, and both). It pointed to the fact that TerraSAR-X and Sentinel-1 might have too little capacity for monitoring maize at the end of the growing season, in the conditions of the campaign. The highest correlations were observed for C-band data in cross-polarization VH (R=-0.55 for cobs and R=-0.53 for plants). A random forest regressor was implemented to capture the non-linear relationship between SAR and in situ data, but poor leave-one-out cross-validation results (R2=0.24) demonstrated the ineffectiveness of the method for plant water content retrieval.

Several factors may have contributed to this outcome. Primarily, the small size of the parcels in the region posed a significant challenge due to the speckle effect limiting the representativity of the radar measurements. Furthermore, the reduced penetration abilty of C- and X-band SAR in high-biomass crops, such as maize, might have led to signal saturation during the entire observation period, in spite of decreasing plant water content.