Potential and limits of new technologies for agricultural statistics

An analysis of crop area statistics in times of synoptic, multi-sensor high accuracy crop mapping

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Crop type mapping has taken a huge leap since the introduction of full, free and open high resolution data from the European Union's (EU) Copernicus Sentinel-1 and -2 and the United States Landsat sensors. Combined with big data analysis platforms and rapid progress in machine and deep learning (MDL) techniques this has led to the routine production of high accuracy synoptic crop map products with consistency at continental scale. The recent release of the Copernicus High Resolution Vegetated Land Cover Characteristics (HR VLCC) service includes a crop type (CTY) layer for the EEA38 countries. A key element of the CTY layer is that it is largely based on applied MDL to time series of features extracted from both the multispectral Sentinel-2 and microwave Sentinel-1 sensors. The MDL models are trained, tested and validated with extensive ground truth data. The latter include multi-annual full country features coverages of Common Agricultural Policy (CAP) arable crop declarations filed through the national GeoSpatial Aid (GSA) applications. GSA features typically outline the agricultural areas for which, among other, an annual crop cultivation is registered as an attribute. The annual GSA set is usually available to authorities responsible for EU CAP monitoring and control towards the end of May of the current year. Increasingly, the finalized GSA data are released in anonymized form as open data. We can, thus, create full country crop maps directly from GSA and derive crop area estimates through simple aggregation. This method is already applied by various National Statistical Offices.

The availability of HR VLCC CTY and the GSA reference sets offers a unique opportunity to revisit statistical assumptions behind crop area estimates, whether derived from sampling survey approaches proposed in literature, and applied in practice (e.g. TERUTI, LUCAS) or from regressions applied to the CTY results. CTY is currently available for the period 2017-2023. We have access to the GSA open data sets from Denmark, the Netherlands and France as test cases. Since we can substitute GSA sets with their matching CTY layers, we can enumerate the impact of residual classification noise on crop area estimates, i.e. test the equivalent of "pixel counting" and the effects of (c)omission. In a next step, we apply (stratified) sampling grids to the national coverages to test the performance of statistical regression estimators that have been proposed in literature. Finally, we conclude on the suitability of "pixel counting" for crop area estimation and extrapolate our findings to the need to estimate subtle annual change in crop area, which is expected to be a major contribution of the HR VLCC CTY data use in future Common Agricultural Policy indicator frameworks especially if error sources are properly understood and accounted for.

The impact of map accuracy on area estimation with remotely sensed data using a stratified random sampling design

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One of the core applications of satellite-based classification maps is area estimation. Regardless of the algorithms used, maps will always contain errors stemming from imperfect input and training/calibration data, incomplete data coverage, and spectral and/or temporal confusion between land cover and land use classes. Because of omission and commission errors, the pixel-counting area estimator will be a biased estimator for area estimation. Therefore, the remote sensing research and application communities have developed a framework and recommended practices to address this problem. One such approach is a stratified random sampling design, in which classification maps could be used for stratification in the sampling design, and areas are estimated from the sample data, which represent reference data or reference class labels. As such, the quality of the map, i.e., producer's (PA) and user's accuracy (UA), will not affect the bias of the estimator, as the bias depends on the sampling design and the choice of estimator. However, map quality will impact the efficiency of stratification: a more accurate map will require a smaller sample size to reach the target variance of the estimate, or it will yield improved precision if the sample size is fixed. This study aims to provide a quantitative assessment of the impact of map accuracies on area estimation within the stratified random sampling design. The relative bias of the pixel counting estimator is expressed using class-specific PA and UA, and shown to be PA+-1. Furthermore, for the case of binary classification, elements of the confusion matrix, as well as the sample size, variance of the area estimator, and relative efficiency of stratification (the ratio of the products of variance and sample size for the two sampling approaches) are expressed using PA and UA. Numerical simulations demonstrate how relative efficiency depends on area estimation objectives, target area proportion, and the map's performance metrics (PA and UA). Such dependence is nonlinear, and the impact of those parameters varies. For example, when the target class is minor or rare (i.e., its true proportion is <<0.5), the impact of PA outweighs that of UA. As the target area proportion increases, the impact of accuracies converges, and UA has a greater impact on efficiency than PA. There are multiple values in the PA/UA space, though constrained, to reach the same objectives, e.g., in terms of relative efficiency, sample size, and target variance. Overall, this study offers map producers a criterion that can be used to benchmark algorithm performance for map generation when area estimation is the primary objective of the classification maps.

Rapid Crop area Estimates combining an area frame survey with Satellite image analysis for Moldova

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The main objective of the Copernicus service Copernicu4GEOGLAM is to provide ad-hoc baseline crop monitoring information including crop-type mapping and area estimates during and at the end of the growing season. This is achieved by implementing a field campaign during the growing season based on a an area frame probabilistic stratified sampling design taking into account the crop growing condition in the country. The objective of the field campaign is twofold: to provide training and validation data for the satellite image thematic classification, and to produce accurate and unbiased area estimates for the most important crops grown in the country. The sample consists of 100 PSUs located in three strata. Seven PSUs were excluded from the survey as they were photo-interpreted as being completely non-agricultural. No PSUs were excluded due to inaccessibility. Out of the 2,300 SSUs in the initial sample, 1451 SSUs were observed with cropland and 849 as non-agricultural. The CVs (Coefficient of Variation or Relative Sampling Error) are relatively high, which is not surprising given the small sample sizes. The stratification efficiency for the overall class “cropland,” including all agricultural land uses and permanent crops, was 1.46. This higher value is expected because the stratification itself was designed to optimize the separation of cropland from non-cropland. When evaluated for the broad target variable it was built for, the design achieves its best performance. By contrast, the efficiency for individual crops is lower, since their occurrence within cropland is more heterogeneous and was not the primary target of the stratification. Differences from the reference data provided by NBSM 2024 are relatively high but remain within the 95% confidence interval (= 1.96 × CV). Sugar beets, one of the crops of interest, are absent because this crop was not observed at all.

Three Quarter of the field observations were used to train a crop type classification based on Sentinel 1 & 2 data whilst the rest was used to assess the quality of the classification. Very high classification accuracies were achieved (greater than 90% on average) for the main crops of interest. The resulting crop type classification was combined with crop proportional PSU level to develop Model Assisted Regression (MAR) crop area estimation approach to use the exhaustive coverage of the crop type map to reduce the uncertainty of the estimates based on the field data alone. The resulting MAR Estimates are much improved thanks to the high quality of the crop type masks with most crops of interest with CV at national level close or lower than 20%. For Maize, sunflower and wheat the CV is less than 5% whereas it was over or close to 15% based on field data alone

Exploring performance of machine learning models for delineation of parcel boundaries: Application to Ukraine

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The accurate delineation of agricultural field boundaries from satellite imagery is vital for land management and crop monitoring. However, current methods face challenges due to limited dataset sizes, resolution discrepancies, and diverse environmental conditions. We address this by reformulating the task as instance segmentation and introducing the Field Boundary Instance Segmentation - 22M dataset (FBIS-22M), a large-scale, multi-resolution dataset comprising 672,909 high-resolution satellite image patches (ranging from 0.25 m to 10 m) and 22,926,427 instance masks of individual fields, significantly narrowing the gap between agricultural datasets and those in other computer vision domains. We further propose Delineate Anything, an instance segmentation model trained on our new FBIS-22M dataset. Our proposed model sets a new state-of-the-art, achieving a substantial improvement of 88.5% in mAP@0.5 and 103% in mAP@0.5:0.95 over existing methods, while also demonstrating significantly faster inference and strong zero-shot generalization across diverse image resolutions and unseen geographic regions.

Satellite imagery-based delineation of land use categories for use in a Land Parcel Identification System (LPIS) in Ukraine

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This work advances compliance with EU Common Agricultural Policy (CAP) requirements by developing a high-quality Land Parcel Identification System (LPIS) within an Integrated Administration and Control System (IACS). Building on prior pilots, the current effort evaluates two complementary satellite datasets—0.3 m Very High Resolution (VHR1) and 0.7 m Very High Resolution (VHR2)—across selected municipalities to assess cost-effective pathways for nationwide deployment where airborne ortho-imagery is unavailable. The workflow encompasses radiometric preparation, manual on-screen delineation of five CAP-eligible land use categories (arable land, permanent crops, permanent grassland, agro-forestry, and personal farming), strict adherence to EU eligibility specifications and best-practice guidelines, and automated image-segmentation–based parcel delineation. Emphasis is placed on aligning parcel boundaries with stable physical features to meet the EU's 0.5 m positional accuracy standard, supported by iterative internal checks and external expert reviews to ensure completeness, consistency, topology, spatial precision, and thematic correctness.

Cross-comparison shows that VHR1 reliably supports sub-meter delineation accuracy, while VHR2 can meet standards with targeted manual refinement and rigorous validation, offering a cost-efficient option under acquisition constraints. The approach also integrates Sentinel-1/2 time series and super-resolution techniques to improve eligibility determinations where features are narrow or irregular. While satellite VHR adoption faces challenges—limited capacity for large-area acquisitions under strict viewing and cloud constraints, and additional constraints on data distribution—the findings demonstrate the technical feasibility of an EU-compliant LPIS using a combined manual/automated approach and structured validation. The resulting methodology provides guidance for achieving 0.5 m accuracy and integrating multi-sensor data, with scalability contingent on improved satellite tasking and homogeneous quality parameters for national rollout.