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# Evaluating an ensemble classification approach for crop diversity verification in Danish greening subsidy control

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ABSTRACT

Beginning in 2015, Danish farmers are obliged to meet specific crop diversification rules based on total land area and number of crops cultivated to be eligible for new greening subsidies. Hence, there is a need for the Danish government to extend their subsidy control system to verify farmers' declarations to warrant greening payments under the new crop diversification rules. Remote Sensing (RS) technology has been used since 1992 to control farmers' subsidies in Denmark. However, a proper RS-based approach is yet to be finalised to validate new crop diversity requirements designed for assessing compliance under the recent subsidy scheme (2014–2020); This study uses an ensemble classification approach (proposed by the authors in previous studies) for validating the crop diversity requirements of the new rules. The approach uses a neural network ensemble classification system with bi-temporal (spring and early summer) WorldView-2 imagery (WV2) and includes the following steps: (1) automatic computation of pixel-based prediction probabilities using multiple neural networks; (2) quantification of the classification uncertainty using Endorsement Theory (ET); (3) discrimination of crop pixels and validation of the crop diversification rules at farm level; and (4) identification of farmers who are violating the requirements for greening subsidies. The prediction probabilities are computed by a neural network ensemble supplied with training samples selected automatically using farmers declared parcels (field vectors containing crop information and the field boundary of each crop). Crop discrimination is performed by considering a set of conclusions derived from individual neural networks based on ET. Verification of the diversification rules is performed by incorporating pixel-based classification uncertainty or confidence intervals with the class labels at the farmer level. The proposed approach was tested with WV2 imagery acquired in 2011 for a study area in Vennebjerg, Denmark, containing 132 farmers, 1258 fields, and 18 crops. The classification results obtained show an overall accuracy of 90.2%. The RS-based results suggest that 36 farmers did not follow the crop diversification rules that would qualify for the greening subsidies. When compared to the farmers' reported crop mixes, irrespective of the rule, the RS results indicate that false crop declarations were made by 8 farmers, covering 15 fields. If the farmers' reports had been submitted for the new greening subsidies, 3 farmers would have made a false claim; while remaining 5 farmers obey the rules of required crop proportion even though they have submitted the false crop code due to their small holding size. The RS results would have supported 96 farmers for greening subsidy claims, with no instances of suggesting a greening subsidy for a holding that the farmer did not report as meeting the required conditions. These results suggest that the proposed RS based method shows great promise for validating the new greening subsidies in Denmark.



## 1. Introduction

The Common Agricultural Policy (CAP) has undergone successive reforms since it was launched in 1962 with focus on viable food production, sustainable management of natural resources and climate action and balanced rural development across the European Union (EU) (Monitoring Agriculture with Remote Sensing (MARS) unit, 2002). Various schemes have been proposed to provide income support for farmers to encourage them to address these objectives and to increase the market orientation for agriculture. To obtain the payment/subsidy, farmers are required to submit their annual subsidy applications in a prescribed form and by dates in accordance with the regulations of each member state.

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Since 1992, the EU introduced a control of the subsidy applications. Each member state follows different approaches to validate or control these applications and sanction the subsidy to eligible farmers.

The CAP underwent reform in 2013, with the aim of attaining higher levels of safe and high quality food production, while preserving the natural resources that the agricultural productivity depends on over the long term. The new CAP 2014–2020, moving to a more land-based approach, is said to be more efficient and flexible. Also, it is targeted on cross-compliance with compulsory basic environmental requirements and obligations to be met by the EU farmers in order to receive full CAP funding (Directorate-General for Agriculture and Rural Development (DGARD), 2013). Owing to this reform, the member states are forced to adapt their existing subsidy control system to validate the new rules required for farm subsidies. From 2015 onwards, the Basic Payment Scheme (BPS) replaces the Single Payment Scheme (SPS), the main former scheme in CAP 2002–2013 (Monitoring Agriculture with Remote Sensing (MARS) unit, 2002). The BPS includes the new compulsory 'green direct payment', which is worth about 30% of the total payment. Hence, the adapted subsidy control system should be capable of verifying compliance with the greening rules that farmers must follow to receive the green direct payment/greening subsidies. The compulsory greening subsidies are targeted to introduce best agricultural land use practices that are beneficial for the environment and climate. The farmers submitting an application for greening subsidies are expected to follow three obligatory agricultural practices: maintenance of permanent grassland; protection of ecological focus areas; and crop diversification. This study presents the application of a new RS based method to verify compliance with the required crop diversification rules in Denmark.

### 1.1. Danish subsidy control with Remote Sensing

According to the Commission Regulation No 3508/92, the EU approved the use of Remote Sensing (RS) technology for the primary control of subsidy applications (European Commission (EC), 2001). Hence, most of the member states opted to perform the control based on satellite or aerial RS methods. In Denmark, currently, NaturErhvervstyrelsen (NAER) is responsible for carrying out a Control with Remote Sensing (CwRS) campaign to validate the subsidy application. It uses RS based methods in association with the Netherlands Geomatics and Earth Observation (NEO) center. RS images are used to verify the areas and crops that the farmers are declaring in the applications: Raster data such as orthophotographs and panchromatic images are used for digitizing the field boundaries to verify the area claimed by the farmers; Multispectral images acquired in different seasons are used to support the digitization and to identify the crops in the field. Till 2004, NAER used images like SPOT XS, SPOT P, LANDSAT TM/ETM and RADARSAT for the control (Pedersen, 2001; Department of Agroecology (DA), 2003). With the advancement of commercial sensors offering very high spatial details, the use of Very High Resolution (VHR) images could be a large benefit in the subsidy control. Hence in 2003, EU opened up for testing the feasibility of VHR images for subsidy control. Consequently Denmark carried out the tests using VHR images from sensors like IKONOS, QuickBird and EROS (Pedersen, 2005; Faculty of Agricultural Sciences (FAS), 2007). The tests showed that the use of VHR images have resulted more precise digitization of field boundaries and reduced the errors in area/crop verification in the control. Since 2005, these VHR images are also being used operationally in Danish agricultural subsidy control. Recently, images from WV-2, GeoEye and LANDSAT8 sensors are also being used.

The Danish subsidy scheme followed from 1992 to 2014 is area based (Pedersen, 2001) and the RS based method used for control is designed to cope with that type of scheme. The farmers submit applications via a web based GIS digitizing program to the Ministry of Environment and Food. The Ministry sends these applications to NAER for the control. The application contains information about the producer and the farm, and boundary of the fields. The NAER maintains a national agriculture register where these applications are stored as a database for administrative and subsidy control. Besides using the boundaries for administrative control, the NAER sends the database to NEO for crop classification. The NAER uses the program 'PDGIS' (a customized GIS system at Plant Directorate), a system based on MAP Info for digitizing the boundary of the field using available RS images. The number of different crops and area of each declared crop field are measured via Computer Aided Photo Interpretation (CAPI) and classification results obtained from NEO. This information is cross checked with the information declared by the farmers. Any false-declarations of area and subsidy category of the crop lead to rejection of the application. Before rejecting applications, farmers are contacted for possible corrections of the declared areas. If the problem cannot be resolved, the NAER will conduct final field verification.

### 1.2. Crop diversification rule for Danish greening subsidy

The new Danish greening payment requires farmers to follow environmentally benign agriculture land use practices. Owing to the new CAP 2014–2020, one of the compulsory practices that Danish farmers must meet in 2015 is a requirement of more crop categories at the farm-scale. The crop diversification rules are based on the minimum number of crops a farmer must grow and the area they cover depending on the total agricultural area of the holding. If farmers do not qualify for one of the exemptions mentioned in the report (Ministeriet for fødevarer, Landbrug og Fiskeri, 2015), then they have to satisfy the crop diversification rule that applies to their farm size. Specifically, farms with less than 10 ha of arable land are not subject to a crop diversification requirement. Farms with 10–30 ha of arable land need to have at least two different crops, with the largest crop covering no more than 75% of the arable land. Farms with more than 30 ha of arable land must have at least three different crops with the largest crop covering no more than 75% of the arable land and the first two largest crops together covering no more than 95% of the arable land.

### 1.3. Crop classification approach

NAER currently depends on the crop classification method developed by NEO, which is actually designed for agriculture structure and Landscape of Netherland. The suitability of the NEO's object-based classification approach for Danish landscape is under investigation. Meanwhile, we took steps to redesign the RS based verification approach by modifying the existing RS based Danish crop identification method to accurately identify the number of different crops cultivated and measure their occupancy proportion within each farmer's holdings. The approach used to identify crop types for assessing compliance under the former subsidy scheme (1992–2014) is 'Winner-takes-all (WTA)'. This is a traditional approach based on stacking input datasets into a supervised classifier (Pedersen, 2002; FAS, 2007). It performs pixel-based crop classification using RS multispectral images recorded at different times during the growth season of crops with training samples collected by Rapid Field Visit (RFV). The pixel based classified results are combined with the digitized field parcels to obtain parcel based classification results and grouped to three categories namely 'accepted', 'rejected' and 'doubtful' to sanction the farm subsidies. Previous studies by the authors (Chellasamy et al., 2014) and (Chellasamy et al., 2015) addressed a method that showed improved classification performance compared to the existing 'Winner-takes-all' crop discrimination method. The pro-