Transferring knowledge between satellite datasets for automated agricultural land discrimination in Afghanistan

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Background

The United Nations Office on Drugs and Crime (UNODC) uses medium resolution satellite imagery to quantify the total area of agricultural production as part of their annual opium poppy (*Papaver somniferum*) survey in Afghanistan, a country responsible for 82% of global illicit opium production (UNODC, 2019). The accurate mapping of agricultural area, known as the agricultural mask, is essential for opium estimates that are used to inform counter-narcotic policy.

Fully convolutional network

Fully Convolutional Networks (FCNs) offer ground-breaking performance for image processing tasks through their ability to encompass local contextual information (Shelhamer et al., 2016) (Fig. 1).

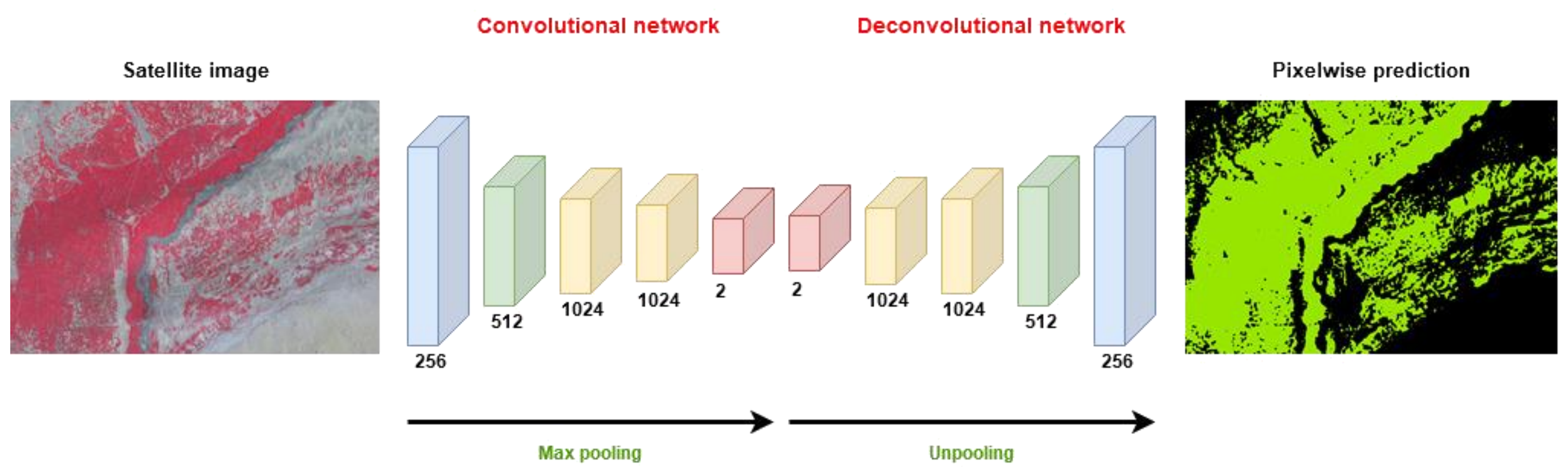

Fig. 1. Example of an FCN for agricultural land discrimination with convolutional and deconvolutional layers.

Research question: **Can a trained model be used on another image source to detect agricultural features?**

The FCN-8 model (Shelhamer et al., 2016) was used as an agricultural mask classifier across Helmand and Kandahar, Afghanistan. The model was trained using DMC imagery (32m) and manually-labelled agricultural masks between 2007 and 2008 and validated on 2009 imagery from DMC and Landsat 5. Two forms of standardisation: (1) Top of Atmosphere (TOA) – a radiometric calibration of the spectral bands and (2) NDVI – a commonly used vegetation index for separating agriculture.

Model robustness between sensors

Agricultural features learnt from DMC were transferable to Landsat 5 (LS5) using 256 px x 256 px input image chips. False colour imagery (NIR,R,G) marginally outperformed Normalised Difference Vegetation Index (NDVI) for agricultural mask delineation of both DMC and Landsat 5, +0.95% and +0.34% respectively (Tab. 1).

Tab. 1. Validation metrics for agricultural delineation across image sensors using different data standardisation techniques.

Data (2007 & 2008: n=830)	Imagery	Validation (2009: n=137) Accuracy (%)	Intersection over Union
NIR, R, G	DMC	94.39	67.21
	LS5	92.01	57.64
NDVI	DMC	93.44	65.89
	LS5	91.67	55.12

Natural vegetation is difficult to separate from agriculture because of their similar spectral properties (Simms et al., 2016). These areas have been well-delineated for both DMC and Landsat 5 using the FCN-8 model (Fig. 2).

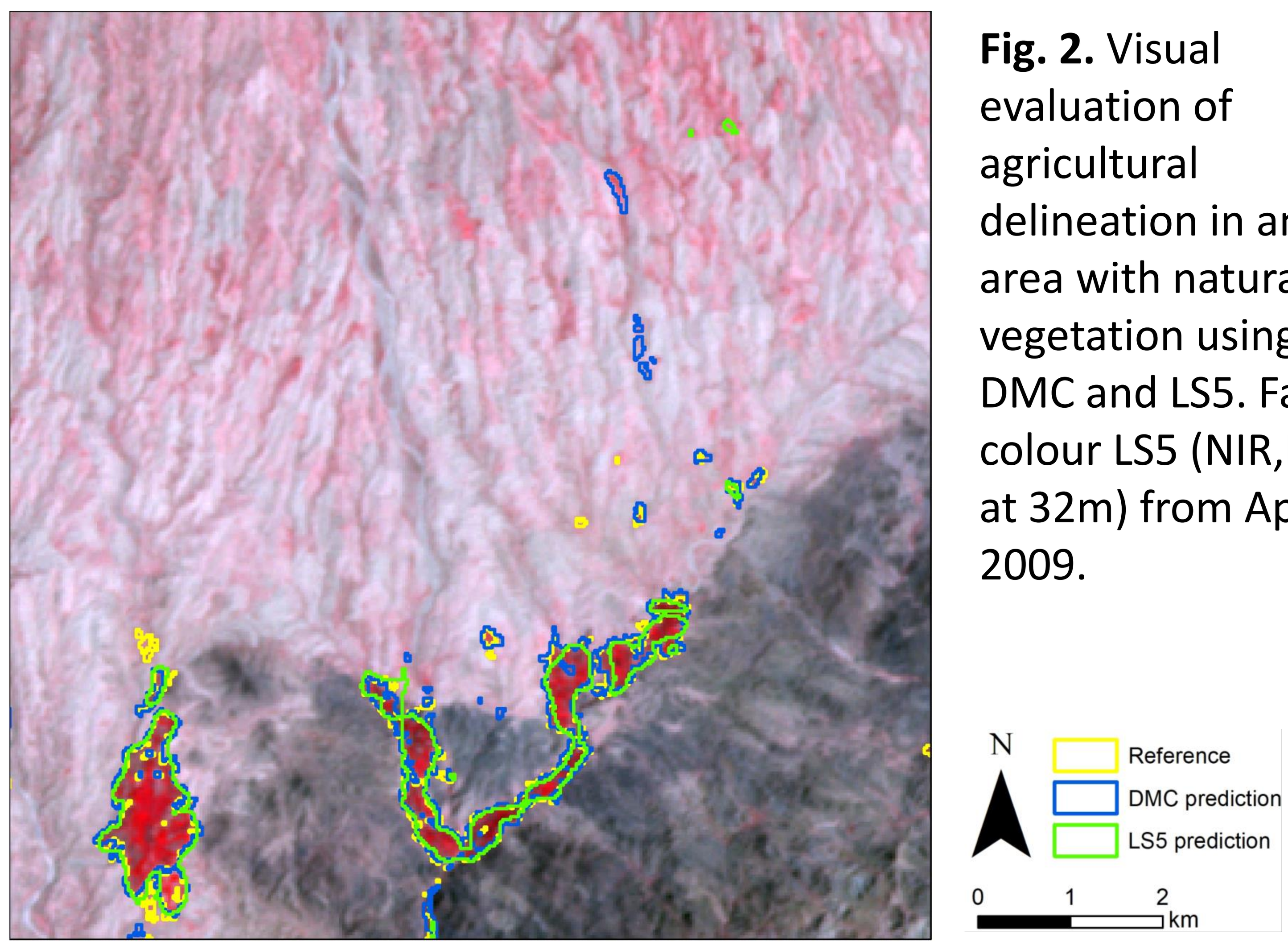

Fig. 2. Visual evaluation of agricultural delineation in an area with natural vegetation using DMC and LS5. False colour LS5 (NIR,R,G at 32m) from April 2009.

Why does it work?

Further investigation of how the FCN learns was explored using 2009 DMC imagery and its underlying spatial, textural and spectral properties. The shape of agricultural land was found to have negligible ability to separate agriculture. The textural features alone achieved an accuracy of 73% and the combined spectral and textural features achieved an accuracy of 94% accuracy (Tab. 2).

Tab. 2. Metrics for agricultural delineation using FCN models trained and validated on 2009 DMC imagery.

Model training data (n=415)	Validation (n=137) Accuracy (%)	Intersection over Union
Spatial		
Shape of agriculture area	53.20	12.84
Textural		
Homogeneity, entropy and correlation	72.87	55.27
Spectral & textural		
NIR	73.65	56.25
R	87.77	62.78
G	86.77	61.84
NIR, R, G (Benchmark)	**93.74**	**65.51**

Conclusions and recommendations

- High classification performance was achieved for agricultural features using the FCN model trained on a different image sensor.
- Textural and spectral properties are more important than shape for agricultural land delineation in this landscape.
- The ability to transfer knowledge between image sensors opens up an exciting opportunity to monitor agricultural change from new and long-term Earth observation programmes.

References

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