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DIFFICULTIES IN USING SPECTRAL PROPERTIES TO MAP IRRIGATED AREAS IN A TEMPERATE CLIMATE: A CASE STUDY OF POTATOES IN ENGLAND

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ABSTRACT

Irrigation in England is supplemental to rainfall and only used on a small proportion of the cultivated land, notably on high value vegetable and potato crops. However, it is a significant water user as most of the irrigated area is located in the driest part of England. The existing data on irrigated areas are based on government and industry surveys. Recently these datasets have been used with Geographic Information Systems (GIS) to produce irrigated maps, but these can only be published at catchment level due to confidentiality constraints on the datasets.

To assess the possibility of using remote sensing data for mapping the irrigated area, one Landsat image for the summer 2003 was used to compare the spectral signature between irrigated and non-irrigated potato fields in the East of England. ISODATA algorithm was used to perform unsupervised classification, and 50 spectral classes were created. A ground truth dataset was then used to identify the most representative spectral class for irrigated and non-irrigated fields.

The result showed that categories both fall into the same spectral class, suggesting there are no significant differences between their spectral properties. Therefore, using satellite imagery may not yet be an appropriate method or need more research for mapping irrigated area in temperate climates such as England. The summer rainfall reduces the water stress differences between irrigated and non-irrigated potato fields such that these satellite sensors cannot yet differentiate the crops.

INTRODUCTION

Irrigation in England is supplemental to rainfall and only used on a small proportion of the cultivated land. However, irrigation is an important factor in certain parts of the food industry, especially for high value crops such as potatoes, fruit and vegetables, and for farmers with contracts to continuously supply supermarkets with top quality food (Knox *et al*., 2000).

Irrigation is a small water user nationally, but is very significant locally, as most of the irrigated area located in the driest part of England; and they use the water during the driest periods of the driest years. About 60% of the irrigated area and 57% of the volume of water used for irrigation is located in East Anglia *(*Knox *et al, 2007).* These factors put the irrigation sector into competition with other water users. Population growth and climate change threats will further increase tension between water users over allocation of the available water in the future.

Accurate irrigated area maps would be very useful for the policy makers involving in water and food management such as the Environment Agency and the British Potato Council, and for researchers wanting to assess the impact of the climate change on irrigated crops, agri-industries and rural economy.

The existing irrigated area datasets are based on government and industry surveys. Recently these datasets have been used with Geographic Information Systems (GIS) to produce irrigated maps at the catchment levels. However, these maps have low spatial accuracy as they can only be published at catchment level due to confidentiality constraints on the datasets, and the base datasets contain sampling and response errors. The use of remote sensing data to map irrigated area in England might overcome these problems and identify the irrigated areas at field level.

Remote sensing techniques have been used in the last two decades to map irrigated areas in arid or semi arid regions [e.g. Beltran and Belmonte (2001) in Spain, Ozdogan et al (2003) in Turkey, EL-Magd and Tanton (2003) in Kazakhstan, Baruffi et al (2005) in Italy, Thenkabail et al (2005) in Pakistan, Kamthonkiat et al (2005) in Thailand, Akbari et al (2006) in Iran, Xiao et al (2005 and 2006) in South and Southeast Asia, Biggs et al (2006) in India, Wardlow et al (2007) in USA and Grant et al (2007) in Portugal].

These previous studies were mostly in arid or semi arid regions where lack of rainfall during the cropping season ensures the irrigated and non-irrigated crops are different. In the case of England, where irrigation is supplemental to the significant rainfall during the cropping season, the same crop can often be grown un-irrigated, albeit at lower yield and quality. The droughtiness may not be adequate to discriminate between irrigated and non irrigated fields. The purpose of this study was to analyse the spectral signature differences between irrigated and non-irrigated potato fields in East of England using seven bands of Landsat image.

MATERIALS AND METHODS

Study area and imagery

The study site is located in East of England where the major crops such as potatoes, sugar beets, cereals, peas and beans with different irrigation management practices exist. It is a relatively dry part of England and accounts for 60 % of the irrigated area and 57 % of the volume of water used for irrigation in England (Knox et al, 2007). This study focused on potatoes fields only because it is the main irrigated crop in England, accounting for 43 % of the irrigated area and 56 % of the water use nationally. More than 58 % of the irrigated potatoes are in the East Anglia region (Weatherhead, 2007).

For this study we looked at the area covered by one Landsat scene, which is approximately 170 km north-south by 183 km east-west (Figure 1). An image from Landsat Thematic Mapper 5 on 13 of July 2003 was acquired. This date was selected because it was the best cloud-free image during the peak growing season 2003 and it came after relatively longest period of no rainfall.

The Landsat image was purchased from USGS Earth Resources Observation and Science (EROS) Center, this product provides radiometrically and geometrically corrected (Level 1G) by using corrected data driven from sensor and spacecraft. However, additional geometric correction carried out using ground point controls from both the Ordnance Survey (OS) reference map for East England and an already corrected Landsat image to minimize the spatial errors.

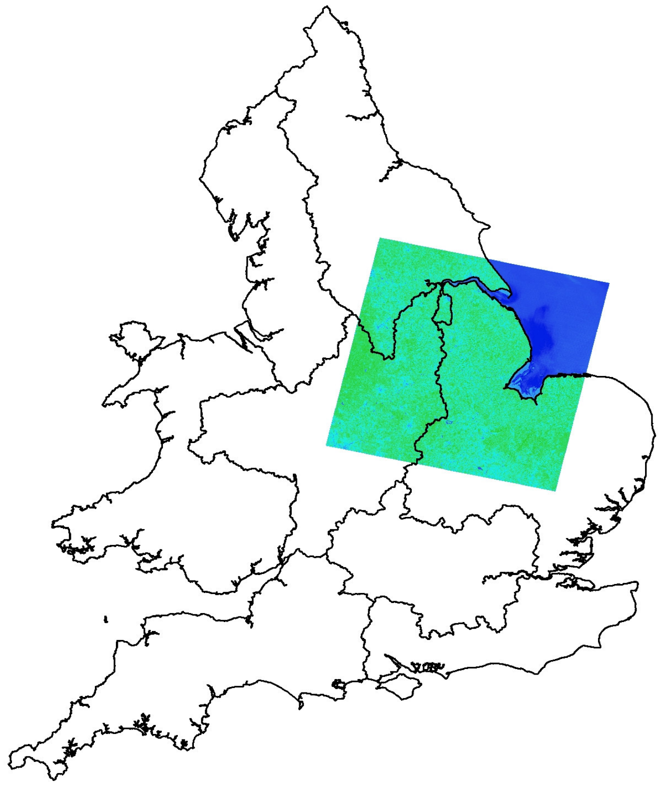

Figure 1: Location of the Landsat image in the study area

Ground Truth Data

The ground truth dataset was derived from data collected as part of the annual survey of potato growers by the British Potato Council (BPC), an organisation which represents potato businesses in the UK. The BPC collect selected data from registered farmers growing potatoes. The BPC database record details on field location, crop varieties, field areas, irrigation and field ID. For the year 2003, information for (7933) potato fields had been recorded, including both irrigated and non-irrigated fields.

Methods

Visible Bands: The Iterative Self-Organizing Data Analysis Technique (ISODATA) algorithm was used to classify and cluster the Landsat visible bands. ISODATA clusters the entire image based on spectral properties using an unsupervised classification. The user determines the number of classes and the algorithm selects random spectral means, then the pixels is assigned based on the minimum distance from these random means. After completion of the first iteration, a new mean for each cluster is calculated and used for the next iteration. The process is repeated until maximum percentage of pixels for the whole class values are unchanged between iterations.

This method was used to classify the study area identifying the spectral class for both irrigated and non-irrigated potato fields, to determine whether they are in the same spectral cluster or not. We assigned the number of classes to be 50, to include most of the land cover types in the study area. The ISODATA ran for 24 times (maximum iterations) to gain high percentage of unchanged pixels in each cluster, with 99% of convergence threshold. Then all irrigated and non-irrigated fields from the BPC dataset were labeled with their cluster, to identify the appropriate cluster to represent each category.

Thermal Band: The thermal band was used as indicator for the differences in the surface temperature of the plant canopy between irrigated and non-irrigated potatoes. A statistical analysis to identify any significant differences in thermal band values between irrigated and non-irrigated fields was carried out. Two sample independent t-tests conducted by using Statistica package for 19 samples from each category. To minimize the effect of variety and soil type initially, the samples selected were for one potato variety (Maris Piper) and located in the free draining soils, according to Hydrology of Soil Types (HOST) classification for soil types in UK (Boorman et al, 1995). The statistical was used.

RESULT AND DISCUSSION

As a result of the unsupervised classification using the ISODATA clustering method, the study area classified 50 classes (Figure 2). These classes represent the land cover types in the study area.

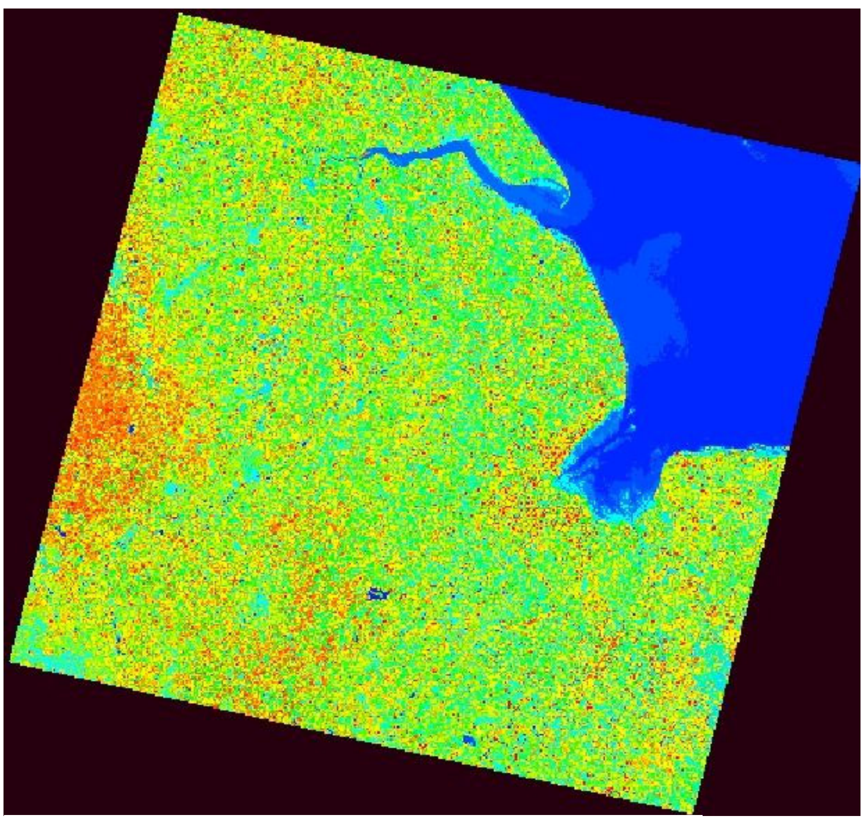

Figure 2: Unsupervised classification by ISODATA algorithm

To determine whether irrigated and non-irrigated potatoes are different or similar in their spectral properties, the BPC dataset was overlaid onto the classified image. The cluster classes for the total of 2365 fields of non-irrigated potatoes and 3170 fields of irrigated potatoes were then determined (Table 1). Nearly half of these fields fall within class 49 for both irrigated and non-irrigated potato fields, which shows that the spectral reflectance from irrigated and non-irrigated fields were very similar. Based this classification and checking spectral classes with the ground data (BPC), class 49 is more likely is the land cover representing potatoes in the study area.

Table 1: Percentage of the potato fields in each spectral class

Non-irrigated fields	**Irrigated fields**
Class 49 contained 45% of the fields	Class 49 contained 44% of the fields
Class 47 contained 10.5% of the fields	Class 47 contained 14.9% of the fields
Class 39 contained 5.1% of the fields	Class 39 contained 5.2% of the fields
The 47 other classes contained less than 5% of the fields	The 47 other classes contained less than 5% of the fields

These results show that the satellite sensors are unable to detect the water stress differences in the visible bands between irrigated and non-irrigated crops. This is believed to be mainly because of the relatively short dry period in summer; the frequent summer rainfall in England keeps the soils in non-irrigated fields moist enough for the plants to survive without showing sufficient stress to be detected by the satellite sensors.
To assess the accuracy of the classification in detecting potato fields in the study area, we estimated the area from the classification and compared it to the area estimated by BPC, at the catchment level. We selected nine catchments in the study area where full included in Landsat scene. As result showed the square of correlation coefficient was 0.80 (Figure 3), which suggests that the classification was reasonably accurate in detecting the fields in which potatoes were cultivated.

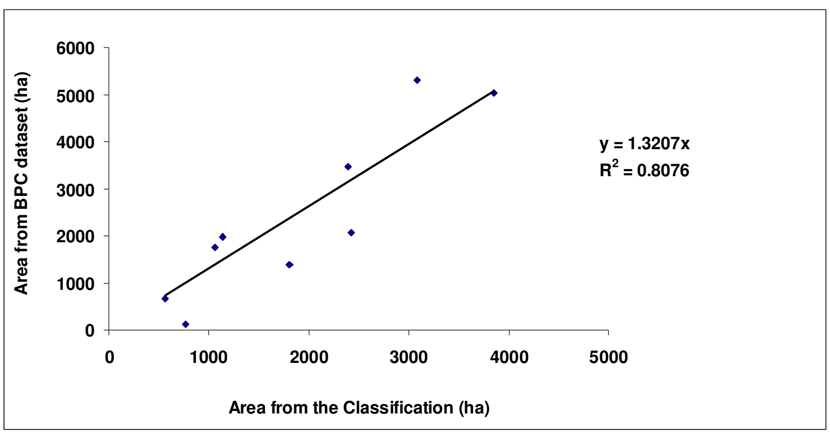

Figure 3: Linear regression between the cropped area (ha) estimated by the digital classification and areas (ha) reported in the BPC dataset for nine selected catchments in eastern England.

The result of the two sample t-test for the thermal band also showed that there was no significant difference between irrigated and non-irrigated potatoes (Table 2). Even for the fields in the free drain soils and the same varieties, the irrigated and non-irrigated fields were similar in their thermal reflectance.

Table 2: Statistical comparison between the two samples using the t-test

Mean Irrigated	Mean Non-irrigated	Irrigated Sample	Non-irrigated Sample	Std.Dev. Irrigated	Std.Dev. Non-irrigated	**p Variances**
138.1	136	19	19	4.74	4.98	**0.83**

Probably the actual evapotranspiration (ET) is a better indication to detect the water stress of the plants than the thermal band. Also creating an accurate potato map is necessary to narrow down the area of interest and clustering the ET value to see if there are any differentiations based on irrigation management.

CONCLUSION

This study showed that using remotely sensed data, we are still are unable to detect the differences between irrigated and non-irrigated crops in temperate climate such as England. This is believed to be mainly due to the frequent summer rainfall which gives plants enough moisture to reduce the differences between irrigated and non-irrigated crops to a level where the satellite sensors cannot detect the differences. However, high correlation between areas estimated by BPC and unsupervised classification may be used as a method to potato map and to their spatial distribution leveling the region. This will be a useful finding for the future research focusing on the impacts of changes in water availability (due to water regulation and/or climate change) on irrigation water demand for potato production.

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