

A Simple Algorithm to Identify Irrigated Croplands by Remote Sensing

Weicheng Wu, Eddy De Pauw

GISU/ICARDA (International Center for Agricultural Research in the Dry Areas)
POBox 5466, Aleppo, Syria – w.wu@cgiar.org and e.de-pauw@cgiar.org

Abstract – The identification of irrigated cropland is essential for crop monitoring, yield estimation and water management assessment in drylands. The standard approach is to use supervised classification on multispectral bands, vegetation indices or the Principal Components or, more recently, the combination of optical images with radar data. More complex methods, such as time-series analysis, sub-pixel calculation method and decision-tree based supervised classification have been proposed to differentiate the irrigated areas and identify the irrigation system. As an alternative approach to identify irrigated land, this paper introduces a simple and easily implemented algorithm, based on the logical operation and thresholding of a combination of thermal temperature (T_s) and vegetation indices (e.g. NDVI). This approach is illustrated through a case study in northern Syria using Landsat TM images. The results show a good consistence with the field observations (99%).

Keywords: Irrigated area, identification, simple algorithm, thermal temperature, vegetation indices, remote sensing

1. INTRODUCTION

In dryland agricultural research related to yield estimation and water use efficiency, a recurring information requirement is to differentiate spatially the irrigated croplands from the non-irrigated ones. Currently the most popular approaches are supervised classification or differencing techniques on multispectral bands or a variety of vegetation indices such as simple ratio, NDVI (Normalized Difference Vegetation Index), NDWI (Normalized Difference Wetness Index), GVI (Green Vegetation Index) or on the Principal Components (Thiruvengadachari 1981, Kolm and Case 1984, Manavalan et al. 1995, Abuzar et al. 2001, Beltran and Belmonte 2001, Xiao et al. 2002, Alexandridis et al. 2008). Some authors have even ventured to use radar data (Ribbes and Toan 1999, Rosenqvist 1999, Shao et al. 2001) or a combination of optical images (e.g., Landsat TM and MSS) and radar data (ERS-1) (Hussin and Shaker 1996) to classify out paddy or rice fields. Toomanian et al. (2004) have explored the possibility to estimate the irrigated area by upscaling Landsat images to NOAA AVHRR NDVI images. Recently, a number of new methods have been proposed to identify and map the irrigated areas, either by time-series analysis of SPOT Vegetation and MODIS NDVI data (Kamthonkiat et al 2005, Biggs et al. 2006) or by integrating decision-tree based supervised classification with a so-called 'effective irrigation potential index' (Ozdogan and Gutman 2008). Thenkabail et al. (2007) developed a sub-pixel area calculation method to map the irrigated areas. These researches have no doubt resulted into competent methods to estimate the

irrigated areas at local, or regional and even global scales using high or coarse resolution remotely sensed data. However, in our own land use/land cover mapping work in Syria using Landsat TM images, we noticed that no matter what classification processing was applied on multispectral bands or vegetation indices, the separability between irrigated or supplementally irrigated areas and rainfed cropland, as evaluated using the Jefferies-Matusita Distance (JMD, Richard and Jia, 1999), was very low (JMD = 0.37- 0.91, only when JMD > 1.5, the pair of classes is clearly separable) with a high percentage of errors of commission and omission (33-71%). The standard approaches were unable to deal with this problem and those of Kamthonkiat et al. (2005), Biggs et al. (2006), Thenkabail et al. (2007) and Ozdogan and Gutman (2008), which use coarse resolution data, were not applicable for local level studies.

A new research area in remote sensing for agricultural applications has focused on soil moisture, and aims at using remote sensing to reveal the relationships among the soil moisture, surface temperature (T_s) and vegetation indices (e.g., T_s /NDVI) (Moran et al. 1994, Carlson et al. 1995, Lambin and Ehrlich 1996, Sandholt et al. 2002). From these researches it is known that the surface temperature (T_s) in vegetated areas is lower than in bare land and other land covers (except water bodies) due to soil moisture and thermal inertia. Goward et al. (2002) revealed that T_s declines with the increase in soil moisture and is negatively correlated with NDVI. For this reason, Vidal and Perrier (1990) have once used the thermal band of AVHRR data to investigate the water balance in the irrigated land. Based on this understanding, it is concluded that T_s could indeed be a promising indicator of irrigation.

2. METHOD AND PROCEDURE

2.1 Study area

In order to develop an operational approach using T_s for local level identification of irrigated land, we selected a pilot area located in Northern Syria. The study area includes the Governorates of Aleppo and Idleb, and is characterized by a range in mean annual rainfall from 600 mm in the northwest to 200 mm in the southeast. The precipitation is mostly concentrated in winter and spring. The two main rivers in this study area, the Euphrates in the east and the Orontes in the west (Figure 1), provide the water resources that make irrigation in the area possible. The irrigated spring crops are mainly wheat and vegetables, the main rainfed crop is barley. Summer crops occur only within irrigated areas and include cotton, maize, sesame, sunflower, water melon. Olive, as main permanent or perennial tree crop, is widely grown in rainfed areas and is often mixed with citrus, fig, cherry, peach, and other fruit trees. The main landform is an undulating plain varying in elevation from 100 to 600 m, with interspersed hills and isolated mountains, rising up to 1500 m in the west and locally covered with forest and maquis. The plains are covered with irrigated, rainfed croplands and rangeland from north to south (Figure 1). The

study area includes Syria's most important agricultural production regions.

2.2 Principles of the algorithm

A preliminary assessment in the study area indicated that T_s in the irrigated areas is generally 2-6°K lower than in rainfed areas because of their higher moisture, whereas the NDVI is higher than in rainfed areas in the same climate condition. A combination of these two indicators would therefore be a good tool for identification of irrigated areas. However, it was also noted that forests and maquis in the western part of the study area, where annual rainfall is more than 350mm, have the same T_s range as the irrigated areas in the spring image. It was therefore necessary to separate these land cover types from the irrigated lands by a differencing and thresholding technique using both spring and summer images, since forest, maquis and permanent tree crops are mostly evergreen without significant phenological change. These principles constitute the core of the algorithm.

2.3 Procedure

Step 1: Atmospheric correction in terms of the COST model (Chavez 1996) for the multispectral bands of Landsat TM images (Table 1) and conversion of digital number into reflectance; followed by calculation of NDVI;

Step 2: Conversion of the thermal band into temperature (T_s) for both spring and summer images according to Chander et al. (2003);

Step 3: Differencing and thresholding technique was applied on the NDVI of spring and summer images to separate the significantly changed areas (for example, irrigated land and

rainfed cropland where $\Delta\text{NDVI} < -0.25$ or $\Delta\text{NDVI} > 0.25$) from the non-significant phenological change land cover such as evergreen forests, maquis, or permanent tree crops (e.g., $-0.25 < \Delta\text{NDVI} < 0.25$);

Step 4: In the identified significantly changed area, a logical operation ($\text{NDVI} \geq 0.5$) AND ($T_s \leq 301^\circ\text{K}$) was applied on NDVI and T_s images to differentiate the irrigated areas from the non-irrigated lands. The thresholds of NDVI and T_s may be slightly different from scene to scene and from spring to summer. In areas without evergreen forests or maquis, Step 3 can be skipped.

Table 1. Landsat TM images used in this study

Path-Row No	Acquisition Date	
174-35	May 30, 2006 May 01, 2007	Sept 19, 2006
173-35	April 13, 2009	Aug19, 2009

RESULT AND VALIDATION

Spring irrigated area of 2007 - 2009, where the main crops were wheat and vegetable, is shown in Figure 1. The result was compared with 423 field observation points collected using GPS in spring (March, April and May) of 2007 and 2010. It was found that only 4 points noted as rainfed cropland in the west part of the study area were identified as irrigated land. Thus the result is in a good agreement with the ground truth data with an accuracy of 99%.

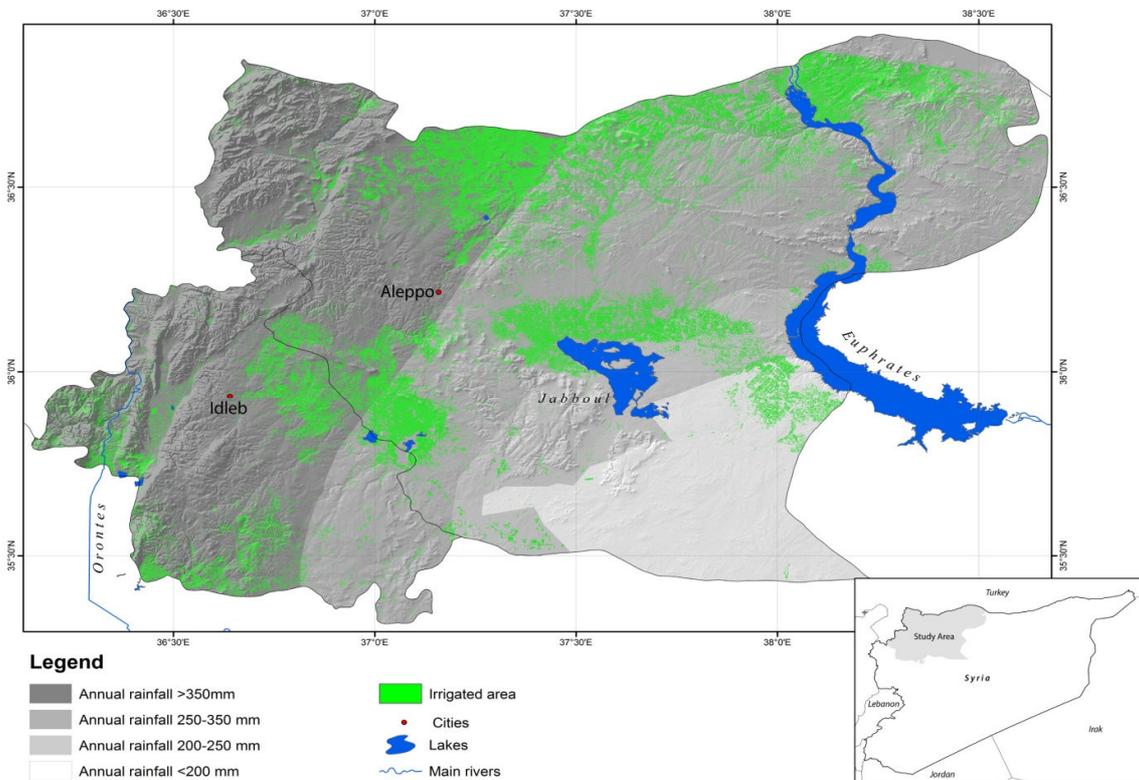


Figure 1: Distribution of spring irrigated cropland in the study area

DISCUSSION AND CONCLUSION

The paper demonstrates in a pilot area in Northern Syria the development and application of an algorithm to identify irrigated cropland. The combination of T_s and vegetation indices such as NDVI appears an efficient tool to separate at local level the irrigated areas from others. The advantages of the algorithm are its simplicity, ease of implementation and effectiveness. As well as for local scale study, the authors also see the great potential to upscale the algorithm for regional and even global level identification of both spring and summer irrigated areas using coarse resolution data such as MODIS taking endemic agricultural phenology into account.

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