International Journal of Applied Earth Observation and Geoinformation 54 (2017) 114–123

Contents lists available at ScienceDirect

International Journal of Applied Earth Observation and Geoinformation

journal homepage: www.elsevier.com/locate/jag

Agricultural cropland mapping using black-and-white aerial photography, Object-Based Image Analysis and Random Forests

M.F.A. Vogels*, S.M. de Jong, G. Sterk, E.A. Addink

Utrecht University, Department of Physical Geography, PO Box 80115, 3508 TC Utrecht, The Netherlands

ARTICLE INFO

Article history:
Received 16 February 2016
Received in revised form 9 August 2016
Accepted 6 September 2016

Keywords:
Agricultural cropland expansion
Land-use change
Black-and-white (historical) aerial photography
GEOBIA
Random Forests

ABSTRACT

Land-use and land-cover (LULC) conversions have an important impact on land degradation, erosion and water availability. Information on historical land cover (change) is crucial for studying and modelling land- and ecosystem degradation. During the past decades major LULC conversions occurred in Africa, Southeast Asia and South America as a consequence of a growing population and economy. Most distinct is the conversion of natural vegetation into cropland. Historical LULC information can be derived from satellite imagery, but these only date back until approximately 1972. Before the emergence of satellite imagery, landscapes were monitored by black-and-white (B&W) aerial photography. This photography is often visually interpreted, which is a very time-consuming approach. This study presents an innovative, semi-automated method to map cropland acreage from B&W photography. Cropland acreage was mapped on two study sites in Ethiopia and in The Netherlands. For this purpose we used Geographic Object-Based Image Analysis (GEOBIA) and a Random Forest classification on a set of variables comprising texture, shape, slope, neighbour and spectral information. Overall mapping accuracies attained are 90% and 96% for the two study areas respectively. This mapping method increases the timeline at which historical cropland expansion can be mapped purely from brightness information in B&W photography up to the 1930s, which is beneficial for regions where historical land-use statistics are mostly absent.

© 2016 Elsevier B.V. All rights reserved.

1. Introduction

Land degradation is widely recognized as a global problem and poses a threat regarding food security, biodiversity, biomass productivity and environmental sustainability (Millennium Ecosystem Assessment, 2005; Mueller et al., 2014). Especially dryland regions, defined as arid, semi-arid and dry sub-humid zones, are vulnerable to land degradation, which is often followed by severe desertification (Mueller et al., 2014; Gisladottir and Stocking, 2005). Key drivers of land degradation are the conversion of natural vegetation into agricultural land and the management practices in the agricultural sector (Foley et al., 2005). Enhanced rates of soil erosion and a decrease in soil-water holding capacity are observed as a result of unsustainable agricultural practices thereby causing environmental damage through sedimentation, pollution and increased flooding (Morgan, 2005).

During the last decades population increases in developing countries have resulted in major LULC changes (Lambin and Meyfroidt, 2011). Cropland expansion, the dominant land-use change, has not yet reached its maximum in Africa, South America and Southeast Asia (Laurance et al., 2014). A consequence of this conversion to cropland is the alteration of the hydrology of watersheds, which is often accompanied by enhanced rates of soil erosion (Yang et al., 2003; Bewket and Sterk, 2005). Generally surface runoff increases in the absence of the natural vegetation cover, thereby triggering sheet, rill, and gully erosion. Land degradation as a result of LULC changes and poor management is also revealed by the flushing of nutrients and fine sediments (including organic material), and loss of soil structure and biodiversity (Bowyer et al., 2009). To what extent such land-use changes, particularly cropland expansion, have affected hydrology, and have initiated land- and ecosystem degradation, has been extensively studied, recognized, and embedded in policy for most developed countries (EEA, 2015). However, in developing countries quantification of the land-degradation problem is poor due to the absence of reliable data, especially for longer time-scales.

To assess the impact of LULC changes on land degradation over longer time-scales, historical land-use (change) maps serve as key input in such studies. Historical cropland can be derived with certain accuracy from satellite imagery, which is available since the first earth observation mission of Landsat in 1972; a time-span of approximately 40 years. Further back in time, an important

* Corresponding author.
E-mail address: m.f.a.vogels@uu.nl (M.F.A. Vogels).

http://dx.doi.org/10.1016/j.jag.2016.09.003
0303-2434/© 2016 Elsevier B.V. All rights reserved.

source for mapping land-cover change are B&W aerial photographs. The collection of aerial photography is extensive and provides the longest temporally continuous record of land cover, with some imagery dating back to the 1930s (Morgan et al., 2010). The use of such photography is limited due to its panchromatic spectral information. An image analyst can visually identify cropland plots in B&W aerial photography by the cropland plot's characteristic rectangular shape, and smooth, regular texture, but such imagery holds little information for machine learning. A promising method evaluated here to identify cropland acreage in B&W photography is Geographic Object-Based Image Analysis (GEOBIA). This approach of LULC discrimination is not pixel-based, but object-based to identify coherent landscape elements based on a heterogeneity threshold (Blaschke, 2010). The advantage of GEOBIA is that its workflow is similar to our visual perception of the world (Addink et al., 2012). This similarity principle is used in this research where GEOBIA is applied on brightness values of B&W photography for the purpose of mapping cropland acreage. Ancillary slope data is used in the classification process. GEOBIA is increasingly used in a wide range of applications, but is generally applied to multispectral imagery. The novelty in this study is its application on only brightness information to map cropland. Few studies exist for the use on B&W photography and these do not actually classify LULC (Morgan and Gergel, 2010).

This study aims at developing a semi-automated procedure to map cropland in B&W photography. To assess the universal applicability of this mapping approach, the method is tested and validated in two contrasting study areas with respect to LULC types: (1) the Awassa Lake region in the Central Rift Valley in Ethiopia and (2) the Kempen region in the Netherlands. This study will investigate and evaluate: (1) the feasibility to delineate cropland plots by segmenting B&W photography on the basis of brightness, and (2) the possibility to distinguish cropland areas from other types of LULC based on texture, shape, slope, neighbour and spectral variables of the segmented objects in the B&W photography using Random Forests.

2. Methods

The cropland acreage mapping procedure on B&W photography comprised four major stages. The original B&W photograph (Fig. 1A) was segmented into coherent landscape elements (objects), e.g. cropland plots (Fig. 1B). Secondly, a training and validation set were generated by means of interpretation of B&W photography and ancillary data sources by randomly selecting a number of objects (Fig. 1B). These landscape objects were then classified by a Random-Forest algorithm into two classes: (1) 'cropland' and (2) 'other land cover', on the basis of object attributes (Fig. 1C). Cropland is here described by the definition of IFAD (2008) as cultivated land, the sum of arable land and land under permanent crops, where arable land is land under temporary crops, temporary meadows for mowing or pasture, land under market and kitchen gardens or land that is temporarily fallow. The 'other land cover' class incorporates all other LULC. Finally, accuracy statistics of this classification procedure were calculated to validate the method.

2.1. Data collection and preparation

2.1.1. Site description

This methodology was applied and evaluated for two regions in different environmental settings: (1) the Awassa Lake region in the Ethiopian Rift Valley and (2) the Kempen region in the Southern part of the Netherlands (Fig. 2). Both regions have a dominant agricultural land use and experienced agricultural expansion over the past 50 years.

The Awassa Lake region is located in the south-central Rift Valley, 300 km south of the Ethiopian capital Addis Ababa. A prominent feature in this area is a steep rim in a dominant north-south direction marking the edge of the Awassa caldera. For decades natural forest has been diminishing in favour of agricultural area in many parts of Ethiopia (McCann, 1997) and this region is no exception. Smallholder farms dominate the area (Dessie and Kinlund, 2008). They have an average plot size of <1 ha per household and mainly cultivate perennial crops. The large agricultural farms mainly produce non-perennial crops.

The Kempen region is a geographical area characterized by sandy soils on the border of Belgium and the Netherlands. For centuries the area was covered by deciduous forest, but intensive logging resulted in the spontaneous development of heathland, which served as rangeland for cattle (Wouters and Vandenberghe, 1994). Today it is one of the most intensively cultivated areas of the Netherlands and it is mainly characterized by large-scale agricultural farmland with a few scattered remnants of the old heathland vegetation and forests. This research will focus on the Kempen region around the municipality of Bladel in the Netherlands further referred to as the Bladel Kempen region. The average plot size in this region is 4.6 ha and the owned land property per farm is on average 18.9 ha, which equals approximately four cropland plots (CBS, 2015; NGR, 2015). Landscape variability in this region is high with an alternation of natural areas of old vegetation (heathlands and forests), intensively cultivated farmland and villages.

2.1.2. B&W aerial photography simulation

B&W aerial photography was simulated from the Web Map Service layer named World Imagery (ESRI, 2015). This data is selected to simulate B&W aerial photography for the reason that this recent data aids in a proper validation of the methodology compared to historical photography. The methodology was evaluated on 15 sectors for each region, comprising agriculturally dominated sectors as well as high landscape-variability regions e.g. cropland area combined with the presence of villages and natural vegetation (Fig. 2). Panchromatic imagery from the WorldView-1 platform (0.5 m spatial resolution) acquired between 19 October 2008 and 11 February 2009 was used to represent B&W aerial photography for the Awassa Lake region. The size of the sectors here is 1375 m × 990 m. For the Bladel Kempen region aerial data from the UltraCam-G camera (0.3 m spatial resolution) acquired on 9 October 2010 was obtained to simulate B&W aerial photography by averaging its three bands (400–700 nm). The average cropland plot size in the Bladel Kempen region is distinctly larger compared to the Awassa Lake region (Fig. 2). The surface area per sector was taken four times larger (2750 m × 1980 m) to account for this effect in plot size difference for proper comparison. In this manner an equal amount of training- and validation objects could be labelled in both study areas.

2.2. Slope as a covariate for the classification of cropland

The Awassa Lake region ranges from 1643 m to 2950 m altitude. Remnants of natural forests are present on the steep slopes of the Awassa caldera rim (Dessie and Kinlund, 2008). The Bladel Kempen region has an extremely low variation in altitude (25–43 m) and a low or no correlation between LULC and slope is present. Common practice is that on steep slopes no or little cropland agriculture persists. For this reason slope is added as a covariate to enhance the discrimination between 'cropland' and 'other land cover' in the classification procedure. The Aster GDEM V2 (LP DAAC, 2011), a product of METI and NASA with a resolution of 30 m, and the AHN (Rijkswaterstaat, 2015), the official Dutch elevation map with a ground resolution of 5 m, is used for slope calculations for the

Download English Version:

https://daneshyari.com/en/article/6348433

Download Persian Version:

https://daneshyari.com/article/6348433

Daneshyari.com