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Desertification in the south Junggar Basin, 2000–2009: Part II. Model development and trend analysis

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Abstract

The substantial objective of desertification monitoring is to derive its development trend, which facilitates pre-making policies to handle its potential influences. Aiming at this extreme goal, previous studies have proposed a large number of remote sensing (RS) based methods to retrieve multifold indicators, as reviewed in Part I. However, most of these indicators individually capable of characterizing a single aspect of land attributes, e.g., albedo quantifying land surface reflectivity, cannot show a full picture of desertification processes; few comprehensive RS-based models have either been published. To fill this gap, this Part II was dedicated to developing a RS information model for comprehensively characterizing the desertification and deriving its trend, based on the indicators retrieved in Part I in the same case of the south Junggar Basin, China in the last decade (2000–2009). The proposed model was designed to have three dominant component modules, i.e., the vegetation-relevant sub-model, the soil-relevant sub-model, and the water-relevant sub-model, which synthesize all of the retrieved indicators to integrally reflect the processes of desertification; based on the model-output indices, the desertification trends were derived using the least absolute deviation fitting algorithm. Tests indicated that the proposed model did work and the study area showed different development tendencies for different desertification levels. Overall, this Part II established a new comprehensive RS information model for desertification risk assessment and its trend deriving, and the whole study comprising Part I and Part II advanced a relatively standard framework for RS-based desertification monitoring.

Keywords: Desertification; RS information model; Trend analysis; Junggar Basin

1. Introduction

The extreme goal of desertification monitoring is to unearth the trend of its development, which is of great significance for pre-making policies to deal with its potential influences (Glenn et al., 1998) and, hence, has become an increasingly highlighted branch in the context of global change (Le Houérou, 1996; Le et al., 2012). For this task, remote sensing (RS) has proved to be an effective solution for characterizing land surface dynamics such as vegetation cover evolutions (Herrmann et al., 2005) and land use/land cover (LULC) changes (Badreldin and Goossens, 2014) and also for providing multi-temporal data required for analyzing desertification development (Badreldin et al., 2013). Previous studies have validated a large variety of RS data such as satellite images for reflecting the temporal changes of desertification at different spatial scales (Liu et al., 2008; Dawelbait and Morari, 2012). In a whole sense, multi-temporal RS images are a preferred data source for extracting spatially and temporally explicit information that can support deriving the desertification trends at the

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regional and, even, global scales (Hostert et al., 2001; Gao and Liu, 2010; Wang et al., 2015).

Retrieving multifold indicators from RS data (Jiang and Lin, 2018) is of fundamental implication but is far from enough for accurately monitoring of desertification statuses, let alone for reliable derivation of desertification trends. After all, although desertification has been explicitly defined in the United Nations Convention to Combat Desertification (UNCCD, 1994), there has been no in-consensus frameworks and methodology capable of precisely quantifying its degrees. In other words, different people applying different methods, unavoidably, may supply different assessments for the same area undergoing desertification (Veron et al., 2006). Even though holistic assessments of desertification via integration of multiple indicators (Symeonakis and Drake, 2004; Le et al., 2012) have been attempted, their common scheme based on a set of thresholds for weighing each indicator (de Jong et al., 2011) cannot generate satisfactory results. The reason is that desertification involves a large variety of drivers and symptoms of land degradation, whereas the traditional approaches less considered the different contributions of these drivers to desertification. Thereby, there is a pressing demand to develop a comprehensive solution, e.g., based on RS, to accurately assess desertification degrees and project its trends.

To fill this gap, many studies have proposed solutions for different circumstances. The primary option was to make the best use of the advantage of simultaneously extracting multifold indicators (Jiang and Lin, 2018), and a variety of assessment methods via fusing such indicators by the means of, e.g., unsupervised classification (Lira, 2004), radial basis function network (Huang and Cai, 2006), fuzzy logic (Lin et al., 2009), and decision tree classification (Li et al., 2015), were proposed and validated to identify the desertification situations. Further, a few of desertification assessment models were developed. The representative model is Medalus, which has been attempted in many of the European research projects regarding Europe desertification (Nearing et al., 1994; Kirkby et al., 2004; Mulligan and Wainwright, 2004). The first predator-prey-schemed desertification risk assessment model in a human-environment coupling sense was proposed by Puigdefábregas (1995), and Puigdefábregas (1998) further outlined a conceptual human-resource coupled model for monitoring of desertification dynamics. Regev et al. (1998) proposed a classic predator–prey modeling way to incorporate a model of human harvesting of renewable resources. Stéphenne and Lambin (2001) proposed a simulation model to project land cover changes involving desertification at the national scales for the Sudano-Sahelian countries. Ibañes et al. (2008) advanced a model to assess the desertification risks using system stability condition analysis, and it was a development of the modeling strategies used by Puigdefábregas (1995, 1998) and Regev et al. (1998).

The above-reviewed models have also been attempted for projecting desertification trends. The representative case is the Medalus model, combining four major factors of climate, soil, vegetation, and land management in a synthetic way to yield the so-called environmentally sensitive area index (Kosmas et al., 1999). Medalus has been used for evaluation of desertification risks in the Province of Extremadura, southwest Spain (Contador et al., 2009), and in the Apulia region, southeast Italy (Ladisa et al., 2012). In turn, such applications also gave clues to improve this model. Izzo et al. (2013) modified the index in the Medalus model and applied it in the Dominican Republic, and Jafari and Bakhshandehmehr (2013) fused the index and fuzzy logic to reveal the environmental sensitivity to desertification in central Iran. Although these traditional models have got a certain range of applications, they are restricted to the complication of variable measurements. As we know, it is not a trivial work to sample all of the variables involving climate, soil, vegetation, and land management. This restriction has prevented the traditional models from achieving more extensive uses. For this problem, RS generally with the strengths of large-area mapping and retrieving different indicators is a sound alternative solution. This was evidenced by the earnest call for developing more RS-based models for desertification monitoring by Albalawi and Kumar (2013).

Development of RS-based models needs to meet higher requirements, particularly when their applicability for desertification trend analysis is also regarded. This is due to that trend analysis is generally based on time-series analysis techniques, whose applications onto RS data, however, have proved to be a contentious issue due to their inherent limitations (Higginbottom and Symeonakis, 2014). Specifically, in order to be considered robust, the methods for time series analysis need to be preset with a lot of assumptions that must be met, such as independence of the dependent variable, normality in the model residuals, consistency in the residual variance over time, and independence in residuals (De Beurs and Henebry, 2005). Due to the effects of spatial autocorrelation (Gaughan et al., 2012) and temporal correlation (Philippon et al., 2007; Richard et al., 2012), it is often difficult to satisfy these assumptions. For example, the consistency in residual variances is heavily impacted by anomalous and outlier values, e.g., those caused by climatic oscillations (Wessels et al., 2012), and even may be broken. Thereby, the problems potentially involving trend analysis (Higginbottom and Symeonakis, 2014) needed to be simultaneously considered in development of RS-based desertification analysis models.

In light of the shortages of merely retrieving indicators for desertification monitoring and the strict demands for the task of trend analysis, the objectives of this Part II include: (1) to develop a comprehensive RS information model (RSIM) for desertification risk assessment, via synthetically using the representative indicators already retrieved in Part I, and (2) to seek reliable methods that fit the character of the proposed RSIM model for deriving the desertification trends in the study area during 2000–2009. The schematic workflow of this study and its link

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