INTEGRATION OF INSAR AND GIS FOR AN ESTIMATION OF GROUND SUBSIDENCE SUCCEPTIBILITY

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1. INTRODUCTION

Studies on coal mine subsidence using GIS-based models [1],[2],[3] and radar application techniques [4],[5],[6] have made substantial improvements independently during recent years. However, a combined use of the two approaches has rarely attempted. In this study, we examine the applicability of space-borne radar measurements of subsidence combined with GIS analysis to the prediction of locations vulnerable to ground subsidence over underground coal mines. While DInSAR provides the information of geological hazard occurrences, GIS incorporated with a hazard prediction model provides potential hazard occurrences. Therefore, there is a great advantage to integrate InSAR and GIS for hazard map construction and long-term monitoring. Here L-band SAR data is used for detection of subsidence locations, and this study is thought to instigate the use of X-band SAR system for the studies on the coal mine subsidence. Especially, KOMPSAT-5, a Korean X-band SAR system, which is supposed to be launched in 2010, is expected to be utilized aggressively in this field.

2. STUDY AREA AND METHODOLOGY

The study area is an underground coal mine in Taebaek City, Korea. It locates at an eastern mountainous coalfield which was the largest coal producer in Korea and composed of sedimentary rocks from the Carboniferous to the Triassic age. For the study area, surface deformations occurred in early 1990s were first observed by JERS-1 L-band radar interferometry, and the detected locations were used for a subsidence hazard prediction model in association with GIS analysis. A probabilistic model and a fuzzy combination operator were used to produce a coal mine subsidence hazard map. The predicted hazardous areas are then verified by other sets of InSAR data acquired about fifteen years later then the initial observation period.

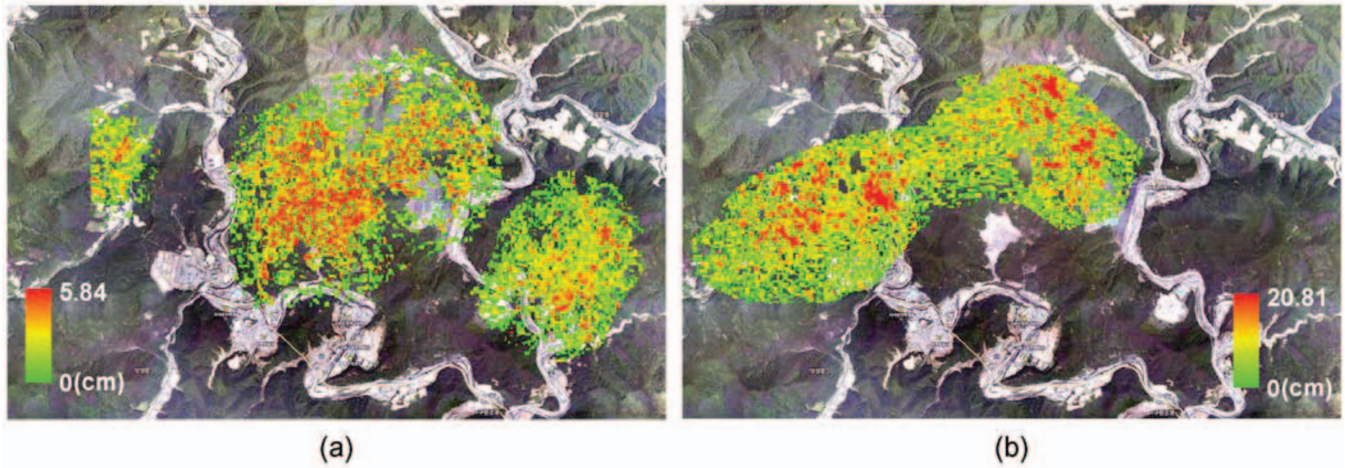

Fig. 1 LOS deformation maps (a) from 1992/11/04 to 1993/12/05 generated from JERS-1 85/238 orbit and (b) from 2007/01/11 to 2008/12/01 generated from ALOS 425/730 orbit SAR interferometry overlaid on an aerial photograph (www.daum.net).

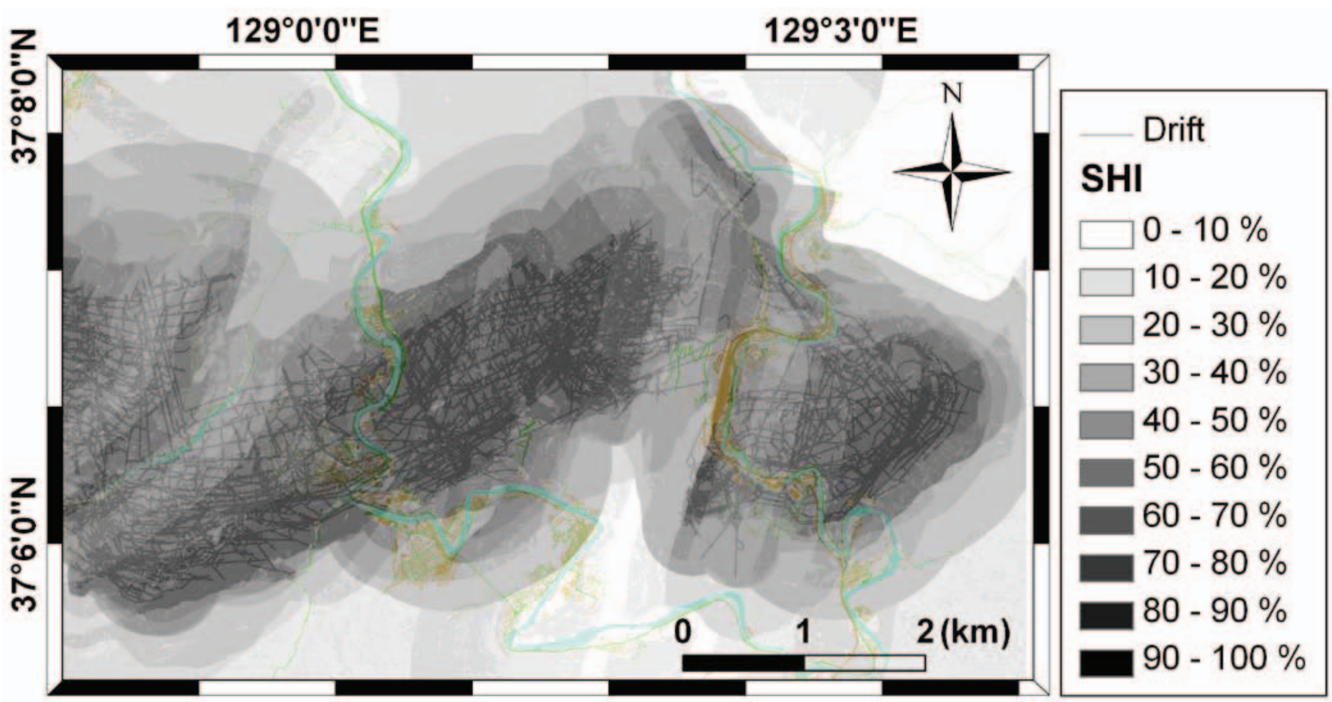

Fig. 2 Subsidence hazard map using a fuzzy algebraic product operator classified into 10.

3. SUBSIDENCE OBSERVATION BY INSAR

Surface deformations of early 1990s between November 1992 and December 1993 were observed from the JERS-1 data (Fig. 1a) using SBAS (Small Baseline Subset) algorithm [7],[8], and those occurred between January 2007 and December 2008 were similarly obtained from the ALOS PALSAR data (Fig. 1b). To confirm whether the surface deformations observed by space-borne L-band SARs are true ground subsidence or not, verification was done by carrying out field surveys with a GPS at the detected deformations to identify subsidence. Several large-scale subsidences were observed at the sites where the deformation was observed by JERS-1 data in the early 1990s, and small-scale ground subsidences were also observed especially at the deformation detected sites in 2007-2008. So, the surface deformation observed by JERS-1 and ALOS SAR are reasonable to be considered as true ground subsidence caused by the mining operation in the study area.

4. COAL MINE SUBSIDENCE HAZARD MAP

In this research, four control factors including surface geology, underground drifts, distance from faults, and ground slope were considered as influencing ground subsidence occurrences. CF analysis, one of probabilistic models [9], was applied to the calculation of the spatial relationship between the location of subsidence detected by InSAR in early 1990s and the control factors, and the results were used as relative weight of each control factor. The relative weight of each factor was converted into the fuzzy membership values [10],[11] in the range [0, 1]. After calculating the final fuzzy membership values of all input spatial data, they were integrated using a fuzzy combination operator as the single membership value for each pixel in the study area. The single value of each pixel in the integrated map indicated the relative degree of subsidence hazard, which can be considered as subsidence hazard index (SHI), and the integrated map was a coal mine subsidence hazard map [1]. The higher SHI value of the subsidence hazard map is an area vulnerable to subsidence associated with coal mine. The generated hazard map was validated using ALOS PALSAR data acquired about fifteen years later than the original JERS-1 SAR observation. The area under curve method [12] was applied to the calculation of the prediction accuracy. The result was 72.5 % accurate, which supported the reliability of prediction.

5. CONCLUSION AND DISCUSSION

The quantitative prediction of locations vulnerable to coal mine subsidence have mainly been carried out based upon field surveyed data. However, field surveys for subsidence occurrences have been limited to the residential areas and national infrastructures. This study demonstrates that the radar interferometry is a complementary tool to observe the ground subsidence in that case. This study is specifically meaningful in that a subsidence hazard map was produced by GIS analysis based on the data acquired from radar observation in the early 1990s and it was then verified by using the data observed about 15 years later.

L-band SAR system was used in this study, however, there is a limitation of spatial resolution to detect the subsidence because the most coal mine subsidence in Korea occurs in small scale. So, the more high resolution of SAR, for instance X-band system is required for more practical use of remote sensing in studying coal mine subsidence. This study is expected to instigate the application of KOMPSAT-5, a Korean X-band SAR system, which is to be launched in 2010, to the detection of the ground subsidence.

6. REFERENCES

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