Detecting Illegal Mining Activities Using Dinsar

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SUMMARY

The city of Zonguldak is located at the center of the biggest underground mining basin of Turkey. In this basin, hard coal extraction has been officially carried out by Turkish Hard Coal Enterprise (TTK) and some private companies authorized by TTK. According to official records, coal productions are driven between the heights of +155 m and -550m and the yearly production is about 3 million ton. However, there are also numerous illegal productions in different places of the basin. These illegal activities not only shortchange TTK economically and threaten life and property safety. To determine and prevent the illegal activities, routine controls on the field are carried out by the TTK officers, but satisfactory results can not be achieved by the traditional methods due to rough and heavily forested terrain.

This study suggests using Space-Based Differential InSAR (D-InSAR) to detect the illegal mining activities in the Zonguldak hardcoal basin. Considering the study area environed with forests, the proper choice for detecting illegal mines is to use SAR sensors providing L-band data which can penetrate vegetation and go through the ground surface. For that reason, JERS-1 data archives has been applied and obtained two SAR images acquired in 1995 for conducting a pilot study. InSAR processing of the images has been resulted phase anomalies caused by surface deformations at different locations of the basin. Some locations at which the deformation anomalies obtained correspond to the areas where the legal activities have been carried out, but some don't. These areas were explored to define the possible reasons of the surface changes, some mine activities were determined at some of the fields.

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1. INTRODUCTION

The city of Zonguldak is located at Western Black Sea coast of Turkey, 330 km east from Istanbul and 270 km north from Ankara (Fig. 1). Its population is about 200.000. The city has a rolling and steep topography; altitudes range from 0 to 100 meters from the coastal plains to inland. The terrain is heavily forested in the immediate vicinity of the city center.

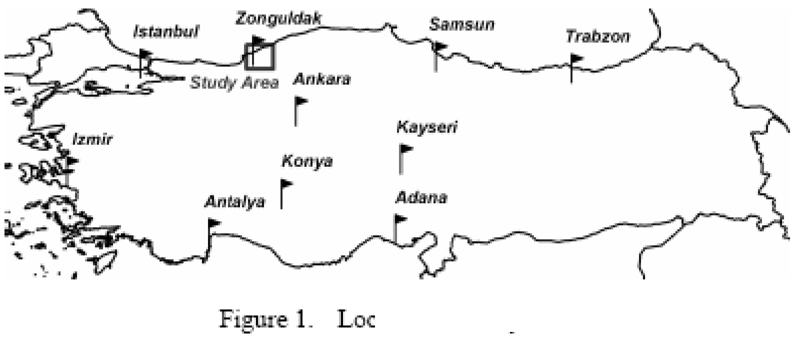

Figure 1. Location of the study area [1]

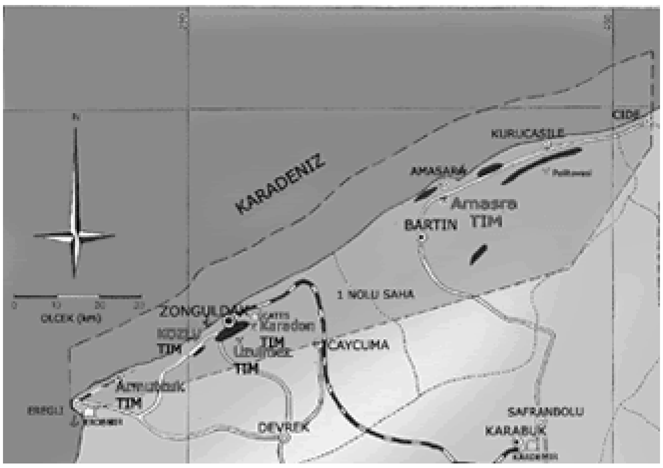

Figure 2. TTK hard coal basin [2]

This city is the major center of coal production in Turkey (Fig. 2). In this basin, hard coal production started in 1848 has been officially carrying out by Turkish Hard Coal Enterprise (TTK) and some private companies authorized by TTK. According to official records, coal productions are driven between the heights of +155 m and -550m and the yearly production is about 3 million ton; total production has been reached 400 million ton since 1848. However, there are also numerous illegal coal productions in different places of the basin. These illegal activities not only shortchange TTK economically and threaten life and property safety. To determine and prevent the illegal activities, routine controls on the field are carried out by the TTK officers, but satisfactory results can not be achieved by the traditional methods due to rough and heavily forested terrain.

In this study, a pilot study using Space-Based Differential InSAR (D-InSAR) has been performed to detect the illegal mining activities in the Zonguldak hard coal basin. Considering the study area environed with forests, the proper choice for detecting illegal mines is to use SAR sensors providing L-band data which can penetrate vegetation and go through the ground surface. For that reason, JERS-1 data archive has been applied.

2. MINING INDUCED SUBSIDENCE EFFECTS

Underground coal mining is performed in the uppermost brittle part of the Earth's crust. This part has a very susceptible stability formed over millions of years. During the mining activities, a large amount of mass is extracted from driven mine seams and large spaces are constituted below ground. Hence, the susceptible stability of the uppermost crust is damaged and a slow motion so-called subsidence is triggered from the depth of coal seam to the earth surface (Fig. 3).

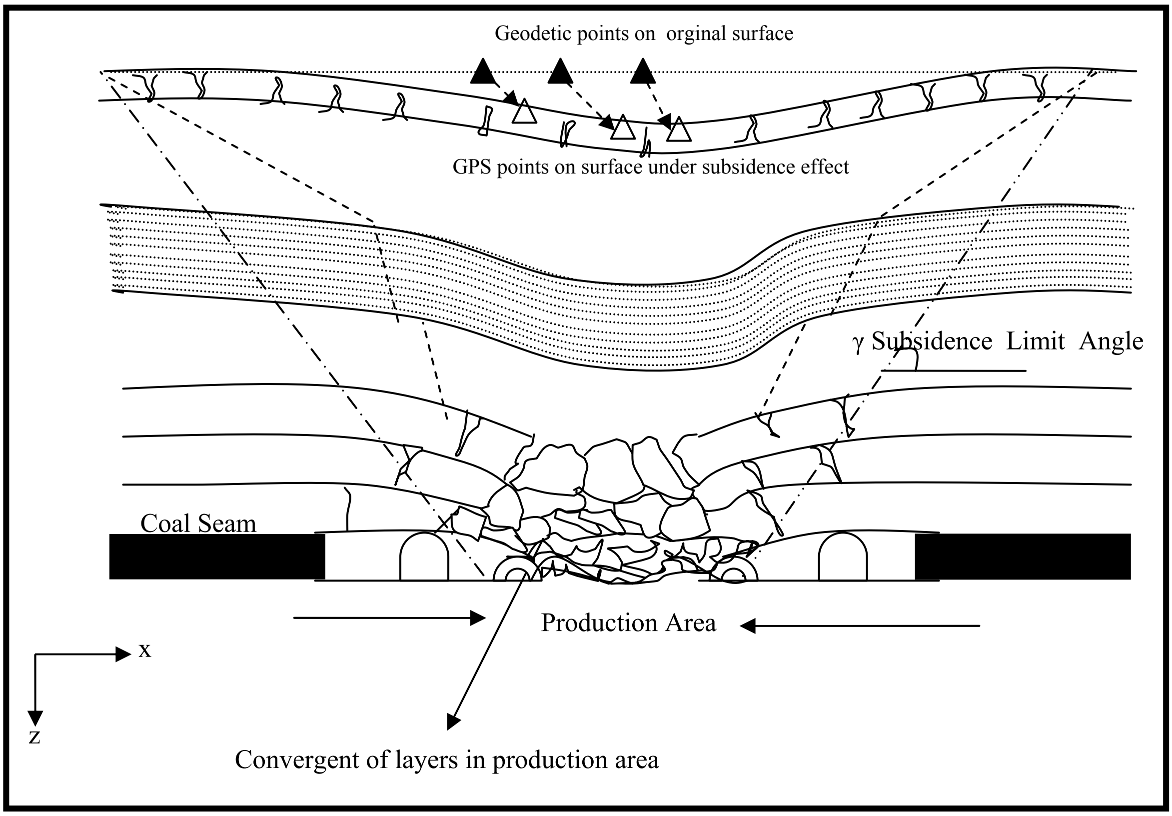

Figure 3. Mining-induced subsidence constitution [3]

The subsidence induced at the depth of mine seam affects a wider area on the surface. The width of the surface area under the subsidence effect and the amount of displacements in this area depend on the geological structure of the ground and the geometry of the production panel such as depth, width, length, thickness and inclination. In most cases, the subsidence progress on the ground can not realize with visual sense, but detect by the geodetic methods such as GPS, Differential InSAR etc.

3. JERS-1 DATA AND DATA PROCESSING

As stated in Introduction the Zonguldak basin is environed with heavily forests. In such a case, L-Band InSAR data becomes the most proper choice to detect the surface changes because microwaves in L-Band can penetrate vegetation and go through the ground surface. For that reason, data archives of JERS-1 SAR sensor were decided to use for the pilot study.

JERS-1 satellite mission was ended in 1998; therefore, two data acquired on September 29th and May 20th, 2005 were used for Master and Slave image, respectively. The time gap between both images is 132 days.

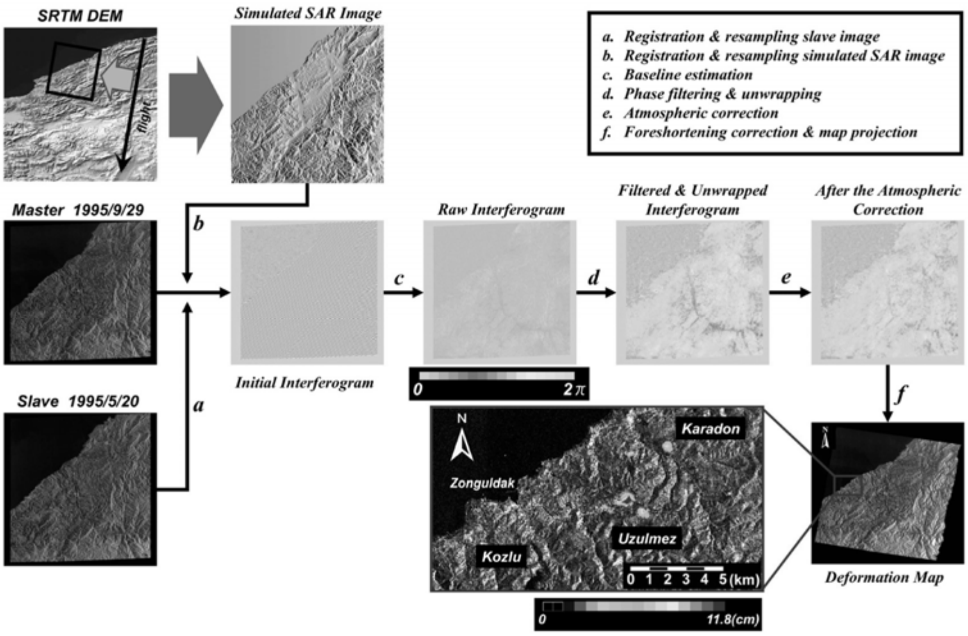

Figure 4. Scheme of InSAR processing [4]

Comparing both SAR images was resulted in phase anomalies expressed by

$$\phi = \phi_{orbit} + \phi_{topo} + \phi_{atm} + \phi_{def} + \phi_{noise} \qquad (1)$$

where ϕ_{orbit} is orbit fringe caused by baseline distance between two observations, ϕ_{topo} is topographic fringe with respect to terrain, ϕ_{atm} is a phase delay caused by reflection of microwave in water vapor layer, ϕ_{noise} is noise component caused by temporal and spatial decorrelation associated with baseline distance or changes in scattering characteristics and ϕ_{def} represents the amount of surface deformation between two observation periods [5].

ϕ_{orbit}, ϕ_{topo}, ϕ_{atm} and ϕ_{noise} have been eliminated during the InSAR processing, and the deformation phase anomalies ϕ_{def} has been obtained. Fig. 4 shows the scheme of the InSAR processing applied.

4. RESULTS

After processing JERS-1 SAR data significant deformation phase anomalies have been detected in the five location of the Zonguldak basin (Fig 5). One of them coincides with the Kozlu region, one with the Karadon and three with the Uzulmez region.

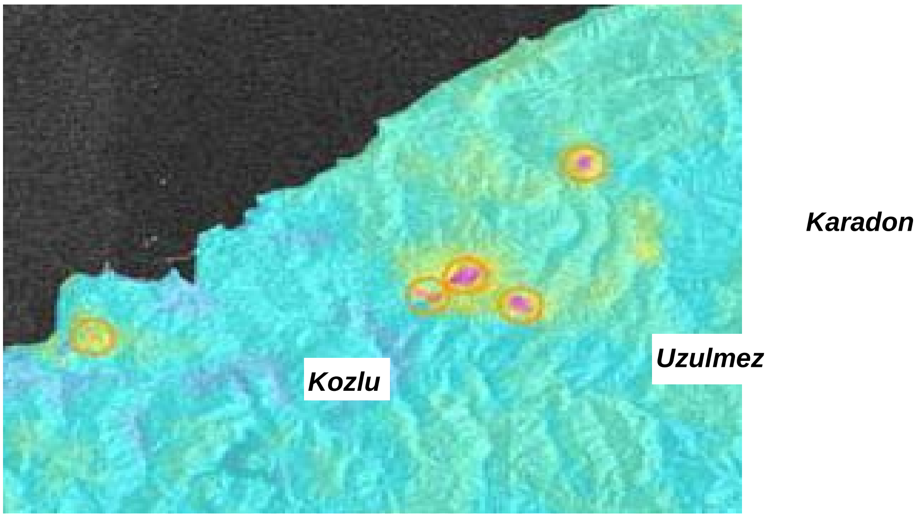

Figure 5. Deformation anomalies obtained from JERS-1

The largest surface deformation has been detected in the Kozlu region with 204 mm. As for the Uzulmez and Karadon, surface deformations over 130 mm have been observed.

The topography of Zonguldak is very steep, so sudden landslides can be experienced there. The surface deformations detected can, therefore, not be considered in advance that they are mining-induced. For that reason, the map archives of coal production of TTK have been investigated, and the deformation zones in Kozlu and Uzulmez have been confirmed as the localities that the legal mining activities were carried out beneath during 1995. However, according to the production maps, the zone in Karadon is outside of the legal production areas. In order to determine the source of the deformation, we explored the zone, and were confronted with the scene in Fig. 6. As this mining activity are not documented in the TTK production maps it is condidered to be an illegal activity, but for the exact decision the production of the private companies must be investigated.

Figure 6. Illegal mining activity detected in Karadon region

5. CONCLUSION

It is fact that Diferential InSAR (DInSAR) is a quite effective tool to monitor surface deformations. As the underground mining activities cause subsidence effects on the ground they can be detected by DInSAR. This means it is possible to guess the localities in which illegal activities are conducted. Using this method, illegal activities can be contended more successfully and economically than the routine field control. This pilot study has been fulfilled to show the effectiveness of the technique on this issue. For future works, a cooperation with TTK will be looked for. If it can be constructed, monitoring will be continued by L-Band Palsar data because JERS-1 mission was ended in 1998.

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BIOGRAPHICAL NOTES

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