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MULTITEMPORAL SOIL MOISTURE ESTIMATION USING C-BAND SAR IMAGES

D.Amarsaikhan[1], G.Bolor[1], V.Battsengel[2] and B.Bayarbaatar[1]
[1]Institute of Geography and Geoecology, Mongolian Academy of Sciences
Ave.Enkhtaivan-54B, Ulaanbaatar-51, Mongolia
[2]Department of Geography, National University of Mongolia
Ikh Surguuliin gudamj-6, Ulaanbaatar-46, Mongolia
Email: amar64@arvis.ac.mn

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ABSTRACT: The aim of this study is to estimate multitemporal volumetric soil moisture content near Ulaanbaatar, the capital city of Mongolia using the backscatter values of ERS-2 and Envisat C-band images. Overall, the study demonstrates that the C-band synthetic aperture radar (SAR) data sets can be used for the investigation of general soil moisture condition, however, for thorough investigation accurate ground sampling is necessary.

1. INTRODUCTION

Soil is defined as the top layer of the Earth's crust and is formed by mineral particles, organic matter, water, air and living organisms. Moreover, soil is a major component of the Earth's ecosystem and it is impacted in far-reaching ways by the processes carried out in the soil, from ozone depletion and global warming, to forest destruction and water pollution. As soil formation is an extremely slow process, it can also be considered as a non-renewable resource. The interface between the earth, the air and the water soil performs many important functions such as food and other biomass production, storage, filtration and transformation of many substances including water, carbon and nitrogen. The air that soil contains is dependent on the soil type and soil saturation level is reached when the volume of air in the soil is higher and the density of the soil is lower (ECD, 2015).

The moisture content in the soil surface layer is very important parameter for different environmental applications, including hydrology, water cycle, agriculture, natural risk assessment, hydrogeology, geomorphology and sub-surface sensing. Soil moisture is one of the few directly observable hydrological variables which play a vital role in the water and energy budgets necessary for environment and climate related studies. The accurate retrieval of soil moisture data is of considerable importance in variety of different applications as to observe the effect of climate change on land surface hydrological variables, enumerate the amount of regional water resources in water limited regions as well as examine the impact of adjustment of the derived land surfaces variables, and so on (Baghdadi *et al.* 2007, Wang Baghdadi *et al.* 2011).

Radar systems emit pulses and receive echoes backscattered from the ground. The intensity value of each pixel is proportional to the radar backscattering coefficient, which in turn depends on several factors. The potential of the microwave backscatter values for the estimation of the soil moisture and surface roughness has been recognised for a long time (Weimann *et al.* 1998, Tansey and Millington 2001, Amarsaikhan and Ganzorig 2002, Baghdadi *et al.* 2007, He *et al.* 2014). The backscatter of soil is mainly dependent on the surface roughness, texture, existing surface patterns, moisture content, as well as wavelength and incident angle. The presence of water strongly affects the microwave emissivity and reflectivity of a soil layer. At low moisture levels there is a low increase in the dielectric constant. Above a critical amount, the dielectric constant rises rapidly. This increase occurs when moisture begins to operate in a free space and the capacity of a soil to hold and retain moisture is directly related to the texture and structure of the soil (Amarsaikhan *et al.* 2005).

In general, the use of SAR data for soil moisture estimation is more complex because of the strong non-linear effects of surface roughness and vegetation cover. For the sharply changing landscapes consideration of topographic normalization is necessary, while for the vegetated areas consideration of longer wavelength is important. Within the framework of this study, estimation of the soil moisture content has been carried out simplifying all of the existing complexities. For the study, 10 ground samples having different moisture conditions have been selected on the basis of the availability of the ground truth data and local knowledge about the area and for the soil moisture estimation a group of pixels selected from non-vegetated flat areas presented in grey scale values were used.

2. STUDY AREA AND DATA SOURCES

As a test site Ulaanbaatar, the capital city of Mongolia situated in central part of the country has been selected. The city is located at about 1,350m above mean sea level on the Tuul River, in a valley at the foot of the Bogdkhan Mountain. The Bogd Khan Uul is a broad, heavily forested mountain rising 2,250m to the south of the capital city. It forms the boundary between the steppe zone to the south and the forest-steppe zone to the north. The Ulaanbaatar city features nice warm summers in between the end May and beginning of September, and long and dry winters. The coldest winter temperatures are usually in January at the time just before sunrise with no wind, due to temperature inversion. Most of the annual precipitation of 267 mm falls from June to September and the highest recorded precipitation in the city was 659 mm (Mongolian Statistical Year Book, 2015).

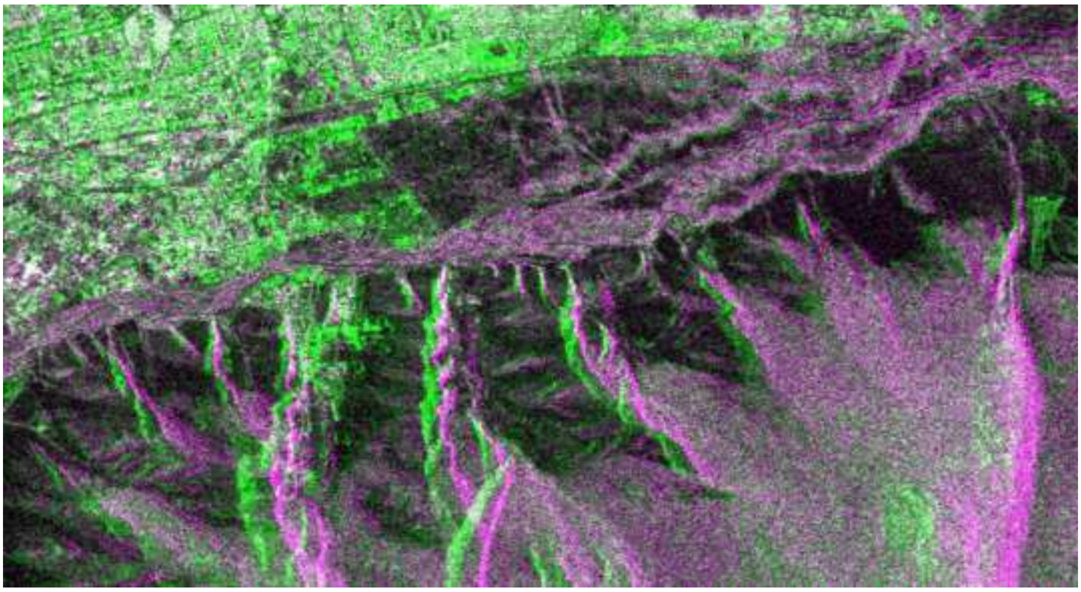


Figure 1. The combined ERS-2 and Envisat SAR images of the test area.
(Red= ERS-2, Green= Envisat, Blue= ERS-2).

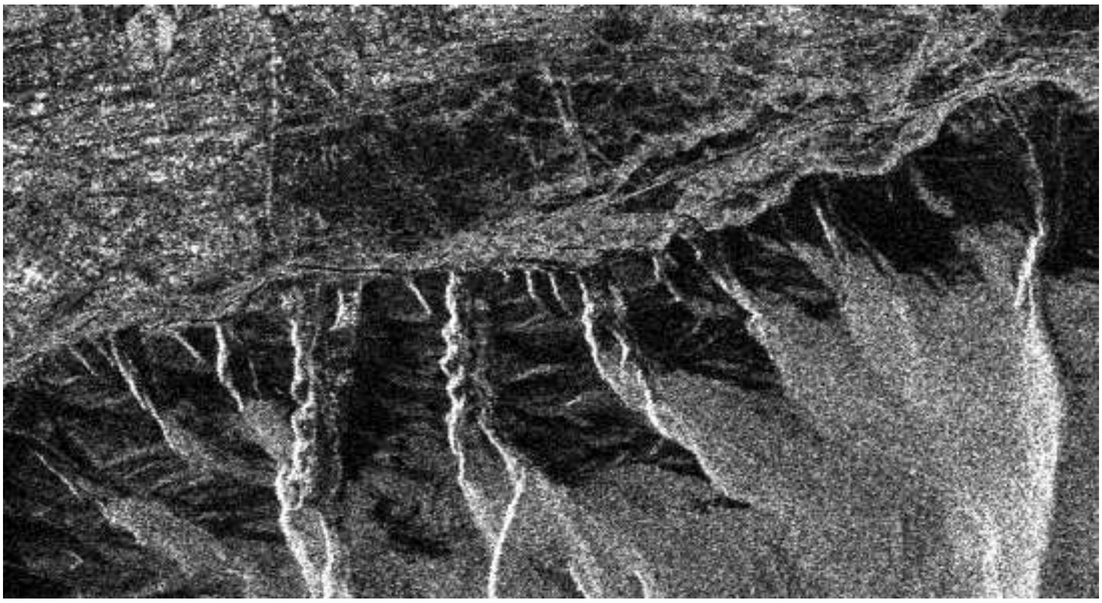
As the microwave data sources, ERS-2 SAR VV polarization C-band data with a spatial resolution of 25m acquired on 25 September 1997 and Envisat SAR HH polarization C-band data with a spatial resolution of 25m acquired on 24 September 2010 were used. In addition, a topographic map of 2000, scale 1:10,000 and a soil map of 1986, scale 1:100,000 were available. Moreover, to support the ground truth checking multispectral SPOT and Landsat images were available. Figure 1 shows the selected test site in a color image created by the use of the ERS-2 and Envisat SAR images.

3. SOIL MOISTURE ESTIMATION

In general, for the estimation of the relationship between the backscatter and soil parameters, (volumetric) soil moisture is calculated from the soil moisture samples and then related to the backscatter coefficients. Also, in most cases radar backscatter values expressed in dB are used for determination of the relationship between the SAR backscatter and volumetric soil moisture, because of its easiness to compare with other results. However, in this study, for the proper estimation, there was not available soil moisture data verified on the ground which should be related to the backscatter coefficients. Therefore, for the estimation and comparison of the soil moisture, backscatter values of the both ERS-2 and Envisat SAR images have been used (Figure 2a,b).

In the present study, the spot areas used in Amarsaikhan and Ganzorig (2002) have been selected. Because in those spots the authors evaluated soil moisture conditions using ERS-2 C-band SAR image. In order to have good soil moisture estimation, the samples have been selected only from flat areas, because of its easiness to calculate the local incidence angles. Some samples were mixtures of soil and scattered sparse vegetation that might have been considered in the soil moisture estimation. However, Dobson et al. (1992) stated that the presence of a grass cover and sparse vegetation would have little influence on the backscatter coefficient, attenuating the strength of the backscatter by less than 0.2dB, with soil moisture and surface roughness having the greatest influence on the backscatter. Therefore, because of the sparsely distributed vegetation cover, its influence was not considered here. As could be seen from the analysis, bare soil, soil with sparse vegetation and agricultural (abandoned) fields situated close to the mountainous areas have lower backscatter values related to the less soil moisture while the soil types situated along the rivers or close to the river beds have higher backscatter values related to the increased soil moisture content. When compared the two radar data sets, in most of the spots, the Envisat image had the lowered backscatter values. This could be related to the fact that in recent years, because of the increased temperatures around the city area, the soil moisture had been decreased.

a)



b)

Figure 2. The selected ERS-2 SAR (a) and Envisat SAR (b) images.

4. CONCLUSION

The main goal of this study was to estimate multitemporal volumetric soil moisture content in a test area near Ulaanbaatar city using the backscatter values of the C-band radar images. As could be seen from the analysis, on the basis of knowledge about the land surface and backscattering properties of the earth surface features, it is possible to judge on the soil moisture condition in different sites. Also it was seen that the backscatter values of microwave data sets could be used for the investigation of general soil moisture condition and for the precise estimation, the backscatter coefficients should be related to the soil parameters defined from the soil moisture samples.

REFERENCES

- Amarsaikhan, D. and Ganzorig, M., 2002. Soil moisture estimation using SAR and infrared data. In: Proceedings of the 33rd Conference of the Remote Sensing Society of Japan, Saga, Japan, pp.91-92.
- Amarsaikhan, D., Ganzorig, M. and Battsengel. V., 2005. Knowledge acquisition in C-band and L-band radar frequencies. In: CD-ROM Proceedings of the Asian Conference on RS, Hanoi, Vietnam, pp.DTP4-1_1-4.
- Baghdadi, N., Aubert, M., Cerdan, O., Franchistéguy, L., 2007, Operational mapping of soil moisture using synthetic aperture radar data: application to the Touch Basin, Sensors, 7, 2458-2483.
- Dobson, M.C., L.Pierce, L.Sarabandi, F.T.Ulaby and T.Sharik, 1992. Preliminary analysis of ERS-1 SAR for forest ecosystem studies. IEEE Transactions on Geoscience and Remote Sensing, vol.30, pp.203-211.
- European Commission Directorate (ECD)-General for Environment, 2015, Unit B1: Agriculture, Forests and Soil, In: http://ec.europa.eu/dgs/environment/index_en.htm
- He, B., Xing, M. and Bai, X., 2014, A Synergistic methodology for soil moisture estimation in an alpine prairie using radar and optical satellite data Remote Sensing, 6, 10966-10985, doi:10.3390/rs61110966.
- Mongolian Statistical Year Book, 2015, National Statistical Office of Mongolia, Ulaanbaatar, Mongolia.
- Tansey, K.J. and A.C.Millington, 2001, Investigating the potential for soil moisture and surface roughness monitoring in drylands using ERS SAR data, International Journal of Remote Sensing, vol.22, pp.2129-2149.
- Wang, S.G., Li, X., Han, X.J. and Jin, R., 2011, Estimation of surface soil moisture and roughness from multi-angular ASAR imagery in the watershed allied telemetry experimental research (WATER), Hydrol. Earth Syst. Sci., 15, pp.1415–1426.
- Weimann, A., M.Von Schonermark, A.Schumann, P.Jorn and R.Gunther, 1998, Soil moisture estimation with ERS-1 SAR data in the East-German loess soil area, International Journal of Remote Sensing, vol.2, pp.225-237.