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*Extended Abstract*

# Assessing Surface Soil Moisture in Arid and Semiarid Rangelands Using NDVI and Meteorological Parameters

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## Introduction

Moisture is one of the most important variables in studies and management of soil and water resources. Soil moisture is also a limiting factor for vegetation growth in arid and semi-arid areas. Therefore the vegetation index calculated using satellite images may in some degree reflect the change of soil moisture. Traditional methods and field measurements of soil moisture are costly and time-consuming and cannot properly indicate the spatial variability on a watershed scale. Satellite images provide better spatial resolution data and are especially useful for isolated locations where meteorological observations are sparse. Because of the close relationship between vegetation growth and water availability, the NDVI (Normalized Difference Vegetation Index) is frequently used to study the soil moisture (Tucker & Choudhury, 1987; Townshend, 1994; Wang, 2005).

## Objective

This research assessed the correlation between surface soil moisture, simultaneous and lagged MODIS-NDVI (250m by 250m), and daily meteorological parameters during the growing season (April to August) for the period of 2003-2005 in arid and semi arid rangelands.

## Methodology

Part of the rangelands in the Khorasan province was used as the study area. This study used as the measurements of surface soil moisture, provided at the same time satellite images were taken reference data. The data of surface soil moisture (0-10 cm) in three stations of Mashhad, Golmakan, and Neyshaboor is used. This data was measured in five–day intervals using the weight-temperature method (gravimetric soil sampling) for years 2003, 2004, and 2005.

MODIS sensor images were used due to the economical considerations, availability of images, and high radiometric, temporal, and spatial resolutions. MODIS images were provided by the Iranian Space Agency for the days with measured field data. In order to consider the maximum growth period of vegetation, the five months of April to August considering for this study. This reduced the operational time and increased the accuracy of analyses. After removing dark and unclear images 23 images were selected.

The Normalized Difference Vegetation Index (NDVI) was calculated using the vegetation-sensitive near-infrared (NIR, band1) and visible (VIS, band2) spectral bands of MODIS reflectivity images using the following formula (1) (Rouse et al., 1973):

$$NDVI = (R_2 - R_1) / (R_2 + R_1) \quad (1)$$

where: $R_1$ and $R_2$ are reflectance of band 1 and band 2.

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Radiometric and geometric corrections were conducted by orbital parameters on all images and the images were converted to BIL format and shifted according to the accurate boundary of the Caspian sea. Using the bathymetry map of the Caspian sea atmospheric correction was conducted using the dark pixel method.

For more accurate estimates of the surface soil moisture some daily meteorological parameters such as wind speed, air temperature, rainfall, and evaporation (provided by the Iranian Meteorological Organization) were also used.

**Results and Discussion**

Correlation analysis was conducted in order to determine the relation between NDVI and observed soil moisture data (SMo) in different lag time (5, 10, 15, 20, 25 days NDVI lags from surface soil moisture data) during the study period. Results showed that, NDVI have a delayed response to soil moisture according to the delayed response of vegetations to changes of soil moisture (Wang, et al., 2001). This lag time depends on the type of vegetation and the way of water supply for vegetations (Adegok and Carleton, 2002). By increasing the dependency of vegetation growth to rainfall, the response lag time will be decreased. (Nicholson & Farrar, 1994; Wang, et al., 2001)

Water availability is a critical parameter for vegetation growth in arid and semi-arid regions. This study has selected the 15 days lag model as the best model to estimate the soil moisture using MODIS NDVI in the study area. The climate of the region, selected time limits, and the findings from previous studies also confirm this selection.

$$SM_{o(15)} = -7.236 + 62.843\ NDVI \qquad (2)$$

Since the study area is a pasture region and the short period of the growth for ephemeral plants depends on the surface soil moisture (0-10 cm), the maximum correction of NDVI was observed in the lag time of two weeks. By increasing the lag time (to more than 15 days), the correlation coefficient decreases radically (Figure 1),

Since the meteorological parameters (wind speed, air temperature, rainfall, evaporation, …) have an important effect on the surface soil moisture, introducing these parameters variations in the models produced more accurate models. There was insufficient information to validate the effect of lag times and the individual effect of each of the above mentioned parameters. The regression coefficients of the simultaneous and lagged model (Equation 2) were also very close. Therefore the simultaneous model is from this point of view also more practical and the coincided NDVI for was preferred to obtain the compositional models of NDVI and meteorological parameters (by simple linear regression).

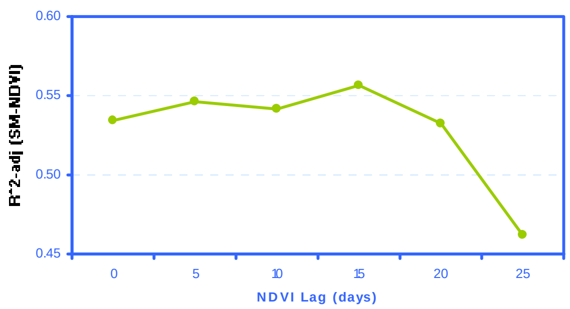


**Figure 1- Correlation between soil moisture and NDVI during the growing season (April to August)**

As observed in Table (1), wind speed and Cumulative evaporation (5 and 10 days) both have negatively strong correlations with surface soil moisture. Wind speed when combined with 5 or 10 days' cumulative evaporation (Ev5 or Ev10) increased the correlation coefficients and produced better regression models.

**Conclusion**

This study showed that the surface soil moisture in semi-arid regions is strongly correlated to the simultaneous and lagged NDVI during the growing season. Surface soil moisture over arid and semi-arid regions and for long periods can be effectively estimated using simultaneous and lagged satellite image-based NDVI and meteorological parameters during the growing season (April-Aug).

**Table 1- Estimation models and Correlations between SMo, Meteorological data and NDVI during April to August**

| | Equation | $R^2$-adj | RMSE |
|---|---|---|---|
| **1** | $SM_o = -2.76 + 42.639\ NDVI - 0.875\ Wind$ | 0.60 | 3.32 |
| **2** | $SM_o = 6.715 + 30.799\ NDVI - 1.025\ Wind - 0.128\ Ev_5$ | 0.66 | 3.09 |
| **3** | $SM_o = 7.713 + 27.917\ NDVI - Wind - 0.07\ Ev_{10}$ | 0.66 | 3.07 |
| **4** | $SM_o = 3.279 + 30.905\ NDVI - 0.056\ Ev_{10}$ | 0.57 | 3.47 |

***Keywords*:** Soil Moisture, NDVI, MODIS, Remote Sensing, Khorasan Province.

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