DESCRIPTION OF ROUGHNESS OF SOIL SURFACE

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Abstract

Soil surface roughness (SSR) introduces fluctuation in the detected energy by the sensor, and produce uncertainty into the actual results of remote sensing. Thus, SSR thereby limit the accuracy in the estimation of surface property. In view of remote sensing, SSR is characterized by roughness parameters such as: RMS surface height, correlation length and auto-correlation function. Further, various topographically dependent hydrologic and erosion processes on arable land such as: storage of water on the soil surface, infiltration capacity, velocity of over-land flow, organization of the drainage pattern are primarily controlled by the SSR. The topographically important SSR parameters are different from remote sensing parameters and are described as roughness parameters of any surface as: ISO 4287:1997. In present investigation SSR parameters regarding, remote sensing and topography of soil surface are studied.

Introduction:

Soil surface characteristics play a key role in different hydrological processes (floods, runoff, evapotranspiration, infiltration). They also drive other processes such as soil erosion, soil contamination by toxic elements, and imbalances in the water and carbon cycles. The geometry of a real surface can be very complex and diverse. Diversity of the surface characteristics may be treated as surface roughness. Effect of geometry is twofold: at wavelength scale it may be termed as micro level roughness and at resolution scale, it is topography or macro level roughness. Quantitively roughness of a surface may be characterized by parameters which are known as surface roughness indices. There are many areas of use of the earth's surface, such as: agriculture, remote sensing and habitation etc. Particular field is associated with its own set of roughness indices and it isn't necessary that two different field contain same set of roughness indices. In present investigation roughness parameters corresponding to remote sensing and topographic domains are studied.

Roughness parameters of soil surface in view of remote sensing:

In passive and active remote sensing electromagnetic radiation, radiations radiated /scattered from soil surfaces are detected at the distant radiometer/Scatter meters. The microwave radiometer is one of the passive sensors and scatterometers are active remote sensing instruments like radars. The observable parameter at the sensor in passive remote sensing is the emissivity, while in case of active remote sensing it is radar backscattering coefficient. Because sensors have the capability to provide high spatial resolution of the order of tens of meters and are more sensitive to surface roughness, to obtain genuine inference from remote sensing observations, the removal of perturbing effects are essential. However, it is difficult to develop a removal method without the knowledge of surface characteristics.

Soil roughness can be considered as a stochastic varying height of the soil surface towards a reference surface. This reference surface can either be unperturbed surface of a periodic pattern or mean surface if only random variations exist. Surface roughness characteristics generally have been described in terms of three important parameters, namely: (i) RMS height[1] (ii) Roughness correlation length and (iii) An auto correlation function of rough surface. The RMS height and correlation length are statistical parameters commonly used in the description of surface roughness and correspond to the vertical-scale roughness and horizontal-scale roughness, respectively and their ratio is proportional to the RMS slope of the surface.

Roughness characteristics of soil surface:

1. RMS surface height: The root mean square (RMS) height describes the variation in surface elevation above an arbitrary plane. Obviously, the greater spread of height measurements means the greater value of RMS height. It represents the standard deviation of the distribution of surface heights. Thus, it is an important parameter to describe the surface roughness by statistical methods. This parameter is more sensitive than the arithmetic average height. It is an estimation of the variance of the vertical dimension in the test surface. The RMS height of a surface can be measured by pin profilometer for agricultural areas[2] and its value generally is in the range 0.25 cm (sown fields) - 4.0 cm (ploughed fields).

2. Correlation length: Correlation length describes the uniformity of the height over finite distances along the surface. The maximum distance over which significant correlation occurs is known as correlation length[1]. In other words, the correlation length can be defined as the distance between two independent points exist at profile. For natural surfaces, as the distance increases, autocorrelation decreases. Smoother surfaces generally have large correlation lengths while rougher surfaces have low values of correlation lengths. A profile of white noise (perfectly rough surface such that two nearly located points have not any correlation) has correlation length equal to zero while a straight horizontal line has correlation length equal to infinity. The correlation length describes the horizontal distance over which the surface profile is autocorrelated with a value larger than 1/e (≅ 0.368). Correlation length in agricultural areas generally varies from 2.0 to 20.0 cm. Using a 1-m profiler, ÁlvarezMozos et al[3] measured average correlation lengths in the range 2.44 (for rolled surfaces) - 7.41 cm (for ploughed fields).

3. Slope: Ratio of RMS height to correlation **length** gives us a measure of the slope of the terrain. In radar scattering models, the roughness of surfaces is defined as the ratio of RMS height σ to autocorrelation length or some variant of this ratio. Campbell & Gravin[4] suggested that this ratio is termed as effective slope of the surface.

4. Autocorrelation function: If the surface roughness is independent of the view direction, the correlation coefficient (ρ) is said to be isotropic, depending on a single parameter (ξ). The normalized autocorrelation function (ACF) for lag (ξ) is related to the spatial resolution of the profile and given by:

$$\rho(\xi) = \frac{\sum_{i=1}^{N-j} z_i z_{i+j}}{\sum_{i=1}^{N} z_i^2}$$

where, lag(ξ) represents a roughness character of a step of surface or segment. For isotropic surfaces, ξ is a function of a single horizontal parameter x or y. Generally, for real surface, ξ is a function of x and y both. Thus, $\xi = j\Delta x$, where, Δx, is the spatial resolution of the profile, and j, is particular number of profiles of extended surface. The ACF can be calculated as the inverse Fourier transformation of the power spectral density[5]. In backscatter models, often three types[5] of ACFs are used, *i.e.* exponential and Gaussian and 1.5 Power. The exponential ACF describes the smooth natural surfaces while the Gaussian ACF correlates rough surfaces and the 1.5 power ACF is an important roughness function suitable for real surfaces. For agricultural fields, however, different studies reveal that the ACF was well approximated by exponential correlation functions.

Wegmuller et al.[6] have shown that the exponential correlation function usually gives a better agreement with the observed correlation function than the Gaussian correlation function for agricultural fields. The observed correlation function for natural surfaces is Gaussian while for agriculture surfaces, it is exponential.

Roughness parameters of soil in view of topography:

Study of roughness of soil surface in view of topography is important due to various hydrologic and erosion processes (floods, runoff, evapotranspiration, infiltration). They also drive other processes such as soil erosion, soil contamination by toxic elements, and imbalances in the water and carbon cycles. Soil roughness determines the storage of water on the soil surface and may indirectly influence its infiltration capacity.

The term soil roughness is used to describe disturbances or irregularities in the soil surface at a scale which is generally too small to be captured by a conventional topographic map or survey. Römkens and Wang[7-8] make a distinction between four types of roughness: (i) microrelief variations, which are due to individual grains or micro-aggregates, (ii) random roughness, which is related to soil clodiness, (iii) oriented roughness, which describes the systematic variations in topography due to farm implements and (iv) higher order roughness, representing elevation variations at the field, basin or landscape level. Studies on roughness and its effects on arable land usually concentrate on random and oriented roughness because these roughness types are far more important than microrelief variations while higher order roughness is adequately described by conventional topographical survey. While analyzing topographically surface roughness, the selection of a measurable, physically significant parameter describing roughness is critical. Here, in present investigation roughness parameters of any surface as: ISO 4287:1997[9] are described. Here, each parameter is classified according to primary profile (P), roughness profile (R), and waviness profile (W) in order to evaluate different aspects of the profile. The parameters are classified in different groups: (i) Peaks and valleys in the height direction. (ii) Average amplitude in the height direction. (iii) Average characteristics in the height direction. (iv) Horizontal direction and (v) Hybrid. Here, peak/valleys are defined for each region that falls above/below the average line. Here, we are describing some important parameters of these groups.

1. Parameters of peaks and valleys in the height direction: (i) Arithmetical Mean Height: Arithmetical mean height indicates the average of the absolute value along the sampling length, when dealing with the roughness profile, this is referred to the arithmetic mean roughness or arithmetic mean waviness for the profile. (ii) Maximum Height of Profile: The maximum height of the profile indicates the absolute vertical distance between the maximum profile peak height and the maximum profile valley depth along the sampling length. (iii) Maximum Profile Peak Height: Maximum profile peak height indicates the point along the sampling length at which the curve is highest. (iv) Maximum Profile valley Depth: Maximum profile valley depth indicates the point along the sampling length at which the profile curve is lowest. (v) Mean height of profile: indicates the average value of the height of the curve element along the sampling length. (v) Total Height of Profile: Total height of profile is the vertical distance between the maximum profile peak height and the maximum profile valley depth along the evaluation length.

2. Parameters of average amplitude in the height direction: (i) Root Mean Square Deviation: Root mean square deviation indicates the root mean square along the sampling length. For the roughness profile, this is referred to as the root-mean-square roughness or root-mean-square waviness for the waviness of profile.

3. Parameters of average characteristics in the height direction: (i) Skewness: It uses the cube of the root mean square deviation to display the dimensionless cube of the sampling length. (ii) Kurtosis: Kurtosis uses the fourth power of the root mean square deviation to display the dimensionless fourth power of the sampling length.

4. Parameters of Horizontal direction: (i) Mean Width of The Profile Elements: Mean width of the profile elements indicate the average value of the length of the profile element along the sampling length.

5. Parameters of Hybrid roughness: (i) Root mean square slope: It indicates the root mean square of the local tilt dZ/dX along the sampling length.

Results and Discussion:

The surface roughness, in the present study, is described as: Roughness of soil surface in view of remote sensing and Roughness of soil surface in view of Topography. In both views, roughness of surface at horizontal and vertical scale of millimeters to a few centimeters is considered. These are the scales with which the agriculturists are most familiar in topography. The same scales also have the greatest effect on the behaviour of scattered and emitted radiation particularly in infra-red and microwaves in active and passive remote sensing. The relationship between roughness and environmental variables such as tillage and soil texture has been extensively studied in past. For smooth surfaces, geometrical variation of surface irregularities and volume discontinuities are small in comparison to wavelength of microwaves. The roughness of agricultural soil surfaces is in decimeter to millimeter range. The roughness of the order of millimeter to decimeter range has the greatest effect on the behaviour of scattered microwaves (radar) and is therefore, of great interest to interpret radar remote sensing data of agriculture. Thus, the present study on the effect of surface roughness at X-band microwave frequencies will be useful for agricultural purposes in the microwave remote sensing.

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