Where space matters, Synthetic Aperture Radar, strategy tool for risk planning.

1- Abstract

This scientific paper explores the applications and advancements of Synthetic Aperture Radar (SAR) technology in efficient land risk planning. SAR is an active remote sensing instrument that utilizes radar waves to capture detailed information about the Earth's surface, regardless of weather conditions, day or night. The paper provides an overview of SAR, discussing its working principle and the information it can extract from SAR images.

The study highlights the diverse applications of SAR in land risk planning. It discusses how SAR can be used with different methodologies and which applications have as crop monitoring, enabling the assessment of crop growth, density, and health by analysing the radar signals reflected from vegetation. The paper also explores the use of SAR for soil moisture detection, which presents challenges due to factors such as surface roughness and polarization. Additionally, the study examines SAR's role in flood detection and water level estimation. Furthermore, the paper explores SAR's capability in motion detection and generating Digital Elevation Models (DEMs) by analysing phase differences in multiple SAR images. It discusses the challenges in detecting movement in densely vegetated areas and the potential of longer waves, such as P-band, for geohazard detection.

This paper show the versatility of SAR technology in land risk planning and emphasizes the need for a compleat approach that integrates different methodologies. It also points the importance of choosing appropriate processing techniques and tools based on specific objectives and regions of interest. The upcoming NISAR mission is identified as a potential game-changer, offering broader data access and revolutionizing land risk planning practices.

Keywords: Synthetic Aperture Radar (SAR), land risk planning, crop monitoring, soil moisture detection, flood detection, motion detection, Digital Elevation Models (DEMs).

2- Introduction human context

In the present day, we have a new perspective of our space and surroundings thanks to new data, information and methodologies of risk planning in remote sensing. We have the highest amount of research going on and enough information to consider the human print through space and the planet. Moreover, we do not consider these tools to integrate a global perspective and local and precise applications. We can extrapolate that in to the distribution of population over the planet respects the resources and the hazard risks. The population is clustered in some specific areas, but the distribution is not randomly distributed around the globe.

The old civilizations were established next to easy energy resources. The easy resources were water, fertile soil, moderate climate and not an extreme relieve. The extension, population and impact of these ancient civilizations were small in comparison to the entire earth surface. Through the decades the energy consumptions were increasing and wood and coal were the main energy consumption. Until the arrival of fossil fuels. With this new energy the population have grown exponentially and also the resources consumption. This large population has habited places that were inaccessible before. So, in order to have a wealthy quality of life for the habitants and the planet we have to think about where and how we are using the resources and locating the population.

The remote sensing can be the clue to an efficient organization and distribution of the population and resources. To be more concrete we will focus our energies on a technique that can have an eye in the sky twenty-four hours a day, acquire images day and night and all the images can be used even though clouds appear on it. We are talking about the synthetic aperture radar (SAR). This powerful technique can be used for different applications in territory planning accordingly to the natural hazards and population distribution. SAR can help to monitor food recourses and the moisture of it soils, detect the flood extension and estimation of water levels and last but not least control of soil motion, over exploded groundwater, land slides and other hazards.

3- Introduction to the technique

SAR is a coherent active remote sensing instrument Figure 1. The sensor works emitting waves of the electromagnetic spectrum (in a pulse) to a target and the wave is reflected and skaters and return to the sensor. SAR sensor is an active remote sensor. This emissivity of energy can be used efficiently in any meteorological and atmospheric condition, as it has their own illumination so can be operational day and night. The sensor acquires information of amplitude and phase of the waves in azimuth and range by a pulsed doppler that coordinates the speed and the position of the signal by the harmonic of the pulse repetition frequency (PRF) that is wide enough to meet but not to overlap the spectrum to able the differentiation of the pulse and establish and image (Ulaby et al., 1982; Wiley, 1965).

The SAR image is a map representation of the scattering properties of the ground surface. The phase in SAR corresponds to the difference between the transition and the signal reception, related with the electromagnetic characteristics of the receptor. The amplitude is related to the intensity of the signal that returns(Bamler & Hartl, 1998).

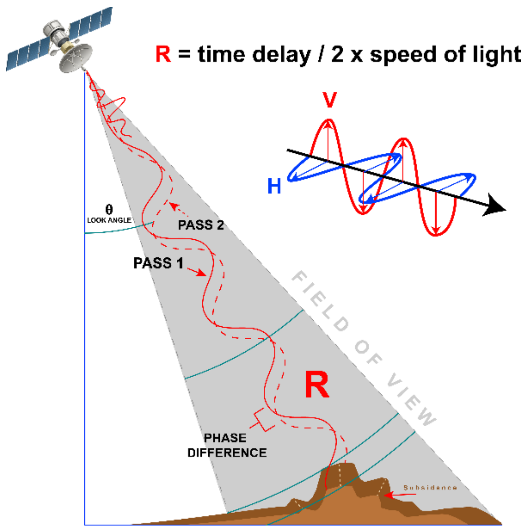

Figure 1: SAR sensor interaction with the target in to different times.

4- SAR applications: land risk planning

As a consequence of its capabilities and different data acquisition modes, SAR technology improved over the last decades, even though the complexity of the data. SAR data has the ability to bee exploited differently. One of the ways to be exploited can be with the different phase polarities. The different direction of the phase and the angle of the wavelength. Also, the phase can be exploited for the detection of the response of the geometry, dielectric characteristic and position on the difference of phase as a digital earth model DEM or deformation detection. Moreover, the SAR data have the intensity or amplitude of the signal. The intensity can be associated with the roughness and the intensity of the signal that is received by the sensor.

The Applications that can be used:

SAR remote sensing is sensitive to the dielectric and geometrical characteristics of the vegetation(Liu et al., 2019). SAR has a penetrating property in to the crops and the canopy, allowing to have a control in it also depending on the sensor band the frequency is sensitive to different vegetation. Higher frequencies can detect the top of the canopy on the other hand lower frequencies have a higher penetration to the canopy, it can obtain information below the vegetation canopy cover(Liu et al., 2019). The clear application with the characteristics mentioned before can be the crop monitoring to test which are the areas were the crops grow faster dense and in better conditions. The crop cycle is paramount to take in account the production of every parcel and the food productivity.

SAR data is challenging in backscattering models, the backscatter has influence of the geometry incidence angle and the roughness wavelength and polarization (Aubert et al., 2013; Foucras et al., 2020). The estimation of bare soil surface moisture requires knowledge of the relationship between the radar signal and the soil moisture regardless of the surface roughness (Aubert et al., 2013). Most studies use dual polarization SAR data and very rarely use full polarimetric SAR data (Gharechelou et al., 2021). The best suited bands for soil moisture retrieval are the one with higher resolution, C- and X-band (Foucras et al., 2020), some studies use L-band which penetrates deeper in to the canopy, but there are less sensors availability for this band(Paloscia et al., 2012; (PDF) Semiempirical Calibration of the Integral Equation Model for SAR Data in C-Band and Cross Polarization Using Radar Images and Field Measurements, n.d.).The soil moisture detection is usually cross ground chequed.

To detect water surfaces it is used also the backscatter of the SAR signal, it content the roughness, dielectric properties and local topography in relation to the radar look angle (Brivio et al., 2002; Clement et al., 2018; Gan et al., 2012). The water body has a specific backscatter, is a specular reflector of the radar pulse, it means a minimum return to the signal at the satellite do to the lack of roughness of the surface (Jung et al., 2010; Schlaffer et al., 2015). In order to delimitate the water bodies different methods are being applied this is include histogram thresholding (Brivio et al., 2002; Brown et al., 2016; Henry et al., 2006), fuzzy classification (Martinis et al., 2015; Twele et al., 2016) region growing (Twele et al., 2016), and texture analysis (Pradhan et al., 2014).

Moreover with the methods listed above it is used a SAR image to generate change detection in landcover by comparing the flood scene with a previous image without flood (Giustarini et al., 2013; Schlaffer et al., 2015). The difference between the images can be combined with other image segmentation techniques to identify areas producing an unusually low backscatter response as the water does. There are some asphalt surfaces than can be confused with water bodies for the lack of roughness. This image combination improves the reliability of the flood delineation compared to the single image methodologies (Matgen et al., 2011). With the flood detection is precise to produce a good post processing of the images and nice visualization to delimitate properly the flooding areas and water levels estimation.

The SAR phase of and image can be used to generate interferograms this neds images in a single look complex SLC . The interferograms are the difference of phase between two images. From the image pixel is possible to extract the part of the phase that is related to the terrain (motion of the terrain). The interferometry can play a key role in the land slide movement and the detection of precursors in deformation of all kind as is sensible to the terrain movements.

In the case of recognising movement in dense vegetation areas, it is very challenging for the InSAR technique to detect movement especially with sensors radars which work on X, C and L bands (Zhang & Lu, 2022). There is a study that exposes that longer waves have better penetration ability, this experiment was conducted by a repeat-pass airborne P band SAR data to detect geohazards over densely vegetated regions in Oregon and California (USA) (Xu et al., 2021). The study previously mentioned had better results with P band than with L band over vegetated areas. P band InSAR could be a revolutionary tool for studying geohazards under dense forest canopies.

Another factor is the processing strategy to use as persistent scatter interferometry (PSI) or small baseline subset (SBAS). This two ways of selecting interferrograms and unwrapping the phase have different advantages. There is one study performed in Southwestern China using Sentinel-1 image (Zhang et al., 2021) sowing the outperforms of SBAS over the study area and could be a fast and powerful method to qualitatively and effectively identify potential landslides in mountainous areas(Zhang & Lu, 2022).

5. Conclusion

We can say that the SAR technology is quite versatile and it is used in many applications related to the land risk plane. The combination of the different methodologies would be further studied to have as much information about our food security and the natural risks surrounding us. SAR can be critical detecting motion or deformation. It seems undeniable that a different approach or different types of band can make a difference. It is critical to use the correct processing and tool for every area of interest and objective to solve. Moreover, future missions like NISAR are enabling users to have access to open data and offering more opportunities which can make a difference in the procedures and investigations. NISAR will also deliver open source data for SAR L band, allowing a more penetrative wavelength through the canopy, vegetation and ground surface. Other benefits could include NISAR’s provision of single look complex images, which allow users to detect movement extracted from the phase. This could be applied to ground motion movements (landslides) under vegetation.

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