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Elevation Angles, Soil Textures, Soil Settlements and Water-Holding Capacity on Landslides: An Experimental Case Study in the Province of Iloilo, Philippines

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Abstract— The soil textures, soil settlements, soil water-holding capacity, and elevation angles are parameters for landslides in the Province of Iloilo. They are usually triggered during heavy rainstorms, causing severe property damage and sometimes causing casualties. This experimental study aims to determine how these parameters are factors for landslides and flood monitoring and uses three methods to provide ease and continuity of measurements. The Fourier transforms infrared (FTIR)spectroscopy analysis for soil textures, the Imhoff cone for the settling and water-holding capacity of the soil, and an improvised apparatus to test how the slopes affect the transportation of soil materials. FTIR Soil analysis reveals that contents of clay and organic matter directly affect soil water-holding capacity due to the larger surface area. The smaller particle sizes, such as clay, have a larger surface area leading to a higher water-holding ability. A landslide-prone zone has a lesser settling time except for the sand that settles fastest due to larger masses. An angle of 20 degrees has more mass movement too much higher slopes like 55 and 85 degrees. The increase in height or angle of the elevation decreases stability, leading to less mass movement. Less mass movement leads to the conclusion that there are rare landslides in the very high slope range due to fewer vibrations or soil movements caused by human activities and being compact or stable. This study is crucial for forecasting and preventing geohydrological processes and developing better landslide warning strategies to mitigate risks and reduce socioeconomic damage.

Keywords— Landslide, FTIR soil analysis, spectroscopy, imhoff cone, elevation

I. Introduction

Landslides are one of the world's geohazards that threaten both exposed areas in urban and rural areas and cause severe consequences on human lives and economic losses. Due to climate change, there is an increase in the frequency and intensity of heavy rainfall along with a shift of locations and recurrence of heavy rain that increases landslide risk in landslide-prone areas. Expansion of urban areas due to population growth, redevelopments of mountains, and shortening of the coastal area caused by roads and railways constructions and deforestation increase exposure to the landslide hazard (Pajalic, Peranic, Maksimovic, Ceh, Jagodnik, Arbanas, 2021). There are so many factors that cause landslides to happen. One factor is soil quality which includes its physical and chemical properties. Second is the soil water holding capacity and settling ability. Lastly, the angle of elevation can be evaluated statistically and interpreted.

A landslide refers to the slow or rapid downward movement of a soil mass due to gravity. It is triggered when the shear stresses developed inside the soil exceed those which can resist. Landslides are caused by the liquefaction of small grain silt sand layers or due to a general failure in combination with increased loads due to an earthquake, increased pore pressure, and reduction in the available shear strength of the soil. In particular, Panay island is prone to typhoons, storm surges, and flash floods which constantly suffer from the effects of the outbreak of such destructive phenomena. For this reason, it is necessary to monitor the sources of landslides, and the mechanisms they present, to proceed with the analysis of stability and the calculation of safety factors (Dariagan, Atando, & Asis, 2021).

On the other hand, the soil is a heterogeneous system, an upper layer of earth in which plants grow, a black or dark brown material typically consisting of a mixture of organic remains, clay, and rock particles. Soil mechanisms and processes are complex and back-breaking for you to be understood and require analytical techniques. Some traditional methods describe the relationship between soil properties such as physical, chemical, and its main soil components. Simple and accurate soil testing procedures in the field and laboratory are necessary for advanced research in landslide monitoring. (Mohamed, Saleh, Belal, & Gad, 2018). The Fourier transform infrared (FTIR) spectroscopy is a unique tool for mineral and organic components of soil samples. The FT Infrared spectroscopy offers a sensitive characterization of minerals and soil organic matter (SOM) and mechanistic and kinetic aspects of mineral–SOM interactions that underlie biogeochemical processes (Margenot, Calderón, Goyne, Mukome, & Parikh, 2017). FTIR

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spectroscopy has been used in advanced research in soil composition properties for characterizing soil mineral components, including mineral identification, structural assessment, soil quality, and in situ monitoring of pedogenic processes (e.g., mineral formation) for landslide monitoring (Margenot. et al., 2017).

Also, the Imhoff cone tests for soil-settling and water-holding ability estimate erosion ranging from loam to loamy sand in texture as a predictor of soil erosion and sediment concentration affecting land fields and human livelihood (Sojka, Carter, & Brown, 1992).

The soil water-holding ability depends on two factors, precipitation patterns, and holding capability. Changes in weather or region precipitation patterns and the amount of water a soil can hold cause a landslide. The holding capacity of water within the pores of soils depends on capillary action and the size of the pores that exist between soil particles. Sandy soils have large particles and large pores that do not have a sizeable ability to hold water making sandy soils drain excessively. Clay soil has small particles and pores that can hold water that tend to have a high water-holding capacity (Margenot, Calderón, Goyne, Mukome, & Parikh, 2017).

On the other hand, a slope or angle of elevation is between the horizontal line and the line of sight where these two straight lines meet at a common point. The slopes or elevation angle have importance in terms of the formation, development, and susceptibility to landslides and a measurement of surface steepness range of zero to ninety degrees, where 0 represents a horizontal area and 90 represents a vertical area (Çellek, 2020, Yılmaz, Topal, & Süzen, 2012). Çellek (2020) stated that the slope or the angle of elevation affects the measured speed and flow of water and other materials, causing a relationship between slopes and landslides. He also stated that in most studies regarding the slope or elevation angle, the classification intervals belonging to the slope values are taken separately to determine the intensities of landslides in the study area. Researchers believe that landslides occur between 30 and 40 degrees or above 25 degrees, while others believe lower than 30 degrees. From the three parameters of this research study, it is possible to say that slope is the most influential and essential parameter of landslide monitoring. The effect of choices of slopes, soil components, and settlement ability are sources of evaluation discussed differently to attain an accurate result that can help lessen the outcome of landslides and floods in the chosen study area.

This research study aims to determine how parameters like the slope/angle of elevation, soil textures, soil water holding capacity, and settlement ability are factors for landslides and flood monitoring that cause billions of property destructions. In this study, the three methods provide ease and continuity of measurements and setting parameters for landslide monitoring. The first method is the Fourier transforms infrared (FTIR)spectroscopy for soil components to provide accurate and valid identifications of soil components investigated. It aimed to identify soil components to ensure that the quality of soil tested in the laboratory is also a factor for soil erosion leading to landslides. The use of the Imhoff cone for the settling and water-holding capacity of soil to test how much the soil samples can hold water. With five soil samples, added water for settling sediment and water-holding volume capacity with the Imhoff cones where samples with different textures were collected from places in the flooded area here in Iloilo province as soil sediment material. Lastly, identify the slope or angle of elevation where landslides occur by using an improvised apparatus to test how the slopes affect the transportation of soil material by controlling the progression speed and motion distance.

Fourier Transform Infrared (FTIR)Spectroscopic Analysis of Soil Textures

In recent decades, most studies have focused on soil components like organic matter, texture, and mineralogy (Hassani, Bahrami, Noroozi, & Oustan, 2014). Nandiyanto, Oktiani, & Ragadhita (2019) stated that Fourier transforms infrared (FTIR) is one of the advanced analytical techniques for researchers to characterize samples in liquids, solutions, pastes, powders, films, fibers, and gases. FTIR analysis is also for analyzing the material on the surfaces of the substrate that is rapid, accurate, and relatively sensitive (Jaggi & Vij 2006). In the FTIR procedural analysis, samples with infrared (IR) radiation affect atomic vibrations of molecules that result in the specific absorption and transmission of energy, making the FTIR determines specific molecular vibrations contained in the sample. The infrared (IR) spectrum has three wavenumber regions: far-IR spectrum (<400 cm-1), mid-IR spectrum (400-4000 cm-1), and near-IR spectrum (4000-13000 cm-1). Mid-IR is the most widely used in the sample analysis, but the far- and near-IR spectrum also provides information about the samples analyzed. In this study, the researcher used the mid-IR wavelength that is into four regions; the single bond region (2500-4000 cm-1), the triple bond region (2000-2500 cm-1), the double bond region (1500-2000 cm-1), and the fingerprint region (600-1500 cm-1).

In imaging spectroscopy, the spectroscopic modes emitted electromagnetic energy from a light source collides with the given phenomenon, light rays were absorbed, reflected, and the other part passed through it. Spectroscopy is a quantitative calibration of reflection, absorption, or passing. One of the advantages of Fourier transforms infrared spectroscopy is that this is a non-destructive technique with no hazard or destruction to the environment (Guerrero, Viscarra, & Mouazen, 2010). Fourier transform Infrared spectroscopy is for farming and environmental studies on soils within two visible and infrared ranges. In addition, infrared spectroscopy may also provide for specifying various soil components. Most studies have shown that soil spectral reflectance is affected by soil properties like humidity, texture, structure, and quantity of organic matter (Soriano-Disla, Janik, Viscarra, Macdonald, 2014). The soil spectral reflectance is within visible and near-infrared (NIR) ranges at wavelengths (350-2500 nm) (Iurian & Cosma, 2014).

Of other important soil properties, which affect the quantity of the given spectral reflection, one can refer to the type and frequency of clay minerals, carbonates, hydroxyl groups in water and soil, organic compounds, and iron and aluminum oxides. The reflective spectra may act as a tool in analyzing many soil properties. Organic carbon is one of the foremost soil properties estimated by satellite images and spectroscopic technologies with high precision because of the accumulated organic carbon in the surface layer of soil. This property has various spectral behaviors because of the existing complexity in the chemistry of organic matter (Viscarra, Walvoort, McBratney, Janik, & Skjemstad, 2006). The most absorbent characteristics resulting from organic carbon often occur at the wavelengths about 1730 nm and 2330 nm, while the little absorbent is at wavelengths about 1150, 1670, 1765, 2070, 2110, 2140, 2190, 2280, 2310, and 2390 nm. The absorbent bands adjacent to 1400 and 1900 nm may be due to the existing water in organic compounds (Babaeian, Homaee, Montzka, Vereecken, & Norouzi. 2015). The carbonate minerals often possess strong absorbent characteristics near 2345 nm and are relatively weaker adjacent to 1860, 1990, and 2140 nm (Viscaraa et al., 2006). Particle size noticeably affects soil spectral behavior as the size of particles becomes sizable with an increase in the light path through soil particles is more absorbed, and reduced reflection leads to spectral curves. In reduction, the size of soil particles increases soil reflectance with light color minerals like silicates and carbonates. Oxide and hydroxide minerals have small spectral reflectance, and the level of soil spectral reflectance decreases as the size of soil particles decreases (Summers, Lewis, Ostendorf, & Chittleborough, 2011). The spectral behavior of soil is a function of its constituent elements, and its chemical components like oxygen, silica, and aluminum lack strong absorbent characteristics within visible and near-infrared ranges. However, the soil's pieces, such as iron oxides, clay, and organic substance, may highly affect spectral curves and absorbent characteristics. The iron oxides influence the rate of reflectance in the visible zones, and organic carbon and clay in the infrared zones (Summers et al., 2011).

In recent research studies, soil chemical properties used spectral reflectance to achieve favorable results related to the soil structures and other components like clay, silt, and organic matter that can estimate by soil spectral data with very high precision (Summers, Lewis, Ostendorf, & Chittleborough, 2011). This study used spectral data for the information on soil components present in the area of study for Iloilo Province to monitor the physical and chemical properties of soil in the flooded area.

In general, the findings of other research studies indicate that using soil spectral data may be employed as an indirect technique for the estimation of the physical and chemical properties of soil. The present study only focuses on the area in the province of Iloilo, and properties in other places in the Philippines with different effects on soil spectral behavior are not part of the study.

Effects of the Slope Angle on Landslide

According to Cellek (2020), the slope measures the elevation change which is a crucial parameter in models used for environmental management, including the Universal Soil Loss Equation and agricultural non-point source pollution models. It is an original factor that creates the foundation for stability studies and affects shear and normal tension on shear surfaces that controls the movement of materials based on gravity. The slope or slope angles influence the landslides and create the foundation for susceptibility studies.

This study ensures the evaluation of slope as a factor and chosen parameters in landslides with an improvised apparatus. Some researchers believe that landslides occur between 30 and 40 degrees, others above 25 degrees, and others below 30 degrees. As a result, different viewpoints on the relationship between slope and landslides that this situation could vary locally and that the slopes of landslide-prone slopes must be evaluated statistically and interpreted (Cedeck, 2020, Pajalic, Peranic, Maksimovic, Ceh, Jagodnik, Arbanas. 2021).

Considering mass motions, according to Cellek (2020), mass motion is higher in the angle elevation lower than 25 degrees compared to higher than 25 degrees, stating that landslides have occurred below 30 degrees and are rare if it is over 30 degrees. The researcher wants to check the other parameters before making a general statement in the area and to express the landslide formation according to the slope values. Cellek(2020) states that a change in slope angle can trigger a mass movement. A slope or elevation becomes too steep to balance mass materials and exceed the angle of repose, making mass movement likely to occur, or the slopes steep enough to reinforce another triggering mechanism such as saturation with water (Claessens, Schoorl, Veldkamp, 2007). The present study discusses and illustrates the changes in slope angle and the differentiation of processes that cause a slow or sudden change in slope angle for landslide evolution models.

According to Claessens, Schoorl, and Veldkamp (2007), in the work of Bridge and Demicco (2008), a combination of tectonic uplift (not included in the study), the lowering of base level, sediment supply, water flow, or gravity drive rivers to incise in a landscape, thereby undercutting and slowly (over) steepening slopes. The gradual erosion of water caused by surface runoff, gully erosion, wind erosion, weathering, and waves cutting cliffs on a shoreline can cause slow removal of lateral support that causes landslides to occur.

Soil Settling and Water Holding Capacity

During landslides, debris flows are a transport that results in large amounts of material delivered rapidly downstream. It has destructive capabilities because of their high impact force due to the velocities reached and the mass in transit that lifts and carries large objects such as boulders and trees, resulting in fluidization of the surface soil layers (Luino, De Graff, Biddoccu, Faccini, Freppaz, Roccati, Ungaro, D'Amico, Turconi, 2022).

Nowadays, the knowledge of the physical and environmental factors influencing landslide activation within the Panay, especially in Iloilo Province, is still lacking and incomplete. Recent studies have investigated soil settling and holding capacities and their relations with landslide occurrence, making this study a source of information and additional information for other researchers. According to Luino, De Graff, Biddoccu, Faccini, Freppaz, Roccati, Ungaro, D'Amico, & Turconi (2022), several empirical and physically based approaches that define thresholds for hydrological conditions—including rainfall, soil water holding, and settling capacity that result in landslides. Several authors have proposed different methods to identify rainfall thresholds for the possible initiation of landslides where a type of soil can hold. Dariagan, Atando, & Asis(2021), the predominant soil types in the region are clay loam of Sta. Rita and Alimodian Series, sandy loam of Sara, Umingan, Louisiana series and clay for Panay Island; Guimbalaon clay, Silay fine sandy loams of volcanic origin for Negros Occidental while for Guimaras, it is Faraon clay, gravely loam, and Sara sandy loam. This type of soil is moderately deep and has a high degree of permeability that has connected pore spaces that allow water to flow from one to another. Low permeability soil has isolated pore spaces that trap waters within them, while in a lump of clay, most pore spaces block the water where it cannot flow easily. Recent studies have only considered rainfall variables as the most vital and easy-to-quantify landslide-triggering factor for the landslide (Dariagan et al., 2021).

Most works find difficulties in correlations between soil water settling and holding capacity and landslide occurrences, especially when the investigation is on warning systems aimed at mitigating the possibly severe consequences and damage to property and population. These works have considered soil water settling and holding capacity as one of several variables for landslide occurrence.

On the contrary, several studies have investigated landslide-conditioning factors, including the activation of mass movements that affect soil water settling and holding capacity. Based on recent research, the researchers presented different simulations and mathematical models to estimate the rainfall conditions that affect soil settling and water-holding capacity leading to the activation of landslides. Infinite slope stability analysis or modeling of water infiltration dynamics and groundwater pressure in soils causes a landslide (Luino, De Graff, Biddoccu, Faccini, Freppaz, Roccati, Ungaro, D'Amico, & Turconi, 2022). Places in Iloilo Province (Barotac Viejo, Leganes, Oton, and Miagao) where the researcher conducted three different methods to investigate the occurrence of shallow landslides to mitigate its effect and give accurate information to these communities are the focus of this study.

Based on the works of Alamanis, Papageorgiou, Xafoulis, & Chouliaras (2020), the activation of mass movements is due to soil moisture (settling and holding capacity), soil type, and slope acclivity. In this paper, the researcher will present a study based on three methods that use soils from four places in Iloilo Province as data for the possible occurrence of shallow landslides that have occurred in the past, with the aim of (i) identifying the soil properties that most significantly influence the activation of flood and landslides in the study area, (ii) differentiating soil water settling and holding capacity within the study area, (iii) identifying slopes or elevation angle for the possible occurrence of shallow landslides and mud-debris flows in the five different study area, and finally (iv) comparing the soil settling and holding capacity based on Imhoff cone test.

II. Methodology

There are three methods used for this research study. First, sand and five different soil samples were collected, gently fragmented by hand, and air-dried for ten days without sieving. Figure 1 contains five different soils and sand from flooded and prone landslide areas of Oton, Leganes, Barotac Viejo, and Miagao. Textures and properties of soil were analyzed using Fourier transform infrared spectroscopy. Soil organic matter was determined using the infrared wave ranges. An electronic balance identifies the weight of soil grains from 0.0000 g to 0.0200g.

Figure 1. Five different soil samples and sand from Iloilo Province

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Second, samples of each soil were placed in an Imhoff cone with 1000ml running water to test the settling and water holding capacity. The PH paper determines the acidity or alkalinity of a liquid used. For the settling ability in figure 2,

each soil suspension was hand stirred for five minutes then a timer took time for the soil to settle. Each sample and the sand underwent a settling test as one of the parameters for floods and landslides occurrence.

(a)

(b)

Figure 2. (a). Soil water settling Set-Up. (b) Four different samples underwent a settling test.

With a PH number of 7 and using the same Imhoff cone apparatus and a timer, 100 g of each five different soil samples and sand tested its soil water holding capacity with 250 ml of water added. The Imhoff cone measured the sediment volume that settled after 4 hours. The reading volume of settled sediment required gentle leveling of the surface of the settled sediment in the Imhoff cones with one-finger taps at the bottom of the cone. The contents of the Imhoff cones were decanted and reweighed using weight-balanced (hardened). Air dry the soil within 24 hours to remove water. Filter papers were carefully removed, dried at 37 °C overnight, and reweighed to determine sediment weight. This process was done three times for each soil. The 100 g soil contained in 1 L of water was the independent variable, with Imhoff-cone settling volume at four hours as the dependent variable for soil settle ability for a landslide. This approach uses the Imhoff cone for a given mass of soil in volume suspension that could vary, ensuring no loss of sediment in the filtering process, these suspended soil mass was an absolute parameter for each sample. In determining the soil water holding capacity for every 100 grams of each soil sample, 250 ml water was added to the Imhoff cone and set for four hours for each soil sample to absorb the water added (Fig 3).

Figure 3. Soil water Holding Set-Up

The last method is an improvised apparatus to test the elevation angle or slope to determine the slope where the landside occurs for shallow landslides. Elevation plays many vital roles in the occurrence of landslides because many factors express the result of its combined effect. An accurate landslide parameter is to anticipate the actual landslides, where the researcher developed an improvised apparatus that can test what degrees mostly landslides occur.

In the present study, an improvised apparatus was developed and employed to put forward the conditioning factors of the landslides triggered by heavy precipitation (see Figure 4 for the setup). Realistic landslides within different slopes or angle elevations require a detailed study of the chosen area with their soil samples in the Iloilo Province and no detailed landslide inventory or information prepared previously in the areas of study. In connection with this, only an angle of elevation or the slope was the testing factor for

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this particular method was tested with three layers of combined soil, sand, and small stones of 5 cm height performed to set up a detailed landslide database for the selected areas. All data on the landslides identified and recorded were produced in the laboratory by the present research. An improvised apparatus determines the effect of the slopes on the landslide occurrence. Soil sample from these different areas of study, a 26 cm x 9 cm x 5 cm canister with a 2 cm depth of less than 1 mm size of soil, was added with a 1 cm depth of more than 1 mm soil size, 1 cm small stones, and sands to measure the slope angle, movement direction, and rainfall. The researcher used three elevation angles, 85, 55, and 20 degrees. Other attributes such as land use, vegetation cover, type of slope (artificial or natural), water conditions, and slope material were not part of the study. Data recorded are part of landslide information, and no failure in the artificial slopes constructed using an improvised apparatus. A piece of information to mitigate the effects of landslide slope, slope aspect, rainfall or water conditions, and altitude were considered as the conditioning factors in the factor analysis studies to determine the importance and weight of the parameters.

Figure 4. Slope/ Elevation Set-Up

III. Results and Discussion

Fourier Transform Infrared (FTIR)Spectroscopic Analysis of Soil Properties.

In figure 5, sample one had the peaks containing a single bond area (2500-4000 cm^{-1}). No hydrogen bond in the material because there is no broad absorption band presence. A sharp at 3423 cm-1 is an Alcohol and hydroxy compound, especially a Hydroxyl group, and H-bonded OH stretch is present, and 3621 cm^{-1} replies to the existence of free alcohol hydroxyl compound(OH). No aromatic structure because there are no peaks between 3000 and 3200 cm^{-1}. A narrow sharp of less than 3000 cm^{-1}, especially at 2360 cm^{-1}, indicates the presence of carbon dioxide. No specific peak for aldehyde has between 2700 and 2800 cm^{-1}. No triple bond region (2000-2500 cm^{-1}) was detected, informing no C≡C bond in the material. Regarding the double bond region (1500-2000 cm^{-1}), the sample has some organic nitrates from the soil or ammonia at about 1652 cm^{-1}. There is no specific peak for aldehyde between 2700 and 2800 cm^{-1}. This material has Thiols and a thio-substituted compound. Since the peaks were only about eight peaks, the material should be a small organic compound. The result showed that a lot of several peaks were detected, informing the complex structure material. In addition to the single bond area (2500-4000 cm^{-1}), there are several peaks. In the double bond region (1500-2000 cm^{-1}), several peaks were also detected: In the fingerprint region (600-1500 cm^{-1}), a sharp at 1033 cm^{-1} informed the Alkyl-related compound present.

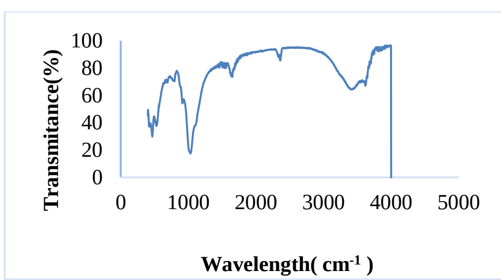

Figure 5. Buray, Oton FTIR Analysis

In figure 6, sample two had peaks containing a single bond area (2500-4000 cm^{-1}). No hydrogen bond in the material because there is no broad absorption band presence. A sharp at 3442 cm^{-1} is a secondary amino, especially Heterocyclic Amine is present from ammonia decomposition, and 3621 replies to the existence of an alcohol hydroxyl compound or free O-H. No aromatic structure because there are no peaks between 3000 and 3200 cm-1. A narrow sharp of less than 3000 cm-1, especially at 2360 cm-1, indicates

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the presence of carbon dioxide. No specific peak for aldehyde has between 2700 and 2800 cm-1. No triple bond region (2000-2500 cm^{-1}) was detected, informing no C≡C bond in the material. Regarding the double bond region (1500-2000 cm-$^{1)}$, the sample has some organic nitrates from the soil or ammonia at about 1637 cm^{-1}. Samples have urea or carbamide compounds formed as the end product of the metabolism of protein and excreted in the urine of mammals. It is synthesized in large quantities from ammonia and carbon dioxide for use in fertilizers, animal feed, and manufacturing a class of polymers known as urea-formaldehyde resins, used in making plastics. There is no specific peak for aldehyde between 2700 and 2800 cm^{-1}. Since the peaks were only about eight peaks, the material should be a small organic compound. In addition to the single bond area (2500-4000 cm^{-1}), there are several peaks. In the double bond region (1500-2000 cm-$^{1)}$, several peaks were also detected: In the fingerprint region (600-1500 cm-^{1}), a sharp at 1033 cm^{-1} informed the Alkyl-related compound present.

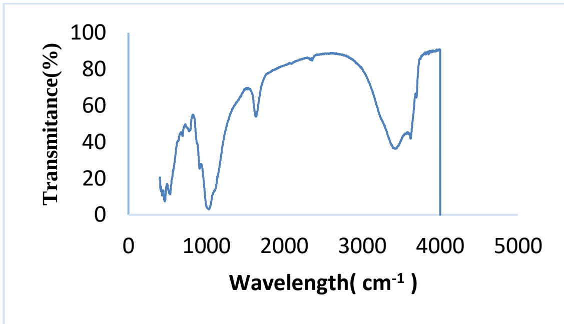

Figure 6. Botong, Oton FTIR Analysis

In figure 7, sample three had peaks containing a single bond area (2500-4000 cm-^{1}). No hydrogen bond in the material because there is no broad absorption band presence. A sharp at 3419 cm^{-1} is an Alcohol and hydroxy compound, especially Heterocyclic Amine is presently produced by the reaction of water with nitriles, and 3621 replies to the existence of an alcohol hydroxy compound. No aromatic structure because there are no peaks between 3000 and 3200 cm^{-1}. A narrow sharp of less than 3000 cm^{-1}, especially at 2360 cm^{-1}, indicates the presence of carbon dioxide. No specific peak for aldehyde has between 2700 and 2800 cm^{-1}. No triple bond region (2000-2500 cm-$^{1)}$ was detected, informing no C≡C bond in the material. Regarding the double bond region (1500-2000 cm^{-1}), the sample has some organic nitrates from the soil or ammonia at about 1652 cm^{-1} (Olefinic (alkene)). There is no specific peak for aldehyde between 2700 and 2800 cm^{-1}. This material has Thiols and a thio-substituted compound. Since the peaks were only about eight peaks, the material should be a small organic compound. The result showed that a lot of several peaks were detected, informing the complex structure material. In addition to the single bond area (2500-4000 cm^{-1}), there are several peaks. In the double bond region (1500-2000 cm^{-1}), several peaks were also detected: In the fingerprint region (600-1500 cm^{-1}), a sharp at 1033 cm^{-1} informed the Alkyl-related compound present. At 464 cm^{-1}, the Thiols, and thio-substituted compounds, especially Aryl disulfides (S-S stretch are present in the sample.

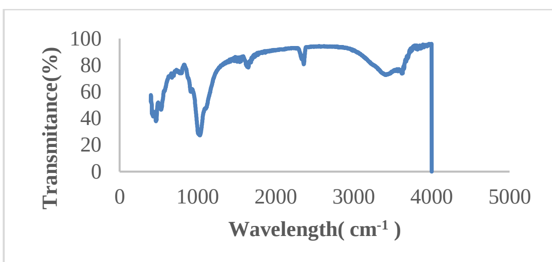

Figure 7. Leganes FTIR Analysis

In figure 8, sample 4 had peaks that contained a single bond area (2500-4000 cm^{-1}). No hydrogen bond in the material because there is no broad absorption band presence. A sharp at 3419 cm^{-1} is an Alcohol and hydroxy compound, especially Heterocyclic Amine is present, and 3691 replies to the existence of an alcohol hydroxy compound. No aromatic structure because there are no peaks between 3000 and 3200 cm^{-1}. A narrow sharp of less than 3000 cm^{-1}, especially at 2360 cm^{-1}, indicates the presence of carbon dioxide. No specific peak for aldehyde has between 2700 and 2800 cm^{-1}. No triple bond region (2000-2500 cm^{-1}) was detected, informing no C≡C bond in the material. Regarding the double bond region (1500-2000 cm^{-1}), the sample has some organic nitrates from the soil or ammonia at about 1683 cm-1 (Aromatic ring (aryl). There is no specific peak for aldehyde between 2700 and 2800 cm^{-1}. Since the peaks were only about eight peaks, the material should be a small organic compound. The result showed that a lot of several peaks were detected, informing the complex structure material. In addition to the single bond area (2500-4000 cm^{-1}), there are several peaks. In the double bond region (1500-2000 cm^{-1}), several peaks were also detected: In the fingerprint region (600-1500 $cm^{-1)}$, a sharp at 1029 cm^{-1} informed the Alkyl-related compound present. At 466 cm^{-1}, the Thiols, and thio-substituted compounds, especially Aryl disulfides (S-S stretch are present in the sample.

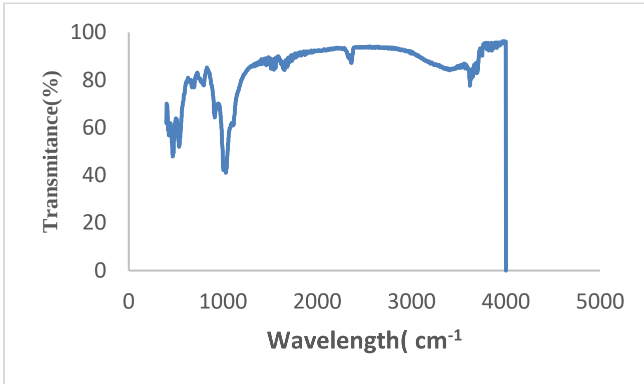

Figure 8. Barotac Viejo Residential Area FTIR Analysis

Figure 9. shows the analysis of Sample five, the soil from the landslide-prone area of Barotac Viejo. The results conclude as follows: (1) Regarding the number of peaks, there are more than five peaks, informing that the analyzed chemical is not a simple chemical. (2) The peaks contained a single bond area (2500-4000 cm-$^{1)}$. No broad absorption band was found, informing there is no hydrogen bond in the material. There is a sharp bond peak at about 3623 cm-1 and 3697 cm^{-1}, replying to the existence of secondary alcohol and OH stretch. No peaks between 3000 and 3200 cm^{-1} indicate no aromatic structure. No specific peak for an aldehyde is between 2700 and 2800 cm-1. (3) One triple bond region (2000-2500 cm^{-1}) was detected, indicating a carbon dioxide bond in the material. (4) Regarding the double bond region (1500-2000 cm-^{1}), a sharp peak at about 1633 cm^{-1} informs some simple hetero-oxy compounds, especially the organic nitrate, which can be from artificial fertilizer and ammonia. This peak at about 1633 cm^{-1} informs a C=C bonding in the material. And at the fingerprint region (600-1500 cm-^{1}), there is an Aliphatic organohalogen compound from an industrial product that comes from pesticides. Based on the above interpretation, conclusions on ample five has to do with farming due to a compound found in pesticides and fertilizers used by farmers for their plants and animals. Since the peaks were only about ten spikes, the material should be a small organic compound.

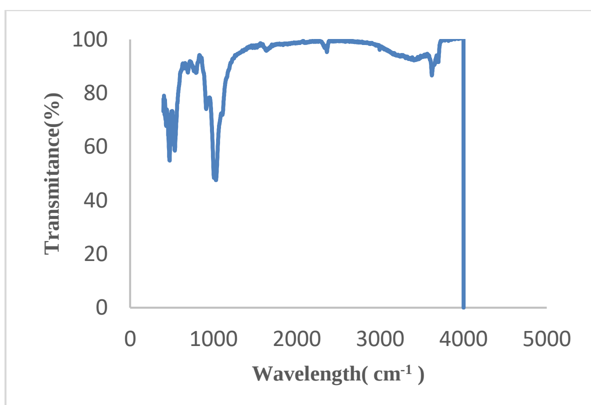

Figure 9. Barotac Viejo Landslide Prone Area FTIR Analysis

In figure 10, the infrared spectrum of the clean sand sample depicts an adsorption peak at 830 cm^{-1} depicting the symmetric and asymmetric stretch vibration for Si—O, respectively. Absorption peaks around 620 cm^{-1} characterize the bending of the Si—O functional group in asymmetric and symmetric vibration regions with the presence of pure silica as the chief component in the sand sample. The clean sand particles show peaks at 2,851.85 and 2,924.64 cm^{-1}, which indicates the symmetric and asymmetric -CH2 stretch. The absorption band around 2,920, 2292, and 2236 cm^{-1} in the three spectrograms shown in Figure 10 depict the C—H symmetric vibration of the saturated hydrocarbons and O—H band due to stretching vibration at 3,435 cm^{-1}. C¼O stretching peaks appeared between 1,627 and 1,870 cm^{-1}, which confirms the presence of carbonyl components like acids and aliphatic esters in the sand particles (Saxena, Kumar, & Mandal, 2018).

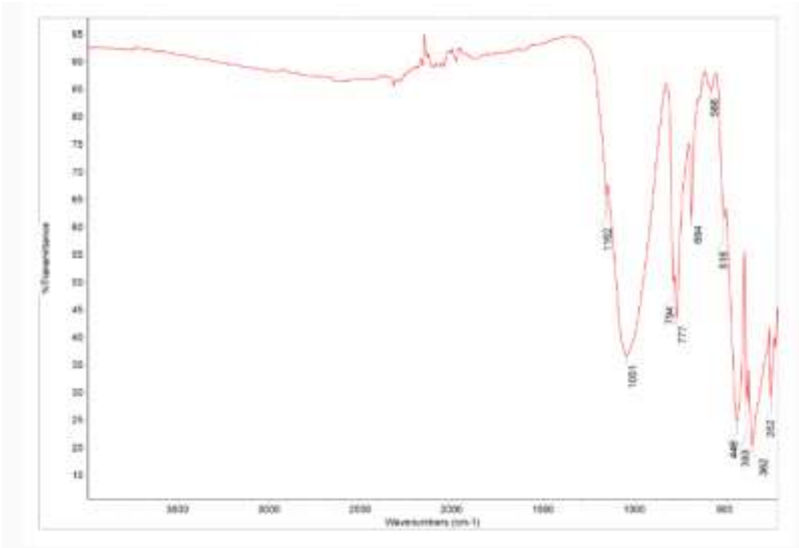

Figure 10. Sand FTIR Analysis (SiO_2) from the Department of Geology at the University of Tartu(https://spectra.chem.ut.ee/paint/fillers/sand/).

Slope Angle on Landslide

As the slope completely controls the movement of materials based on gravity, based on the preferred angles, the results of 85º, 55º, and 20º are in table 1. Five centimeters of soil with sand and small stones are used to test these angles. In the first trial, the clay soil has initial 50 ml of water added to make the soil and the rest of the layer's moisture. A total mass of 1500 grams and 50 ml of water for the first trial. After the first trial, a mass movement of 270.5 g, with a 20º angle. A 94-length PVC pipe with 4 liters of water, water travels to 38 cm height with 0.5 cm diameter, and a 32-length PVC serves as a sprinkler. Only the first layers with larger masses fall from a 20º angle. After one hour, the second trial was conducted for the water inside the soil to be absorbed and settled. For the second trial, a total mass of 2100g (water and clay, sand and stones). Meaning a 550 mL of water was absorbed by the soil. A mass movement of 450g falls from this angle. For the third trial, the same procedure and a weight of 2200 grams with a mass movement of 550g.

For the 55º angles were done on the second day for clay soil and other layers to drain first with the absorbed water and maintain a weight of 1500 grams, and done the same procedure with the first trial to maintain the accuracy of the results. A total mass of 1500 grams and 50 ml of water for the first trial. After the first trial, a mass movement of 250g, with a 55º angle. Using the same setup and measurement in the first trial, only the first layers with larger masses fall from a 55º angle. After one hour, the second trial was conducted for the water inside the soil to be absorbed and settled while maintaining the original weight. For the second trial, a total mass of 2000 grams (water and clay, sand and stones). Meaning a 450 ml of water was absorbed by the soil. A mass movement of 380 g falls from this angle. For the third trial, the same procedure and a weight of 2100 grams with a mass movement of 385 grams are lesser than a 20 º angle.

The test for an 85 degrees preferred slope angle is on the third day for clay soil and other layers to drain first with the absorbed water and maintain a weight of 1500 grams, and the same procedure with the first trial to maintain the accuracy of the results. These resulted in a mass movement of 195 g for an 85ºangle. With the same setup and measurement in the first trial, only the first layers with larger masses fall from an 85 º angle. After one hour, the second trial was conducted for the water inside the soil to be absorbed and settled while maintaining the original weight. A sample of 1900g (water and clay, sand, and stones) and 350 ml absorbed by the soil resulted in a mass movement of 250.5g from this angle. For the third trial, the same procedure and a weight of 2000 grams with a mass movement of 300g are lesser than 20º and 55 º slopes. These results revealed that a higher angle slope has a lesser chance of experiencing mass movement.

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Table 1. Mass Movement data

Three Layer samples (clay soil, sand, small stone)	First Trial + 50. ml	Second Trial + 450ml	Third Trial + 200 ml
Angle (degrees)	mass(g)	mass(g)	mass(g)
20.00	270.50	450	550
55.00	250	380	385
85.00	195	250.5	300

Soil Settling and Water Holding Capacity

Imhoff cones with dry soil to determine the settling time for five soils and sand. This settling time was affected by the agitation method (handshaking and stirring). The information on the soil settling capacity of the samples and sand conducted in the laboratory is in table 2. Compared to other soil samples, the results revealed that soil from a landslide-prone area has a lesser settling time except for the sand that settles fastest due to larger masses. Granulated soil samples have a longer settling time required. A soil with higher clay contents had more suspended clay-sized particles after hand stirring for 5 minutes. With different particle size distributions, the slope of the settling relationship is difficult to determine because of the inability to account for the mean aggregate size of the soil sample or the sample's aggregate stability due to the limited functions of the instrument used. These properties may vary from soil to soil and change with time and exposure to various environmental influences.

Table 2. Soil Settling Time

Soil Settling Capacity					
			Time(hrs.)		
Samples	Type	Location	Trial 1	Trial 2	Trial 3
1	Soil	Buray, Oton	4 .333	5.167	5 .75
2	Soil	Botong, Oton	3.333	2.16	2.75
3	Soil	Leganes	2.16	2.43	4.33
4	Soil	Residential, Barotac Viejo	3.11	3.167	4.33
5	Soil	Landslide Prone Area, Barotac Viejo	2.19	2.42	2.15
6	Sand	UP Visayas, Miagao	0.45	0.35	1.15

A 100g of soil and sand were placed inside the Imhoff cone to determine the soil-water-holding capacity. Using the Imhoff cone, the accuracy of these methods is good, but they are very time-demanding. Results revealed that the soil water holding capacity depends on soil texture (particle sizes) and organic matter. In terms of soil texture, smaller particle sizes, such as in the case of clay, have a larger surface area. The larger the surface area, the easier it is for the soil to hold onto water leading to a higher water-holding capacity. Compared to sand, which has large particle sizes but a smaller surface area. The sand has a smaller surface area leading to low water-holding ability. Also, sand is gritty and therefore does not hold more water because pores are so large that water can rapidly move through it(Table 3).

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Soil organic matter is another factor that can help increase water-holding capacity (Reichert, Albuquerque, Kaiser, Reinert, Urach, & Carlesso, 2009). Soil organic matter has a natural magnetism to water. Botong and Buray Oton is farm area causing an increase in the percentage of soil organic matter leading to an increase in soil water holding capacity due to a decayed material from a living organism (plant or animal material).

Table 3. Soil Holding Capacity Time

		Soil Water Holding Capacity			
			Time(hrs.)		
Samples	Type	Location	Trial 1	Trial 2	Trial 3
1	Soil	Buray, Oton	1.54	1.5	2.46
2	Soil	Botong, Oton	2.07	2.3	2.2
3	Soil	Leganes	0.5	1.2	2.46
4	Soil	Residential, Barotac Viejo	0.56	1.41	2.3
5	Soil	Landslide Prone Area, Barotac Viejo	1.41	2.16	2.3
6	Sand	UP Visayas, Miagao	0.035	0.0235	0.038

IV. Discussion of Results

Fourier Transform Infrared (FTIR)Spectroscopic Analysis of Soil Properties

Types and soil properties are one of the parameters of landslide monitoring. Analysis of soil properties and responses to landslide mitigation practices such as afforestation may facilitate clarification of the mechanisms underlying soil changes. Properties, compositional functional groups, and minerals lie in the type of soils and fractions from forests and adjacent farmlands (Luino et al. 2022) that were established at different times, such as 5,10, 20, and 30 years(yr.) at the Province of Iloilo.

Organic Carbon(C) and Nitrogen(N) content depends on the duration of land-use change, tree species used, and climate (temperature and precipitation).

In our study, with FTIR analysis, all samples have soil organic carbon (OC)and nitrogen (N). A higher OC will have a higher clay content, and soils with a lower clay content have a lower N accumulation. Generally, the input of N is positively correlated with the accumulation of OC, meaning the higher the soil organic carbon content, the ability of the soil to retain nitrogen will also be higher.

The interaction between C and N can reflect whether organic carbon (OC) accumulation is sustainable in the long run since clay content affects soil water-holding capacity due to the larger surface area of the clay soil. These findings indicated that soil texture regulates the changes of OC and N. The smaller particle sizes, such as in the case of clay, have a larger surface area. The larger the surface area, the easier the soil to hold onto water leading to a higher water-holding capacity.

The changes in soil properties were strongly associated with the changes in functional groups, followed by minerals. Of them, asymmetric COO- & C=O stretching & O-H bending, and symmetric COO- stretching were the key factors responsible for the changes in soil properties.

Slope Angle on Landslide

Slope angle and its changes from any angle trigger mass movement, a parameter to where a landslide occurs. Either a slope angle can become too steep for shear strength to balance shear stress causing mass movement occurs, or the slope becomes steep enough to reinforce another triggering mechanism decreasing shear strength or increasing shear stress.

Changes in slope angle, as well as the differentiation of processes where using 20º,55º, and 85º where a mass movement occurs due to change in slope angle. The results revealed that landslide occurrence does not monotonically increase with the increase of the slope angle (Cellek 2020). Even though landslide evolution connects to the steepness of the slope in a geomorphologic environment, but high slope angle does not produce mass movement due to stone layers within the 5-cm layers of sequence which influence the behavior of masses.

Slope stability depends on two factors: the angle of the slope and the strength of the materials on it. For shallow landslide (referring to 20º angle), the results found in Table 1 are applications of Newton's Law. The 5 cm layered with rocks placed on a slope is being pulled toward Earth's center (vertically down) by gravity. We can split the vertical gravitational force into two components relative to the slope angle; one pushes the masses down the slope (the shear force**),** and the other exerts a force on the slope (the normal force**).** The shear force, which wants to push the masses down has to overcome the strength of the connection between the 5 cm layered and the slope, which may be weak if the mass has split away from the main masses, especially a body of rock, or maybe very strong if the block is still a part of the rock. For example, if the shear strength is greater than the shear force, the masses will not move. If the slope is steeper and the shear force is approximately equal to the shear strength, the masses may or may not be moved under these circumstances. And if the shear force is considerably higher than the shear strength will cause a mass movement even if the slope is steeper. This explains why there is more mass movement with 20 angles (Young et al. 2004).

Soil Settling and Water Holding Capacity

Soil texture and organic matter are the key components that affect soil water-holding capacity. Clay soils have smaller particle sizes in terms of soil textures and have a larger surface area. The larger the surface area, the easier for the soil to hold onto water resulting in a higher water-holding capacity. Sand has large particle sizes with a smaller surface area resulting in a low water-holding capacity.

Soil organic matter (SOM) is another factor that can help increase water-holding capacity. The larger the SOM, the more Nitrogen(N) a soil can accumulate. Soil organic matter has a natural magnetism to water. If the farm increases the percentage of soil organic matter, the soil water holding capacity will increase. SOM is decayed material that originated from a living organism. The SOM and N content of the soil, the more clay it is.

V. Conclusion

The present study generates the following conclusions;

1. The FT Infrared spectroscopy analysis of soil (clay) contents and organic matter directly affects soil water-holding capacity due to the larger surface area of the clay soil.
2. The smaller particle sizes, such as in the case of clay, have a larger surface area. The larger the surface area, the easier it is for the soil to hold onto water leading to a higher water-holding capacity.
3. Soil from a landslide-prone area has a lesser settling time except for the sand that settles fastest due to larger masses. Imhoff cone is not enough instrument to determine the settling ability of soil samples that has different particle size distributions. Settling relationship with other factors in landslide monitoring is difficult to identify because of the inability to account for the mean aggregate size of the soil sample or the sample's aggregate stability due to the limited functions of the instrument used. These properties may vary from soil to soil and change with time and exposure to various environmental influences.
4. The slope is one of the parameters and plays many vital roles in landslides. An angle of 25 degrees has more mass movement compared to much higher slopes like 50 and 80 degrees. The increase in height or angle of the elevation decreases stability, leading to less mass movement. Less mass movement leads to the conclusion that there are rare landslides in the very high slope range due to fewer vibrations or soil movements caused by human activities and being compact or stable.

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References

1. Alamanis, N., Papageorgiou, G., Xafoulis, N., & Chouliaras, I. (2020). Effects of Landslides and Soil Settlements on the Built Environment: A Meta-analysis. 7. 6-15.
2. Babaeian, E., Homaee, M., Montzka, C., Vereecken, H., and Norouzi. A.A. (2015). Towards retrieving soil hydraulic properties by hyperspectral remote sensing. Vadoze Zone J. 14(3),doi: 10.2136/ vzj2014.07.0080.
3. Bridge, J.S., & Demicco, R.V. (2008). Earth Surface Processes. Landforms and Sediment Deposits. Cambridge University

Press, Cambridge, New York.

4. Çellek, S. (2020). Effect of the Slope Angle and Its Classification on Landslide. Natural Hazards and Earth System Sciences Discussion(preprint) https://doi.org/10.5194/nhess-2020-87,2020.
5. Claessens, L., Schoorl, J.M., Veldkamp, A., (2007). Modeling the location of shallow landslides and their effects on landscape dynamics in large watersheds: an application for northern New Zealand. Geomorphology 87(1–2), 16–27.
6. Dariagan, J.D., Atando, R.B. & Asis, J.L.B. (2021) Disaster preparedness of local governments in Panay Island, Philippines. *Nat Hazards* 105, 1923–1944. https://doi.org/10.1007/s11069-020-04383-0.
7. Guerrero, C., Viscarra R.R.A, & Mouazen, A. M. (2010). Diffuse reflectance spectroscopy in soil science and land resource assessment. Geoderma. 158: 1-2.
8. Hassani, A., Bahrami, H., Noroozi, A., & Oustan, S. (2014). Visible-near infrared reflectance spectroscopy for assessment of soil properties in gypseous and calcareous soils. Journal of Watershed Engineering and Management, 6(2), 125- 138.
9. Iurian, A. R, Cosma, C. (2014). A practical experimental approach for the determination of gamma-emitting radionuclides in environmental samples. Nucl. is unknown and the path forwards. Plant and Soil 375, 1e19.
10. Jaggi, N., and Vij, D. (2006). Fourier transform infrared spectroscopy. In Handbook of Applied Solid State Spectroscopy. Boston: Springer, 411-450.
11. Kang, X., Wang, S., Wu, W. Xu, G., Zhao, J., & Liu, F. (2022). Soil–water interaction affecting a deep-seated landslide: From field monitoring to experimental analysis. Bull Eng Geol Environ 81, 82. https://doi.org/10.1007/s10064-021-02556-0.
12. Kayastha, P. (2015): Landslide Susceptibility mapping and factor effect analysis using frequency ratio in a catchment scale: a case study from Garuwa sub-basin, East Nepal, Arabian Journal of Geosciences, 8, 10, 8601-8613, doi: 10.1007/s12517-015-1831- 6.
13. Luino, F., De Graff, J., Biddoccu, M., Faccini, F., Freppaz, M., Roccati, A., Ungaro, F., Amico, M., Turconi, L. (2022). The Role of Soil Type in Triggering Shallow Landslides in the Alps (Lombardy, Northern Italy). Land 2022, 11, 1125. https://doi.org/ 10.3390/land11081125.
14. Margenot A.J., Calderón F.J., Goyne K.W., Mukome F.N.D and Parikh S.J. (2017). IR Spectroscopy, Soil Analysis Applications. In: Lindon, J.C., Tranter, G.E., and Koppenaal, D.W. (eds.) The Encyclopedia of Spectroscopy and Spectrometry, 3(2), 448-454. Oxford: Academic Press.
15. Meral, R., Dogan, E., & Demir, Y. (2010). Turbidity measurements and modified Imhoff cone method for estimation of suspended sediment concentration. Fresenius Environmental Bulletin. 19. 3066-3072.
16. Mohamed, E., Saleh, A., Belal, A., & Gad, A. (2018). Application of near-infrared reflectance for quantitative assessment of soil properties. *The Egyptian Journal of Remote Sensing and Space Science*, *21*(1), 1-14. https://doi.org/10.1016/j.ejrs.2017.02.001.
17. Nandiyanto, A. B.D., Oktiani,R., Ragadhita, R. (2019). How to Read and Interpret FTIR Spectroscope of Organic Material, Journal of Science & Technology,4(1), 97-118. http://dx.doi.org/10.17509/ijost.v4i1.15806.
18. Nguyen, T., Janik, L.J. & Raupach, M. (1991) “Diffuse reflectance infrared Fourier transform (DRIFT) spectroscopy in soil studies”, Aust. J. Soil Res. 29(1), 49–67. doi: http://dx.doi.org/10.1071/SR9910049.
19. Pajalic, S., Peranic, J., Maksimovic, S., Ceh, N., Jagodnik, V., Arbanas, Ž. (2021). Monitoring and Data Analysis in Small-Scale Landslide Physical Model. Applied Sciences, 11, 5040. https://doi.org/10.3390/ app11115040.
20. Reichert, J.M., Albuquerque, J.A., Kaiser, D., Reinert, D.J., Urach, F., & Carlesso, R. (2009). ESTIMATION OF WATER RETENTION AND AVAILABILITY IN SOILS OF RIO GRANDE DO SUL, R. Bras. Ci. Solo, 33:1547-1560,
21. Robertson, A.H.J., Shand, C., & Perez-Fernandez, E. (2016). The application of Fourier transforms infrared, near-infrared and X-ray fluorescence spectroscopy to soil analysis, *Spectroscopy Europe/World*, 28 (4), 1-5.
22. Saikia, B., Parthasarathy, G., Borah, R. and Borthakur, R. (2016) Raman and FTIR Spectroscopic Evaluation of Clay Minerals and Estimation of Metal Contaminations in Natural Deposition of Surface Sediments from Brahmaputra River. *International Journal of Geosciences*, **7**, 873-883. doi: 10.4236/ijg.2016.77064.
23. Saxena, N., Kumar,S., & Mandal, A.(2018). Adsorption characteristics and kinetics of synthesized anionic surfactant and polymeric surfactant on sand surface for application in enhanced oil recovery. Asia-Pacific Journal of Chemical Engineering.13(4), 1-14. https://doi.org/10.1002/apj.2211
24. Sojka,R.E., Carter, D.L., & Brown, M.J. (1992). Imhoff Cone Determination of Sediment in Irrigation Runoff, Soil Science Society of American Journal, 56:884-890.
25. Soriano-Disla, J.M., Janik, L.J., Viscarra Rossel, R.A., Macdonald, L.M., McLaughlin, M.J. (2014). The performance of visible, near-, and mid-infrared reflectance spectroscopy for prediction of soil physical, chemical, and biological properties. Appl. Spectrosc. Ver. 49, 139e186. http://dx.doi.org/10.1080/ 05704928.2013.811081.
26. Stenberg, B., Viscarra, R.A., Mouazen, R. A.M., & Wetterlind, J. (2010). Visible and near infrared spectroscopy in soil science, Adv. Agron. 107, 163–215. doi: http:// dx.doi.org/10.1016/S0065-2113(10)07005-7.

27. Summers, D., Lewis, M., Ostendorf, B., and Chittleborough, D. (2011). Visible near-infrared reflectance spectroscopy as a predictive indicator of soil properties. Ecological Indicators, 11(1), 123-131
28. Tkachenko, Y., & Niedzielski, P. (2022). FTIR as a Method for Qualitative Assessment of Solid Samples in Geochemical Research: A Review. Molecules, 27, 8846. https:// doi.org/10.3390/molecules27248846.
29. Viscarra R.R. A, Walvoort, DJJ, McBratney AB, Janik LJ, & Skjemstad JO. (2006). Visible, near infrared, mid infrared or combined diffuse reflectance spectroscopy for simultaneous assessment of various soil properties. Geoderma. 2006; 131:59–75.
30. Yılmaz, Ç., Topal, T., & Süzen, M. L. (2012). GIS-based landslide susceptibility mapping using bivariate statistical analysis in Devrek (Zonguldak-Turkey), Environmental Earth Sciences, 65(7), 2161-2178, doi:10.1007/s12665-011-1196-4.
31. Young, H., Freedman, R., Ford LA., Sears, FW., (2004). Sears and Zemansky's University Physics with Modern Physics, 11th ed. Pearson Addison Wesley, San Francisco. P. 167-187.