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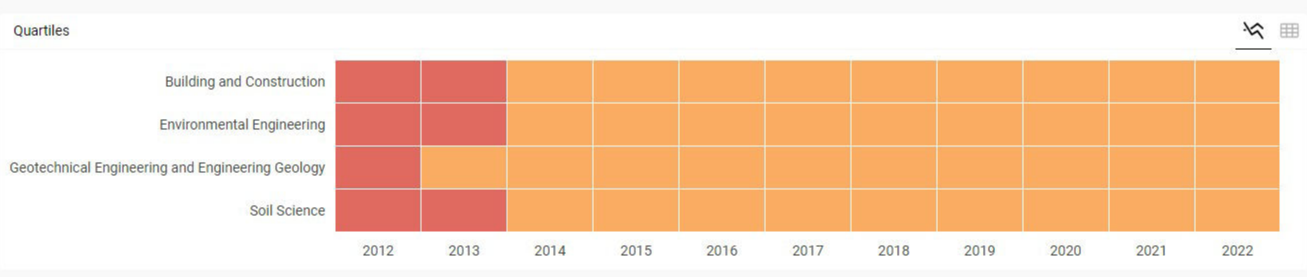

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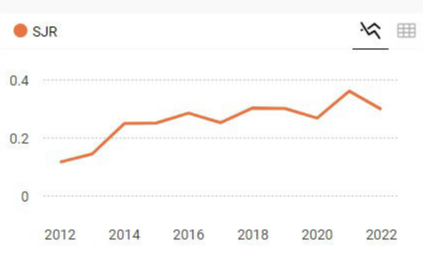

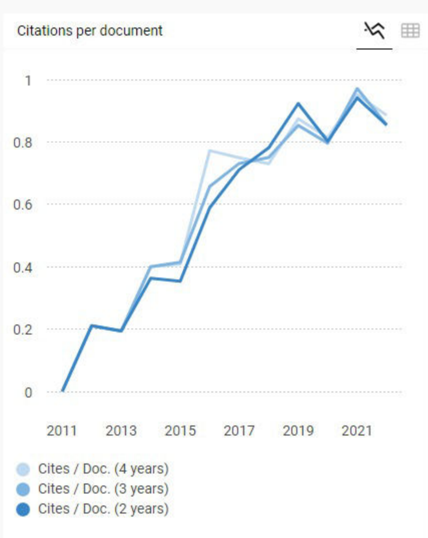

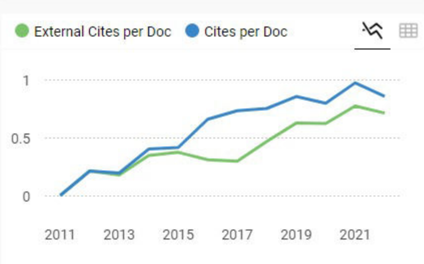

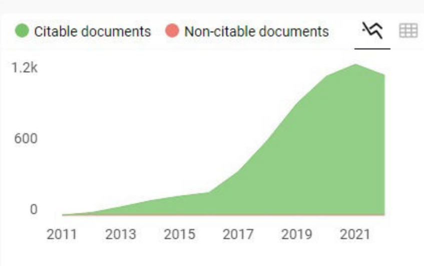

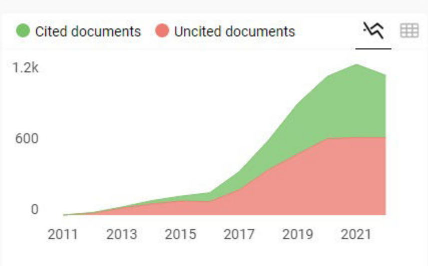

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Layla Yassin 9 months ago

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Thanks and best regards

reply

Melanie Ortiz 9 months ago — SCImago Team

Dear Layla, thank you very much for your comment. SCImago Journal and Country Rank uses Scopus data, our impact indicator is the SJR. We suggest you consult the Journal Citation Report for other indicators (like Impact Factor) with a Web of Science data source. Best Regards, SCImago Team

dwikoranto 2 years ago

Thank you, I started joining to get information about journals.

reply

Melanie Ortiz 2 years ago — SCImago Team

Dear Sir/Madam, welcome and thanks for your participation! Best Regards, SCImago Team

nahla salim 3 years ago

Dear Sir
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Thank you very much

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Melanie Ortiz 3 years ago — SCImago Team

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Aisyah Salimah 3 years ago

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All the metadata have been provided by Scopus /Elsevier in their last update sent to SCImago, including the Coverage's period data. The SJR for 2019 was released on June 2020, 11. We suggest you consult the Scopus database directly to see the current index status as SJR is a static image of Scopus, which is changing every day.
Best Regards, SCImago Team

Mohammed Ali Al-Bared 5 years ago

Thanks a lot for your response

But the thing that i am still wondering is that for year 2016, the category of Building and construction was rated as Q2. Why it changed suddenly? although year 2016 has passed

Thanks again

reply

Mohammed Al-Bared 5 years ago

Dear Sir / Madam,

I published my paper in the International Journal of GEOMATE few months ago and my paper was categorized under Building and construction materials. For year 2017, this category (Building and Construction) was under Quartile 2 in SJR. The rules of my university is to publish in at least Q2 Journals and that is why i selected this journal for my publication. Surprisingly, the Q of the Building and Construction category changed to Q3 although the year 2017 has passed. I really don't understand this sudden change. Can you please clarify this?

Thanks a lot

reply

Elena Corera 5 years ago — SCImago Team

Dear Mohammed Al-Bared,

thank you very much for your particiation. According to your question, each year Scopus provides us an update database and, according to that new information, indicators are calculated. Annual data updating can change journal's quartile.

I hope we solve your question.

Best regards,
SCImago Team

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Geotechnique, Construction Materials and Environment

TERRACING SLOPE STABILITY ANALYSIS USING BIO-ENGINEERING SOIL REINFORCEMENT WITH 3D MODEL APPROACH

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*Corresponding Author, Received: 12 April 2023, Revised: 10 Aug. 2023, Accepted: 17 Aug. 2023

ABSTRACT: Landslides can occur on natural slopes as well as on artificial slopes due to cliff cutting or embankment construction. Management of landslides on the slopes can be done by means of changes in geometry through the implementation of terraces or strengthening of the slopes. One method of strengthening the slope is with soil bio-engineering, whereby vegetation such as vetiver plants are grown. Vetiver roots increase the cohesion value in the soil and in addition to retaining the force on the slopes, the roots are able to penetrate the soil layer up to 3 meters. This does not take time as even at the age of one month, the roots of this plant grow as much as 0.5 meters and, after every 2 months, increase by 0.5 meters. The terrace system on the slope is able to increase the safety factor value by 21% and when the terrace is strengthened by vetiver roots, which are 3 meters deep, it is able to increase the safety factor value by 49%. The more the slope is strengthened by the vetiver root, the greater the percentage increase in the safety factor value against landslides.

Keywords: Landslides, Soil Bio-engineering, Terracing, Vetiver, Safety factor.

1. INTRODUCTION

Landslides still frequently occur in Asia, especially in Indonesia. In November 2022, there have been around 38 landslides happened in Indonesia, down from 99 in October 2022. Throughout the rainy season in Indonesia, which normally takes place from November to March, fatal landslides and flash floods are not unusual across the archipelago. Indonesia's disaster organization envisioned that there are more than a hundred and twenty million people stay in areas vulnerable to landslides. Landslides are caused by surface erosion or the movement or transport of soil or parts of soil from one place to another, and factors that affect soil erosion are rain, soil, slope, vegetation, and humans. A landslide is a mass movement of a rock fragment with a sliding/slipping, rotating (rotational) type of movement caused by gravity so that the movement is faster and the water content is less [1-3].

Prevention of landslides on slopes can be done by changes in slope geometry and reinforcement. One of the geometry changes is the terracing system that is, constructing ridges and channels across the slope. Terracing serves to reduce the length of the slope or reduce the level of slope to control surface runoff and soil losses. The results of previous analyses that have been carried out in Central Java, Indonesia, show that landslides have the potential to occur in moderate slopes between 8-150 [4]. So, the use of terracing can be done to reduce the risk of landslides. The type of terrace that is mostly developed on slopes in Indonesia is the bench terrace because it is suitable for development on agricultural land. Making terracing is useful for increasing water infiltration into the soil and reducing the amount of surface runoff so as to minimize the risk of erosion by water.

With slope reinforcement, one alternative involves a soil bio-engineering system involving a green technology concept whereby plants are grown on the slope. This method utilizes the use of roots from plants as an additional restraining force on the slope. Plant roots have a positive effect on soil aggregation and stability by trapping fine particles into stable macro-aggregates and supplying organic residues that can decompose into the soil [5]. As with previous analyses in Thailand, it shows that the presence of vegetation on a slope or forest area affects the value of the safety factor. In this study, it was also stated that the existence of vegetation in locations that are evenly distributed produces a greater safety factor value compared to slopes overgrown with vegetation with uneven distribution of roots. In addition, a large safety factor is found in areas that have vegetation with deep roots [6].

One of the plant roots that is able to strengthen the soil layer to a depth of 3 meters is the root of the vetiver plant, where vetiver roots are capable of resisting erosion on the soil and can stabilize the soil so as to minimize the risk of slope collapse. The main advantage of VS (Vetiver System) compared to other vegetation is its low cost and longevity. For example, using vetiver as slope stabilization can save up to 85-90% in costs. Low long-term maintenance costs are quite low and quite effective applied to soils that are infertile and prone to erosion. In addition, it is also suitable for use in areas with low working costs [7].

Slope failure occurs when the shear capacity of the shear plane is exceeded by shear stress due to the weight of the soil above it. This can occur due to loss of support at the foot of the slope, increased load on the slope, reduced soil shear capacity, and changes in the groundwater table.

Slope stability is determined by the shear capacity of the slip area. If the shear capacity is exceeded by the shear load from the soil mass above the slip area, a landslide will occur. In soil mechanics, the shear capacity is determined by the cohesion parameter (c) and the soil internal shear angle (φ). Value formulation according to Mohr-Coloumb [8]. Therefore, this study needs to be conducted to analyze the performance of terracing in slope stability to minimize the occurrence of landslides. This research was conducted to determine the effect of vegetation on the value of the safe factor on slopes using the Plaxis 3D application. With Plaxis 3D, terraced geometry can be modeled more realistically.

2. RESEARCH SIGNIFICANCE

Landslide problems often occur in Indonesia, especially in hilly areas, so it is necessary to conduct research that can provide alternative solutions for handling shallow slides and surface erosion in this hilly area. One of the solutions for handling shallow slides and surface erosion is to carry out a slope reinforcement system by building terracing on the slopes and strengthening using vetiver root. To determine the effect of the terracing reinforcement system and the effect of vetiver root depth on slope stability, an analysis was carried out using this 3D modeling approach.

3. METHODOLOGY

3.1 Soil Parameter

The soil used in this model is clayey sand obtained from various sources. The soil is modeled by Mohr-Coulomb, which is an elastic-plastic model with the principle that strain and strain change are distinguished into elastic and plastic parts to evaluate whether plasticity has occurred; a yield function is used as a function of strain and stress [9]. Mohr coulomb is a simple soil model that is commonly used in slope analysis Soil parameter data is an assumption with parameter limits (Table 1).

Table 1 Soil parameter

Layer	1	2			
Soil Type	Clayey Sand	Clayey Sand	Clayey Sand	Clayey Sand	Clayey Sand
Slope	All	28	33	40	42
γsat	20	17	17	17	17
$\gamma unsat$	16	15	15	15	15
c'	1	2.5	2.5	2.5	2.5
φ'	30	15	18	20	24
E	20000	10000	10000	10000	10000
v	0.3	0.3	0.3	0.3	0.3

Note: slope in % unit, γsat and $\gamma unsat$ displayed in kN/m^3 units, c' and E in kN/m units..

In this model, the analysis carried out is slope stability analysis (safety factor analysis), where the most influential soil parameter is the shear strength parameter (c and φ). Therefore, the Mohr-Coloumb soil model is sufficient to accommodate this slope stability analysis. However, it should be remembered that the Mohr-Coulomb soil model is a simple model that has limitations, especially when related to deformation analysis. If there is a deformation analysis, it is necessary to use more advanced soil models. An example of an advanced soil model is the Hardening Soil model, which accommodates more advanced stiffness parameters such as E_{50}, E_{ur}, and E_{oed} so this soil model is more suitable to used in deformation analysis.

3.2 Terrace Dimension

Vetiver Terracing is a mechanical soil and water conservation building made to shorten the length of the slope or reduce the slope of the slope by digging and backfilling the soil across the slope with the aim of reducing runoff and increasing water infiltration, thereby minimizing the possibility of erosion [10]. A bench terrace is a series of plains built along a contour at suitable intervals. This building is equipped with a water drain (SPA) and planted with grass to strengthen the terrace. There are types of bench terraces that are tilted outward and tilted inward. Bench terraces are made by cutting the slope and leveling the ground at the bottom so that a row of stairs or benches forms. The terrain dimension in this model is determined based on [11]. Bench terraces that are tilted inward are used for low permeability soils with the aim that water that does not infiltrate immediately does not flow out of the slope. In this study, the dimensions of terraces refer to the relationship between slope, bench terraces. (Table 2).

Table 2 Terrace Dimension

No	Slope	Height	Width	Terrace Height	Terrace Width
	(%)	(m)	(m)	(m)	(m)
1	28	10	35	0.75	2.5
2	33	10	30	1	3
3	40	10	25	1	2.5
4	42	10	24	1.25	3

3.3 Vetiver Root Parameter

Vetiver is a large type of grass that is used for various ecological and phytoremediation purposes (improving the environment by using plants) on land and water, such as rehabilitation of ex-mining land, prevention of slope erosion, coastal abrasion resistance and slope stabilization through a technology called Vetiver Grass Technology (VGT) or Vetiver System (VS) [12]. Roots are an important part of handling landslides on slopes because they can bind the soil, absorb water from the soil and release it into the atmosphere [13].

Soil parameters strengthened with vetiver roots will cause an increase in the cohesion value in soil. The increase in soil cohesion after vetiver reinforcement may vary depending on the diameter, number and slope of the vetiver roots [14]. The presence of roots in the soil affects the increase in the soil cohesion value but does not significantly affect the shear angle value [15] and holds soil particles in place through the resulting root system [16].

The increase in cohesion in the modelled vetiver roots is 15 kPa [17]. The increase in vetiver root cohesion is calculated based on the root depth and root diameter of the vetiver, where the TR value is 44.64 MPa or 44640 kPa [18]. The diameter of the root reinforcement to be modelled is 0.5 m. For root length, vetiver plants at the age of 42 days grow to 42 cm [19]. At the age of 5 months, the roots of the vetiver grew up to 140.8 cm. First, vertiver roots can grow up to 3-4 m (Table 3).

Table 3 Vetiver Root Parameter

No	Z	Tr	Cr	Root Age
	(m)	(Mpa)	(kPa)	(Month)
1	0.5	44.64	200.88	1
2	1.0	44.64	133.92	3
3	1.5	44.64	66.96	5
4	2.0	44.64	15	7
5	2.5	44.64	15	10
6	3.0	44.64	15	12

4. MODEL SIMULATION

In the present work, Plaxis 3D version 22 is used to simulate changes to existing slope geometry with a terrace system and then the terrace is strengthened by vetiver grass. The gradient of slope that modelled in this simulation is 28°, 33°, 40°, and 42° (Figs. 1-2) [8]. In slope stability analysis, the initial stresses are generated by using the gravity loading method. The initial stresses are developed due to the weight of the soil.

The choice of mesh type in Plaxis 3D modeling determines the division of elements and connects nodes in the created model so that the finer the distribution of elements, the more accurate the calculation results will be. In this research modeling, a medium mesh was chosen because the distribution of these elements is accurate enough to calculate slopes (Figs. 3-4).

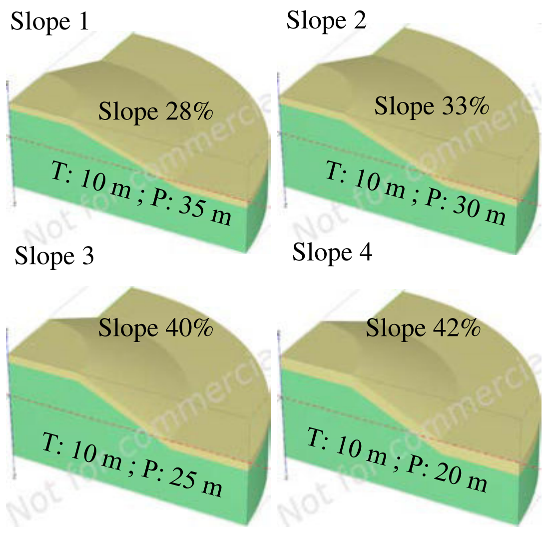

Fig.1 Geometric modelling of existing slope

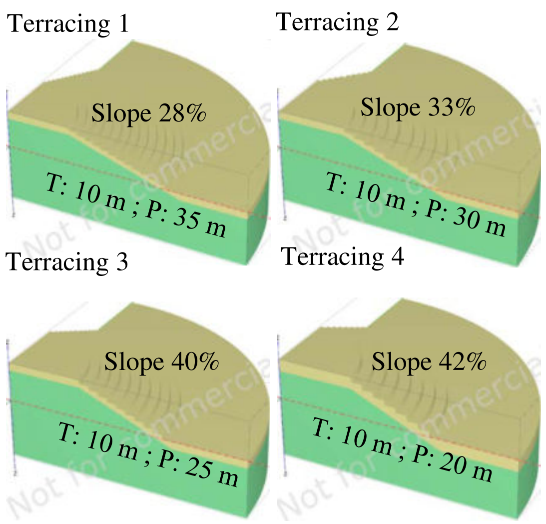

Fig.2 Geometric modelling of terraced slope

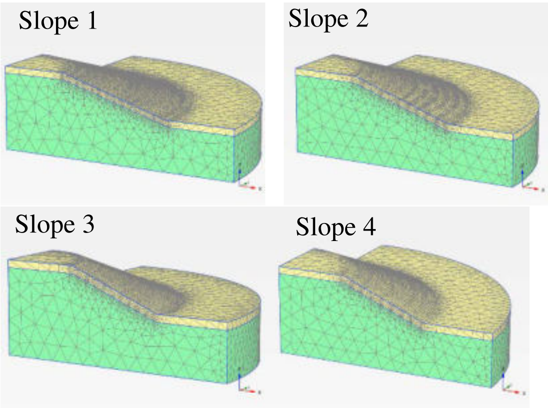

Fig.3 Mesh without terraced slope

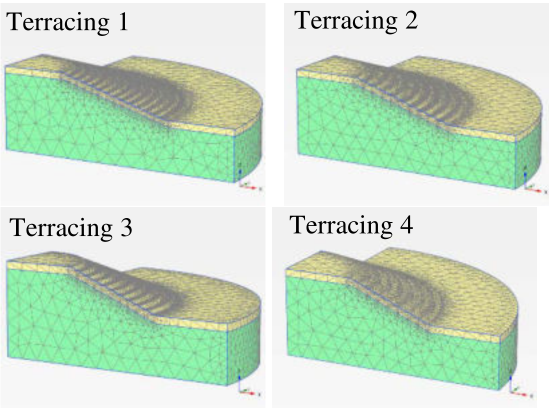

Fig.4 Mesh with terraced slope

5. OUTPUT AND ANALYSIS

In this study, slope stability analysis was carried out using Plaxis 3D using a finite element approach with four different slope conditions, starting from modeling the condition of the existing slope, then the geometry of the existing slope is changed by means of excavated terraces or terraces without reinforcement then the terraces are given vetiver root reinforcement where the output produced is in the value of the safety factor and the slip area.

5.1 Existing Slope Stability

The results of the modelling analysis on the existing slopes with four modelled slopes gradient 28%, 33%, 40%, and 42%, using Plaxis 3D obtained the safety factor value and slip area (Figs.5-6). Where the safety factor value is still less than the permit safety factor value > 1.5 (SNI 8460:2017), the slope is categorized as unsafe and there is a need to increase the slope safety factor value and make the slope stable or safe (Table 4). Efforts to increase the value of the safety factor on the first existing slope are by changing the geometry of the existing slope with a terracing system.

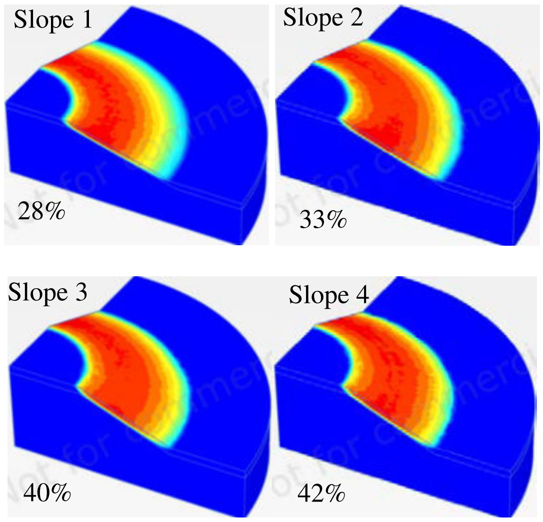

Fig.5 Critical failure surface of existing slope

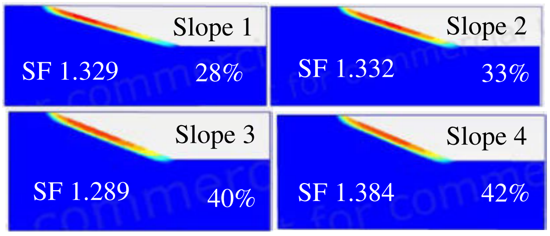

Fig.6 Critical failure surface and safety factor value of the existing slope

Table 4 Safety factor of the existing slope

No	Slope	Slope Safety Factor
1	28%	1.329
2	33%	1.332
3	40%	1.289
4	42%	1.384

5.2 Terraced Slope Stability

The results of the terrace modelling analysis on the existing slope using Plaxis 3D when the slope's geometry is changed with a terracing system shows that the value of the safety factor increases and the value of the safety factor is already more than the permit safety factor value, which is 1.5 (SNI 8460:2017) so that the terraced slopes are categorized as safe (Table 5). This is because changes in geometry on slopes with a terracing system can reduce the length of the slope and minimize slope level, so the terracing contributes to stabilizing the slope and increases the value of the safety factor on the existing slope (Figs. 7-8).

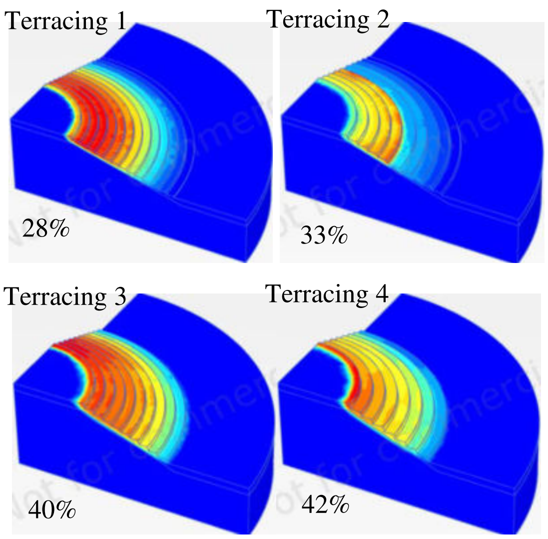

Fig.7 Critical Failure surface of terraced slope

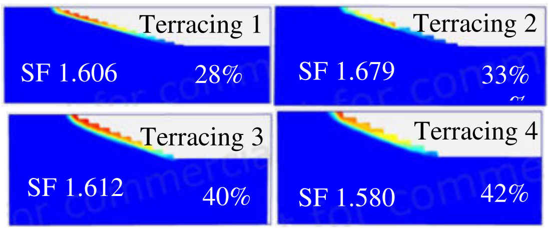

Fig.8 Critical failure surface and safety factor value of the terraced slope

Table 5 Safety factor value and increased safety factor percentage of terraced slope

No	Slope	Slope Safety Factor	Terraced Safety Factor	Increased Safety Factor Percentage
1	28%	1.329	1.606	17%
2	33%	1.332	1.679	21%
3	40%	1.289	1.612	20%
4	42%	1.384	1.580	12%

5.3 Terraced Slope Stability with Reinforcement

As time goes by, the vetiver roots are getting longer, causing the value of the factor of safety to increase (Figs. 9-16). It can be seen that the deeper the root penetration, the value of the safety factor increases, and the slip area gets deeper in this case because vetiver plant roots bind the soil structure so as to increase the value of soil cohesion and make the soil hard and strong (Table 6-9). The body of the vetiver plant itself acts as a barrier to the surface run-off rate in order to expedite the process of infiltration.

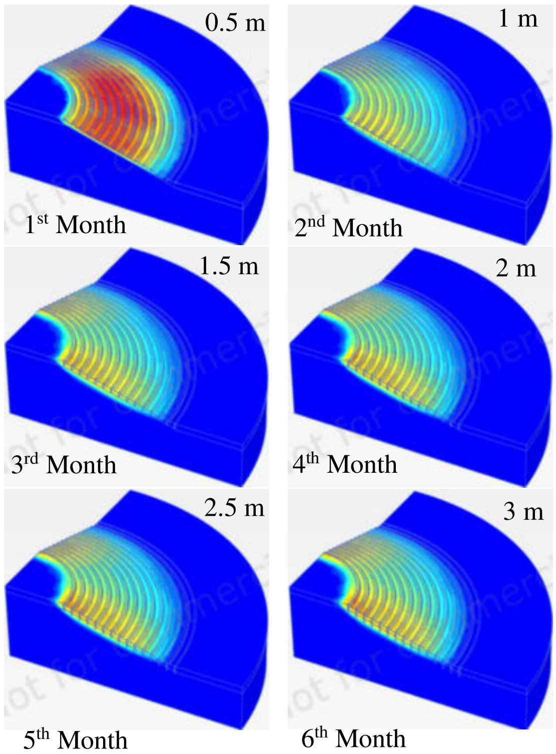

Fig.9 Critical failure surface of terraced slope gradient 28% with vetiver grass

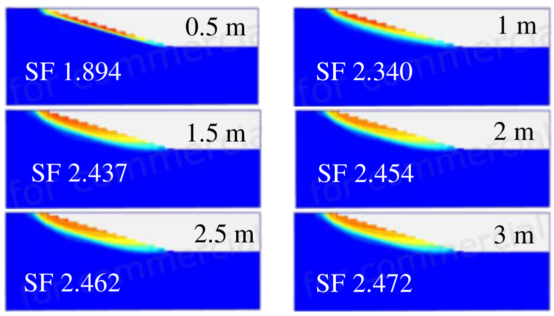

Fig.10 Critical failure surface and safety factor value of terraced slope gradient 28% with vetiver grass.

Table 6 Safety factor value and percentage increase in vetiver root reinforcement at 28% terraced slope

No	Age	Root Depth	Safety Factor Value	Increased Percentage of Safety Factor Value
	month	m		
1	1	0.5	1.894	32.5%
2	3	1.0	2.340	51.5%
3	5	1.5	2.437	55.5%
4	7	2.0	2.454	56.2%
5	10	2.5	2.462	56.5%
6	12	3.0	2.472	56.9%

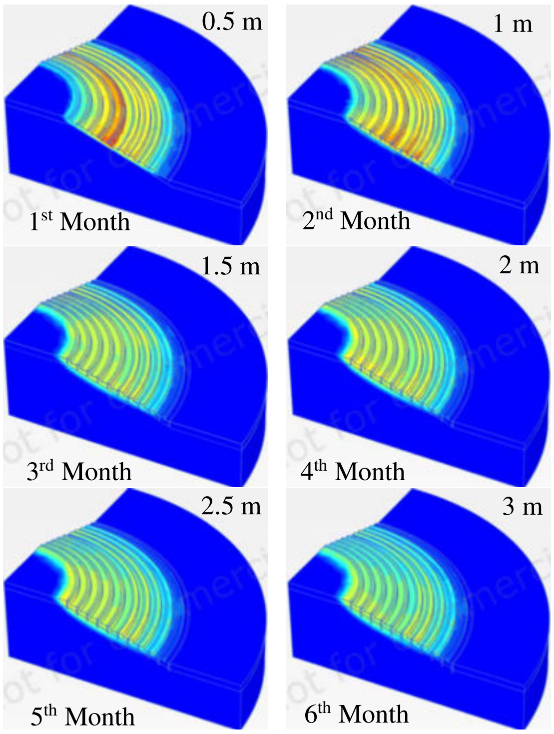

Fig.11 Critical failure surface of terraced slope gradient 33% with vetiver grass

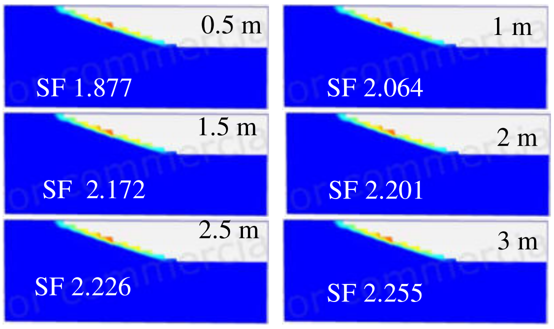

Fig.12 Critical failure surface and safety factor value of terraced slope gradient 33% with vetiver grass

Table 7 Safety factor value and percentage increase in vetiver root reinforcement at 33% terraced slope

No	Age	Root Depth	Safety Factor Value	Increased Percentage of Safety Factor Value
	month	m		
1	1	0.5	1.877	31.2%
2	3	1.0	2.064	40.1%
3	5	1.5	2.172	45.3%
4	7	2.0	2.201	46.6%
5	10	2.5	2.226	47.7%
6	12	3.0	2.255	49%

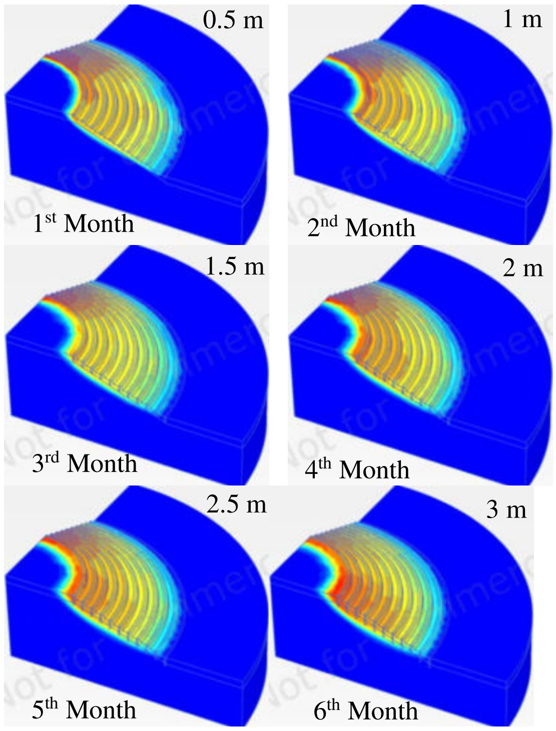

Fig.13 Critical failure surface of terraced slope gradient 40% with vetiver grass

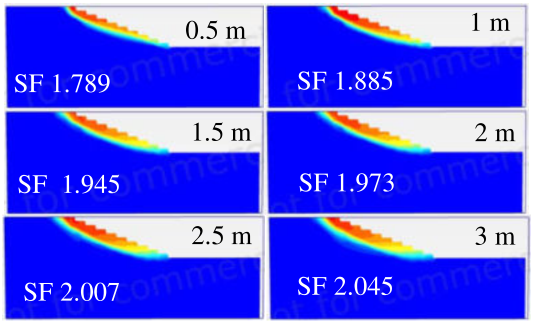

Fig.14 Critical failure surface and safety factor value of terraced slope gradient 40% with vetiver grass

Table 8 Safety factor value and percentage increase in vetiver root reinforcement at 40% terraced slope

No	Age	Root Depth	Safety Factor Value	Increased Percentage of Safety Factor Value
	month	m		
1	1	0.5	1.789	29.9%
2	3	1.0	1.885	35.0%
3	5	1.5	1.945	38.1%
4	7	2.0	1.973	39.5%
5	10	2.5	2.007	41.2%
6	12	3.0	2.045	43.1%

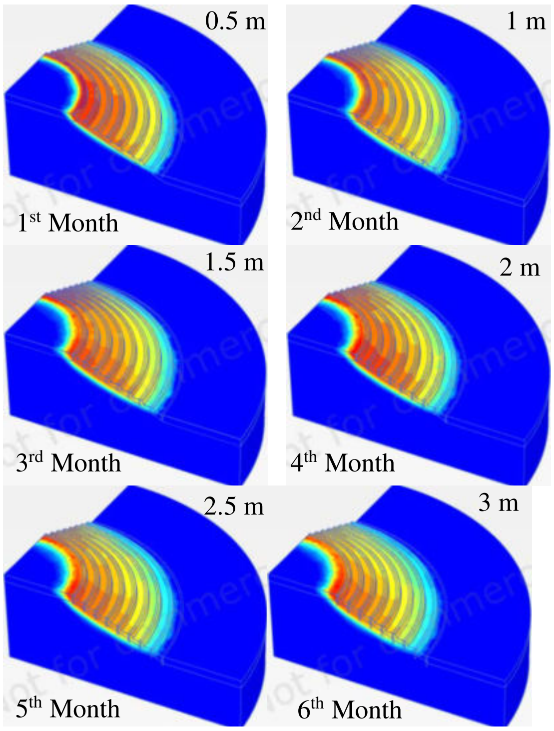

Fig.15 Critical failure surface of terraced slope gradient 42% with vetiver grass

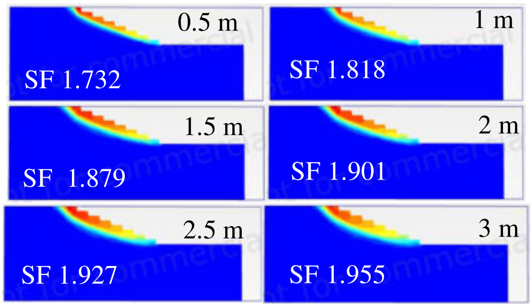

Fig.16 Critical failure surface and safety factor value of terraced slope gradient 42% with vetiver grass

Table 9 Safety factor value and percentage increase in vetiver root reinforcement at 42% terraced slope

No	Age	Root Depth	Safety Factor Value	Increased Percentage of Safety Factor Value
	month	m		
1	1	0.5	1.732	21.2%
2	3	1.0	1.818	25.9%
3	5	1.5	1.879	29.2%
4	7	2.0	1.901	30.3%
5	10	2.5	1.927	31.7%
6	12	3.0	1.955	33.1%

It can be seen that the deeper the root penetration, the value of the safety factor can increase because the roots of the vetiver bind the soil structure so that it increases the soil cohesion value and makes the soil hard and strong beside that body of the vetiver plant acts as inhibiting the rate of surface run-off to facilitate the infiltration process it makes slope stable and safe (Fig.17).

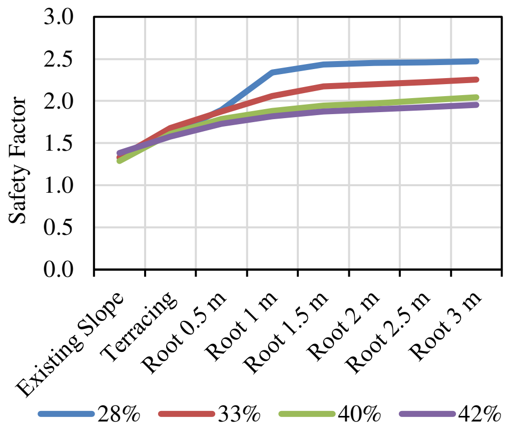

Fig.17 Chart of increased safety factor value

6. CONCLUSION

1. Changes in the geometry of the existing slope by making terraces affect the increase in the value of the safety factor. On slopes 28% experienced an increase of 17%, and on a slope of 33%, an increase of 21%, on Changes in the geometry of the existing slope by making terraces affect the increase in the value of the safety factor. On slopes 28% experienced an increase of 17%, on a slope of 33% an increase of 21%, on a slope of 40% increased by 20%, and on the slopes of 42% experienced an increase of 12% where with terracing is able to make the slope stable.
2. In the example slope used here, reinforcement of soil through the use of vetiver roots on terraced slopes is very effective because the growth of plants is fairly fast with good deep root penetration to increase the value of soil cohesion so that the soil structure and the value of the slope safety factor is increased. Vetiver roots were able to increase the safety factor value by 49% on the slopes. The more the slope was reinforced by vetiver roots, the greater the percentage increase in the value of the safety factor.
3. In this example, the slope used here, analysis of terrace slope stability with reinforcement of slope based on root depth with the root age approach, shows that the deeper the penetration depth of the roots, the greater the value of the safety factor obtained. Root penetration of 0.5 meters is able to increase the value of the safety

factor by 29%. In the third month, the penetration of 1 meter is able to increase the value of the safety factor by 38%. In the fifth month the root penetration of 1.5 meters is able to increase the value of the safety factor by 42%. In the seventh month, at 2 meters, the penetration is able to increase the value of safety factor by 43%. In the tenth month, the root penetration of 2.5 meters is able to increase the value of safety factor of 44%. After a year, the root penetration of 3 meters can increase the value of the safety factor by 45% .

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