Earth & Environmental Science 2019 v1.3

IA2 high-level annotated sample response

August 2018

Student experiment (20%)

This sample has been compiled by the QCAA to assist and support teachers to match evidence in student responses to the characteristics described in the instrument-specific marking guide (ISMG).

Assessment objectives

This assessment instrument is used to determine student achievement in the following objectives:

2. apply understanding of the use of renewable or non-renewable resources to modify experimental methodologies and process primary data
3. analyse experimental evidence about the use of renewable or non-renewable resources
4. interpret experimental evidence about the use of renewable or non-renewable resources
5. investigate phenomena associated with the use of renewable or non-renewable resources through an experiment
6. evaluate experimental processes and conclusions about the use of renewable or non-renewable resources
7. communicate understandings and experimental findings, arguments and conclusions about the use of renewable or non-renewable resources.

Note: Objective 1 is not assessed in this instrument.

Instrument-specific marking guide (ISMG)

Criterion: Research and planning

Assessment objectives

2. apply understanding of the use of renewable or non-renewable resources to modify experimental methodologies and process primary data
5. investigate phenomena associated with the use of renewable or non-renewable resources through an experiment

The student work has the following characteristics:	Marks
• informed application of understanding of the use of renewable or non-renewable resources to modify experimental methodologies demonstrated by – a considered rationale for the experiment – justified modifications to the methodology • effective and efficient investigation of phenomena associated with the use of renewable or non-renewable resources demonstrated by – a specific and relevant research question – a methodology that enables the collection of sufficient, relevant data – considered management of risks and ethical or environmental issues.	5–6
• adequate application of understanding of the use of renewable or non-renewable resources to modify experimental methodologies demonstrated by – a reasonable rationale for the experiment – feasible modifications to the methodology • effective investigation of phenomena associated with the use of renewable or non-renewable resources demonstrated by – a relevant research question – a methodology that enables the collection of relevant data – management of risks and ethical or environmental issues.	3–4
• rudimentary application of understanding of the use of renewable or non-renewable resources to modify experimental methodologies demonstrated by – a vague or irrelevant rationale for the experiment – inappropriate modifications to the methodology • ineffective investigation of phenomena associated with the use of renewable or non-renewable resources demonstrated by – an inappropriate research question – a methodology that causes the collection of insufficient and irrelevant data – inadequate management of risks and ethical or environmental issues.	1–2
• does not satisfy any of the descriptors above.	0

Criterion: Analysis of evidence

Assessment objectives

2. apply understanding of the use of renewable or non-renewable resources to modify experimental methodologies and process primary data
3. analyse experimental evidence about the use of renewable or non-renewable resources
5. investigate phenomena associated with the use of renewable or non-renewable resources through an experiment

The student work has the following characteristics:	Marks
• appropriate application of algorithms, visual and graphical representations of data about the use of renewable or non-renewable resources demonstrated by correct and relevant processing of data • systematic and effective analysis of experimental evidence about the use of renewable or non-renewable resources demonstrated by – thorough identification of relevant trends, patterns or relationships – thorough and appropriate identification of the uncertainty and limitations of evidence • effective and efficient investigation of phenomena associated with the use of renewable or non-renewable resources demonstrated by the collection of sufficient and relevant raw data.	5–6
• adequate application of algorithms, visual and graphical representations of data about the use of renewable or non-renewable resources demonstrated by basic processing of data • effective analysis of experimental evidence about the use of renewable or non-renewable resources demonstrated by – identification of obvious trends, patterns or relationships – basic identification of uncertainty and limitations of evidence • effective investigation of phenomena associated with the use of renewable or non-renewable demonstrated by the collection of relevant raw data.	3–4
• rudimentary application of algorithms, visual and graphical representations of data about the use of renewable or non-renewable resources demonstrated by incorrect or irrelevant processing of data • ineffective analysis of experimental evidence about the use of renewable or non-renewable resources demonstrated by – identification of incorrect or irrelevant trends, patterns or relationships – incorrect or insufficient identification of uncertainty and limitations of evidence • ineffective investigation of phenomena associated with the use of renewable or non-renewable resources demonstrated by the collection of insufficient and irrelevant raw data.	1–2
• does not satisfy any of the descriptors above.	0

Criterion: Interpretation and evaluation

Assessment objectives

4. interpret experimental evidence about the use of renewable or non-renewable resources

6. evaluate experimental processes and conclusions about the use of renewable or non-renewable resources

The student work has the following characteristics:	Marks
• insightful interpretation of experimental evidence about the use of renewable or non-renewable resources demonstrated by justified conclusion/s linked to the research question • critical evaluation of experimental processes about the use of renewable or non-renewable resources demonstrated by – justified discussion of the reliability and validity of the experimental process – suggested improvements and extensions to the experiment that are logically derived from the analysis of evidence.	5–6
• adequate interpretation of experimental evidence about the use of renewable or non-renewable resources demonstrated by reasonable conclusion/s relevant to the research question • basic evaluation of experimental processes about the use of renewable or non-renewable resources demonstrated by – reasonable description of the reliability and validity of the experimental process – suggested improvements and extensions to the experiment that are related to the analysis of evidence.	3–4
• invalid interpretation of experimental evidence about the use of renewable or non-renewable resources demonstrated by inappropriate or irrelevant conclusion/s • superficial evaluation of experimental processes about the use of renewable or non-renewable resources demonstrated by – cursory or simplistic statements about the reliability and validity of the experimental process – ineffective or irrelevant suggestions.	1–2
• does not satisfy any of the descriptors above.	0

Criterion: Communication

Assessment objective

7. communicate understandings and experimental findings, arguments and conclusions about the use of renewable or non-renewable resources

The student work has the following characteristics:	Marks
• effective communication of understandings and experimental findings, arguments and conclusions about the use of renewable or non-renewable resources demonstrated by – fluent and concise use of scientific language and representations – appropriate use of genre conventions – acknowledgment of sources of information through appropriate use of referencing conventions.	2
• adequate communication of understandings and experimental findings, arguments and conclusions about the use of renewable or non-renewable resources demonstrated by – competent use of scientific language and representations – use of basic genre conventions – use of basic referencing conventions.	1
• does not satisfy any of the descriptors above.	0

Task

Context
You have completed the following practicals in class: • Model location, exploration and extraction of a metallic resource. Use a locality map to predict the location of a metallic resource (suggested practical). • Analyse and interpret geophysical and geochemical exploration datasets (mandatory practical). • Design and conduct experiments to model other separation or processing techniques (e.g. crushing, smelting and froth flotation, gravitational separation) (suggested practical). • Conduct an experiment to model turbidity management strategies, using settling ponds (mandatory practical). • Investigate the effect of slope/revegetation on the volume of water run-off and amount of topsoil lost through erosion (suggested practical).
Task
Modify (i.e. refine, extend or redirect) an experiment in order to address your own related hypothesis or question. You may use a practical performed in class, a related simulation or another practical related to Unit 3 (as negotiated with your teacher) as the basis for your methodology and research question.

Sample response

Criterion	Marks allocated	Result
Research and planning Assessment objectives 2, 5	6	6
Analysis of evidence Assessment objectives 2, 3, 5	6	6
Interpretation and evaluation Assessment objectives 4, 6	6	5
Communication Assessment objective 7	2	2
Total	**20**	**19**

The annotations show the match to the instrument-specific marking guide (ISMG) performance-level descriptors.

Key: Research and planning Analysis of evidence Interpretation and evaluation Communication

Note: Colour shadings show the characteristics evident in the response for each criterion.

Research and planning [5–6]

a considered rationale for the experiment

The rationale contains evidence of a logical, scientifically informed basis for the experiment.

Student experiment

Can a mathematical model be used to describe the relationship between the slope gradient of the land and the mass of soil lost through water erosion?

Rationale

The relationship between runoff, soil erosion and the gradient of land surface is not well understood (Fang, Sun and Tang, 2014). Runoff is defined as water that flows over land rather than infiltrating into it (Tarbuck, Lutgens, and Tasa, 2016). Soil erosion is defined as the movement of particles of soil, surface sediments and rocks by the action of water and or wind. The mass of soil moved by runoff can be affected by:

- size and velocity of raindrops
- permeability of the soil
- soil particle size and shape
- slope angle
- exposure and vegetative cover.

(Hubble, Huxley, Imlay-Gillespie, 2011), (Moore and Burch, 1986).

	Rainfall erosivity is a term that is used to describe the potential for soil to be washed off from disturbed, de-vegetated areas and move with surface waters during storms (Soil and Water Conservation Engg, 2013). Soil erosion by running water occurs where the intensity and duration of rainstorms exceeds the capacity of the soil to allow the rainfall to infiltrate the soil (Murty and Jha,1985).
Research and planning [5–6] **a considered rationale for the experiment** The response carefully communicates the purpose and reasons for the experiment. The rationale explicitly communicates the reasons for modifying the original experiment.	Rehman et.al (2015) conducted an experiment to assess runoff and sediment losses under different slope gradients (1,5 and 10%). A positive correlation was found between increasing the slope and the volume of water runoff and soil eroded from the slope. The purpose of conducting this experiment is to refine Rehman's experiment by investigating the effect of slope gradients (2, 4, 6, 10, and 12%) on the amount of soil loss. It is expected that modifying Rehman's experiment by increasing the number of slope gradients investigated will provide information that can refine Rehman's results to determine a specific mathematical model for the positive correlation established by the original experiment. Mathematical models demonstrate greater validity when more accurate data is available to verify the model (Robinson,1997). This experiment will also extend Rehman's experiment by investigating a larger range of slopes than Rehman. It is expected that by increasing the range of slope gradients to be investigated (2-12%), the positive correlation established by Rehman will be tested beyond the parameters of the original experiment (1-10%). This will help broaden the possible application of this model to environments with greater than 10% slope gradients.
a specific and relevant research question The research question is clearly defined to allow the collection of sufficient and relevant data. The research question is connected to the rationale and the topics covered in the unit.	**As such, the research question to be investigated is:** *Can a mathematical model be used to describe the relationship between the slope gradient of the land and the mass of soil lost through water erosion?*

Research and planning [5–6]

justified modifications to the methodology

The response gives sound reasons for how the modifications to the methodology will refine, extend or redirect the original experiment, and includes strategies for achieving these modifications.

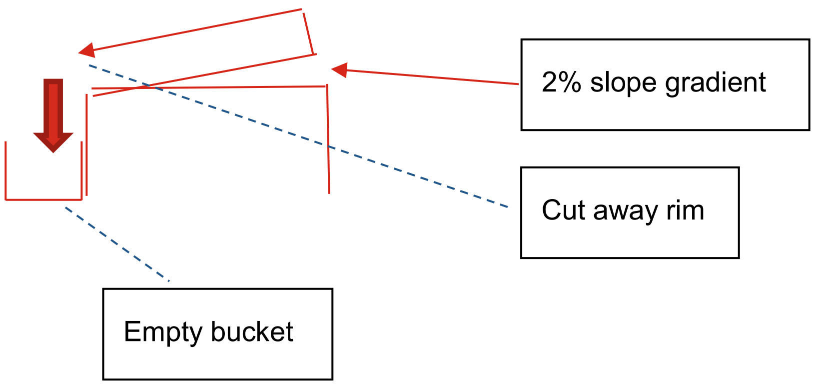
Modification to experiment methodology

The specific modifications to Rehman's original experiment are as follows:

Table 1: Modification to experiment methodology

Modification* to Rehman's experiment	Reason why this modification will refine or extend the original experiment
Double the number of slope gradients investigated from 3 to 6 (e.g. Diagram 1)	Mathematical models demonstrate greater validity when more accurate data is available to verify the model (Robinson,1997). By using 6 points of data rather than 3, a more valid mathematical model will be able to be generated.
Extend the range of slope gradients investigated up to 12%	Rehman's experiment found that a proportional relationship existed between the slope gradient and the mass of soil collected. By extending the range of slope gradients, this experiment will establish whether or not the proportional relationship is maintained on steeper slopes.

Diagram 1: Experimental set up for a 2% slope gradient



considered management of risks and ethical or environmental issues

The response shows careful and deliberate identification and planning to handle risks and ethical or environmental issues in the experiment.

Management of risks

During the planning of the methodology for this experiment, some risks were identified. The risks and their associated managements strategies are outlined below:

Table 2: Management of risks

Risk identified	Management strategy
The bags of soil are heavy and need to be lifted	The correct lifting technique must be used to minimise stress on the lower part of the back.
Particles of soil may be flicked into a person's eye	Safety glasses must be worn at all times
Water spills on the floor	A visual check must be made after each trial to ensure that the floor is dry. Rubber soled footwear will also prevent any slip

Research and planning [5–6]

a methodology that enables the collection of sufficient, relevant data

The methodology shows careful and deliberate thought. It enables collection of adequate data so an informed conclusion to the research question can be drawn.

Analysis of evidence [5–6]

collection of sufficient and relevant raw data

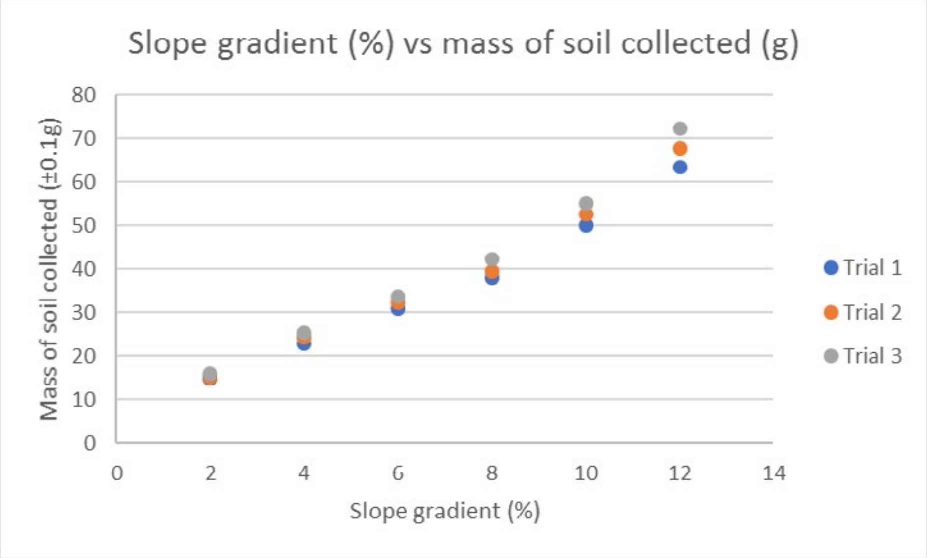
The raw data is adequate for forming a conclusion and has direct bearing upon the research question. Five variations of the independent variable and three repetitions of each measurement are adequate.

Raw data

Table 3: Mass of soil collected across three separate trials with respects to slope gradient

Slope gradient (%)	Mass (g) of Soil collected in runoff (±0.1g)		
	Trial 1	Trial 2	Trial 3
2	15.0	15.3	16.2
4	23.0	24.5	25.5
6	31.0	32.4	33.7
8	38.0	39.5	42.3
10	50.1	52.5	55.2
12	63.5	67.9	72.3

Graph 1: Raw data of mass of soil collected across three separate trials with respects to slope gradient.



Graph 1 appears to show a linear relationship between an increase in soil slope and mass of soil collected. Using Excel, a trend line could be produced to examine the coefficient of correlation (R2 value) between the independent and dependent variable to judge how well a linear model represents the collected data.

Communication [2]

appropriate use of genre conventions

Raw data is recorded with the associated uncertainties and expressed consistently to the correct number of significant figures.

Analysis of evidence [5–6]

correct and relevant processing of data

Raw data is manipulated accurately to provide evidence that is applicable to the research question.

Processed data

Quantitative Data (Processed data)

Table 5: Mass (g) of soil in runoff water for different slope gradient (cm)

Slope gradient (%)	Mass of Soil collected in runoff (± 0.1g)			Average mass of soil (g)	Average mass of soil (g)
	Trial 1	Trial 2	Trial 3		
2	15.0	15.3	16.2	15.5 ± 0.6*	15.5 ± 4%
4	23.0	24.5	25.5	24.3 ± 1.3*	24.3 ± 5%
6	31.0	32.4	33.7	32.4 ± 1.4*	32.4 ± 4%
8	38.0	39.5	42.3	39.9 ± 2.2*	39.9 ± 5.5%
10	50.1	52.5	55.2	52.6 ± 2.5*	52.6 ± 5%
12	63.5	67.9	72.3	67.9 ± 4.4*	67.9 ± 6.5%

*note that absolute uncertainties of the mean are much greater than the measurement uncertainty of ± 0.1g. As such, the measurement uncertainty will be insignificant.

Processed data: sample calculations

1. Average values in **Table 3**.

   Average soil mass for the 2% slope: $\frac{(15.0+15.3+16.2)}{3} \pm \frac{(16.2-15.0)}{2}$

   = 15.5 ± 0.6g

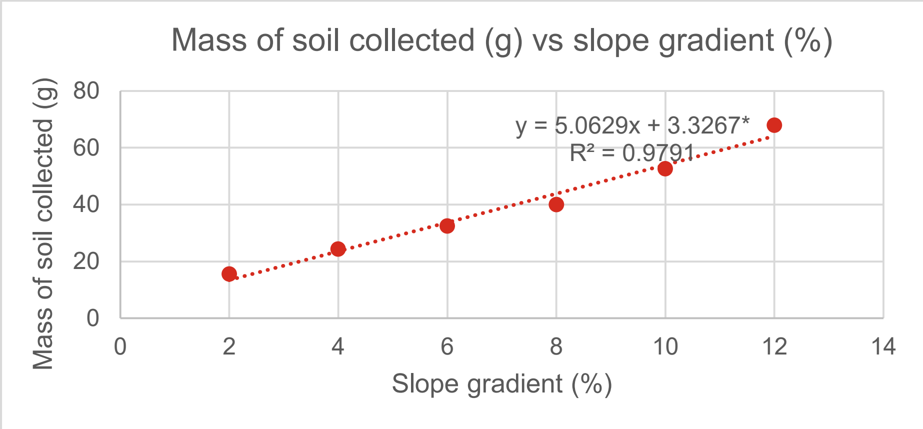
2. Conversion of absolute to percentage uncertainty

   $\frac{0.6}{15.5} \times 100$

   = 3.9%

Analysis of data

Graph 2: Mass of soil collected with respects to slope gradient.



*Note: A linear trendline has been chosen to model the data because it is both simple to use and a good fit for the data. The R^2 value returned by the linear trendline is equal to 0.9791.

Graph 2 suggests a linear relationship between the slope gradient and the mass of soil collected. A linear trendline was generated using excel to model the relationship between the slope gradient and the mass of the soil collected. The model can be described using the following mathematical equation:

$$y = 5.0629x + 3.3267$$

Analysis of evidence [5–6]

thorough identification of relevant trends, patterns or relationships

The identified trends, patterns and relationships are not superficial and allow a justified conclusion to the research question to be drawn.

The data therefore suggests that the relationship between the slope gradient and mass of soil eroded by runoff can be modelled by the equation:

$$m = 5.0629g + 3.3267$$
$$m = 5.1g + 3.3$$

where $m = mass\ of\ soil\ collected\ (g)$ and $g = gradient\ of\ the\ slope\ (\%)$.

This model suggests that as the gradient of the slope increases, there is a directly proportional increase in the amount of soil eroded from the surface due to runoff (i.e. the mass of soil lost is approximately 5 times the value for percentage slope gradient).

thorough and appropriate identification of the uncertainty and limitations of evidence

The response suitably identifies uncertainty and limitations of the data in a way that is not superficial or partial. The response examines the uncertainty to determine if the evidence that will be used to draw a conclusion to the research question is reliable and valid.

Further analysis of the data suggests that there is a degree of uncertainty about the accuracy of data used in the model. As seen in graph 2, there are two data points (i.e. for 8 & 12%) which don't fit the linear model proposed which suggests that the data is inconsistent with the other processed data. Evidence of this limitation can be seen in Table 5, whereby the two largest calculated values for uncertainty of the evidence for the 8 and 12% slope were 5.5 and 6.5% respectively. Although the line of best fit in graph 2 supports a linear relationship between slope gradient and mass of soil lost, the curve in graph 1 appears to represent an exponential growth curve (i.e. a curve upward at the higher slope

Analysis of evidence [5–6] **thorough and appropriate identification of the uncertainty and limitations of evidence** The response suitably identifies uncertainty and limitations of the data in a way that is not superficial or partial. The response examines the uncertainty to determine if the evidence that will be used to draw a conclusion to the research question is reliable and valid. **Interpretation and evaluation [5–6]** **justified conclusion/s linked to the research question** The conclusions draw upon scientific understanding and evidence, and directly respond to the research question. **Analysis of evidence [5–6]** **thorough and appropriate identification of the uncertainty and limitations of evidence** The response examines the uncertainty to determine if the evidence that will be used to draw a conclusion to the research question is reliable and valid. **Interpretation and evaluation [3–4]** **suggested improvements and extensions to the experiment that are related to the analysis of evidence** The suggested modifications address the limitations of the experiment. However, the response does not use evidence to show that these modifications would improve the reliability and validity of this experiment.	It should be noted that this model is limited to exposed slopes where there is no ground cover, and a single rain event occurs. The limitation of the model is due to the limitations of the data collected. Data was not collected on slopes with rocks, roots, grass or trees present. Further, data was collected on a slope that was uncompacted and dry before a 'rain' like event. **Interpretation and evaluation** Based on the evidence collected, a model was produced that suggests that an increase in the slope of the land will result in a directly proportional increase in the mass of soil lost through runoff. The model suggests that the mass of soil collected (in grams) is approximately 5 times larger than the slope gradient. These findings are consistent with existing scientific understanding of the mechanism of soil erosion due to runoff. As stated in the rationale, the mass of water runoff depends on how much water is allowed to infiltrate the soil surface. The water that runs over the surface of the land (runoff) tends to carry with it soil, depositing it at the base of the slope. The greater the slope gradient, the less likely water will infiltrate the soil, and the more likely it will run along the surface, increasing the erosivity of the simulated rainfall. The increased erosivity leads to an increased amount of soil eroded from the surface. Whilst Huxley, Imlay-Gillespie (2011) and Moore and Burch (1986) indicate this, appendix 1 shows the relationship between the mass of water runoff collected, and the mass of the soil collected at the base of the slope. The data suggests a linear relationship, confirming the theoretical understanding established in the rationale. The results presented in table 5 show that there is a larger measure of percentage uncertainty for calculated average values at the steeper slopes (i.e. 8, 10 and 12%). Larger measures of uncertainty can be explained by the larger spread in results (range) for the independent variable for these slopes. To reduce the range of collected results and improve the accuracy and precision of the measurements (and consequently, the reliability of the experiment method) a number of steps could be taken. 1. The initial soil level should be below the level of the rim of the tray. This will reduce the mass of soil lost over the side of the tray instead of over the front during the process of runoff. This would allow a more accurate measure of the mass of soil being eroded. 2. The initial soil level should be below the level of the rim of the tray. This will reduce the mass of soil lost over the side of the tray instead of over the front during the process of runoff. This would allow a more accurate measure of the mass of soil being eroded. 3. The process of separating all the soil washed into the container from the runoff water could be refined. A filtering technique was used, however some soil passed through the filter paper and was not included in the final measurement. By using a different technique, this systematic error could be reduced, resulting in a more accurate measure of the mass of soil being eroded.

4. A more reliable way of delivering a consistent “rainfall” event over the top of each tray could be developed. Rainfall erosivity as mentioned in the rationale, is dependent upon the kinetic energy and velocity of rain. Ensuring that the kinetic energy and velocity of the ‘rain’ is controlled, more reliable data would be collected. It is suggested that by setting up a raindrop shower over the top of the tray with the correct volume of water or by conducting trial runs with a watering can prior to the experiment, will ensure rainfall delivery with a consistent kinetic energy and velocity.

Interpretation and evaluation [5–6]

justified discussion of the reliability and validity of the experimental process

The discussion uses evidence from the identification of the limitations to determine the validity of the experimental process.

The experimental method (and subsequent model) are valid only when applied to exposed soil covered slopes between 2-12% gradients. The experimental method is not valid enough such that the model produced can fully answer the research question. Instead, the model only suggests an answer to the research question under the following conditions:

- The model is applied to exposed soil surfaces between 2-12% gradients
- The exposed soil surfaces were initially dry and uncompacted
- The slope does not have trees, grass, rocks or other potential features that will prevent erosion
- The slope experiences a single rain event.
- The soil type is the same as that used during the experiment.

The validity of the experimental method is responsible for the limitations to the data and application of the model.

Interpretation and evaluation [3–4]

suggested improvements and extensions to the experiment that are related to the analysis of evidence

The suggested improvements would improve the validity and reliability of the experiment. However, the response does not use evidence to inform the modifications.

Further investigation could look at:

- extending the range of the experiment to look at soil loss at higher slopes to test the reliability and validity of the linear model.
- extending the length of slope in a controlled environmental setting to test the validity of a linear model fitting the collected data and
- redirecting the experiment to see if data collected from other soil types can be explained by the same linear model or if the data can be represented by a similar model.

Communication [2]

fluent and concise use of scientific language and representations

Throughout the response, any errors in the use of scientific language do not hamper the reader from easily understanding the intended meaning. The response avoids unnecessary repetition of information and is within the prescribed length, i.e. 1500–2000 words.

In conclusion, the results from this experiment help to conditionally answer the research question and support earlier work by Rehman (2015). It would appear that areas with bare soil on steeper slopes will result in greater amount of soil erosion due to greater runoff during rainfall events. This will have implications for managing areas devoid of vegetation in urban and agricultural settings.

An understanding of slope and the effect it has on soil loss is important in order to sustainably manage land use and maintain natural or managed ecosystems. The top layer of soil is important to all ecosystems as it provides the nutrients for plant growth. Efforts should be made to better understand the effects of clearing land of its vegetation on soil processes like erosion.

Word count: 1946

Communication [2]

acknowledgment of sources of information through appropriate use of referencing conventions

The sources of information are acknowledged using a referencing style that is suitable for the purpose of the scientific report.

References

- Fang, H, Sun, L & Tang, Z 2014, ‘Effects of rainfall and slope on runoff, soil erosion and rill development: an experimental study using two loess soils’, *Hydrological Processes*, vol. 29, no. 11, pp. 2649–2658, http://onlinelibrary.wiley.com/doi/10.1002/hyp.10392/abstract.
- Hubble, T, Huxley, C & Imlay-Gillespie, I 2011, *Earth and Environmental Science: The HSC Course,* Cambridge University Press, Melbourne.
- Murty, VVN & Jha, MK 1985, *Land and Water Management Engineering*, Kalyani Publishers, New Delhi.
- Moore, ID & Burch, GJ 1986, ‘Physical basis of the length-slope factor in the Universal Soil Loss Equation’, *Soil Science Society of America Journal*, vol. 50, pp. 1294–1298.
- Rehman, O, et al. 2015, ‘Assessment of runoff and sediment losses under different slope gradients and crop covers in semi-arid watersheds’, *Soil Environ*, vol. 34, no. 1, pp. 75–81.
- Robinson, S 1997 Simulation Model Verification and Validation: Increasing the User’s Confidence. In S. Andradóttir, K. J. Healy, D. H. Withers, and B. L. Nelson (Eds.), Proceedings of the 1997 Winter Simulation Conference Operations and Information Management Group, Aston Business School, Birmingham, B4 7ET, UNITED KINGDOM.
- Tarbuck, EJ, Lutgens, FK & Tasa, DG 2016, *Earth: An Introduction to Physical Geology,* 12th edn, Pearson, New Jersey.

Note: Appendixes provide background information and context only. They are not considered when making judgments about the quality of the response.

Appendix 1

When comparing the mass of the soil collected and the mass of water runoff, the data suggests that the mass of soil is proportional to the mass of water runoff.