Examiner's commentary

The candidate selected an original topic and was able to discuss a global environmental issue (soil erosion) from a specific local perspective. There is an excellent explanation of the relevance of the research question and rationalization of personal engagement. The level of engagement with the research topic is evident throughout the whole essay. This essay involves a review of scientific data and a collection of data from an original laboratory investigation. The methodology used allows the candidate to collect simple but appropriate data. The sources selected and used are pertinent and have academic credibility. It is rewarding to observe an extended essay in Environmental Systems and Societies that can follow a systems approach and use this approach in the analysis and interpretation of the data. Overall, it is a very complete extended essay with the expected level of simplicity and academic rigour for an IB student.

Investigation on how does the improvement of land use, specifically terrace farming, improve the soil erosion problem in Loess Plateau Region

[redacted]

Acknowledgement:

With all of my gratitude, I would like to thank Mr. , my supervisor, for his support and guidance through both researching and writing process of this paper.

Table of Content:

1. Introduction :

Loess Plateau is the best know Plateau among the Four Greatest Plateau in China, which locates on North side of the middle part in China Mainland, as shown by the map below. (Wei, et al., 2016) The Loess Plateau has total area of 640 thousand kilometer square, where it crosses over 7 provinces in China (LiDing, Chen, et al., 2007). The Loess Plateau is one of the world regions where the worst soil and water loss happens, along with extremely fragile ecosystem. According to the researcher conducted by China Ministry of Water Resource (Zhou et al,. 2016), at the beginning of 2001, there is 340 thousand square kilometers of soil and water loss, in which over 290 thousand square kilometer of soil undergo soil erosion of 5000 tons per square kilometer. Among the regions covered in Loess Plateau, Gansu Province has the greatest area of soil erosion, which accounts for over 36% of total soil erosion of Loess Plateau, followed by ShanXi, and ShannXi. (LiDing, Chen, et al., 2007). The water and soil loss is a serious problem faced by ecologists and geographer around the world since it could not only cause loss of original landscape but also leads to consequences including loss of soil fertility, severe reduction in crops yield, and lowering life quality of farmers who makes living in Loess Plateau. The water and soil and water loss always accompanies with the soil erosion that leads to detrimental effects to the environment of Loess. The soil erosion happens when the soil surface, along with its matrix, are damaged, moved, precipitated, and eroded under the effect of water, wind, or thaw (Pimentel, D., Harvey, C., Resosudarmo, P., Sinclair, K., Kurz, D., McNair, M., ... & Blair, R., 1995). With regard to the negative effects of soil erosion in the Loess hilly area in China, it stays as one of the most difficult challenges to China ecologist and conservationist. The Soil erosion on Loess hilly area has led to massive decline of land

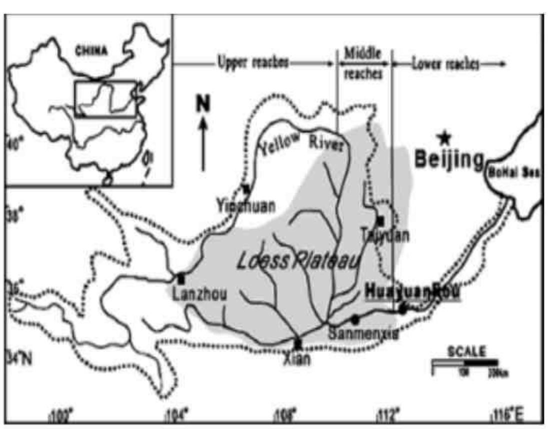


Figure 1. Location of Loess Plateau (Wei, et al.,

productivity, in which the farmers could no longer cultivate because the loss of fertile soil. (Montgomery, D. R., 2007) Also, enormous amount of sand and soil sediments rushed into the Yellow river, causing the riverbed to increase at 8-10 cm annually (Initial). Approximately, the consequences of soil erosion in Loess regions has already result in 10 billion of economic costs so far.

The causes of soil erosion in loess hilly area in China is widely researched by both Chinese Government and individual researchers. Most conclusion points out that the human activities may play a crucial role in both saving and worsening the soil erosion. Back in late 1800s of Qing Dynasty in China, the total population in Loess Plateau region reaches its peaks in feudalistic age: 41 million of people. (Zheng, F. L. 2006) This is due to the large scale of arable soil in loess regions, mostly included Gansu and Ning Xia Provinces. However, the population growth of Loess regions doesn't stop but rather boosted again in mid 1900s. In 1970s, the average population growth rate in Loess hilly regions is up to 35.3%, which is even more than growth rate of the whole nation, which is 21.2%. (LiDing, Chen, et al., 2007) In 1990 the total population in Loess hits 903 million, as compared to 491.3 million in 1960s, which made it the region that has fastest population growth rate. The consequences of this population boost are very obvious. The increase in population causes more lands to be turned into arable land for agricultural purposes, which leads to large scale of deforestation and loss of grass land in Loess Regions. During 1949 and 1985, there is an 30.6% increasing rate of arable fields (Sun, J. 2002), and as of 2001, over 60% of Loess land are considered arable lands that that serves agricultural and economics purposes.

While farmers keep exploiting the Loess soil, the soil erosion would cause huge damage to their lives too. The more arable fields are cultivated, the less stable the soil which makes it extremely vulnerable to soil erosion (Lal, R. A. T. T. A. N. 2001). On annual average, 180 million tons of soil organic matter, including ammonia nitrates, phosphorus, and potassium (NPK) would be lost along with the soil loss, and 1.54 million tons of it are total nitrogen, which accounts for 3.35 million tons of Urea fertilizer, leading to great economic and environmental costs. (LiDing, Chen, et al, 2007). Ammonia Nitrate (NH_4NO_3) are massively used in high-nitrogen fertilizer for agricultural uses, and it is essential nutrient for crops since nitrogen is responsible for both external and internal metabolism of plants, and it also makes up key fundamental component of amino acids in plants, which is vital for crops development. The phosphorus is the component of nucleic acids and regulate the protein synthesis in plants, which is always associated with cell division, tissue development, and repair of tissue. (Law-Ogbomo, K. E., & Egharevba, R. K. A., 2009)

In order to prevent further soil erosion and protect society of farmers in loess hilly regions, several attempts are carried out by Chinese Government. One of the best-known conservation policy “Grain for Green” is initiated in late 90s which aims to improve the land use of tilting landscape in Loess gully regions and at the same time to conduct vegetation rehabilitation in order to strengthen soil content in combating soil erosion. (BoJie, Fu, 2012) Meanwhile, individual approaches focusing on farmland reform, for example terrace farming, check-dam farming, and land closure, are also adopted as local government endeavoring to save loess from soil erosions. Terrace farming is an agricultural land use that is used to transform tilted slide in to level terraced in order to slow down the run-off thus preventing soil erosion. (Chapagain, T., & Raizada, M. N., 2017) The check-dam farming aims the same objectives as terrace farming does, but the construction of dams should satisfy certain requirement and lots of post-wok maintenance is necessary.

1.1 Rationale:

My hometown ShannXi is located in Loess regions of China where every year the community committee and farmers would working together to prevent the soil erosion in order to protect the revenue made by selling cultivated crops. Since 2000 Grain to Green Program (GTGP) is initiated by China Environmental Department, which aims to transform the farmland back into woodland or large-scale grassland so that the severe soil erosion will be ceased or slowed down on Loess plateau regions of China. However, decreasing fraction of farmland use means the productivity of farming also decreases. Just during the last Chinese New Year, terraced field seems to appear more frequently than last few years. It is interesting to watch terrace farming in region of central plains of China where rainfall is not usually heavy. This makes me wonder does terrace farming really improve the problem of soil erosion, and how does it help crop development as compared to the natural cultivation on the natural hillside.

In research of Lü Y, Fu B, Feng X, Zeng Y, Liu Y, et al. (2012) which aims to investigate the holistic effect of GTGP on restoring ecological condition on Loess regions of China, the researchers adopted the Universal Equation of Soil Loss (UESL) to estimate ongoing condition of soil erosion of loess plateau. As figure 1 shown, over half of loess regions in China has shown decrease in soil erosion, and this is simply attributed to the significant effect of vegetation rehabilitation driven by GTGP. However, the improvement of farmland use is rather neglected in dealing with long term soil erosion problems. Instead of simply converting farmland into woodland in order to achieve afforestation, more attentions are still needed to be paid on the more productive way of transforming the existing land-use in order to further restoring the agricultural condition of Loess regions, and one example of that is the adopt of terrace farming.

Therefore, mainly two types farming structures (Terraced Mode vs. Slope Model) are going to be compared and examined in the following paper

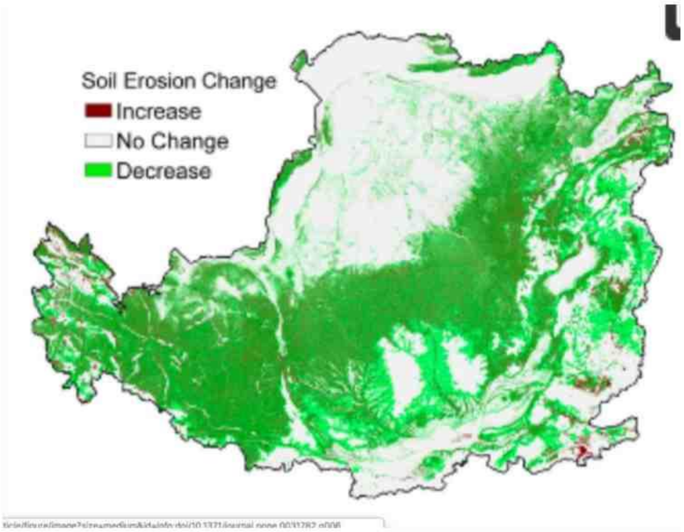


Figure 2. Restoration of Soil Erosion of Loess Plateau regions from 2000-2008. (Lu et al,

A: Terrace Farming Model Simulation

The construction of terrace field in real life situation is a very complex engineering process because it requires intensive labor work and careful measuring in order to cope with the topography of the farmland. The purpose of building the terrace is for slowing the speed of water rushing down the hill, which could carry massive amount of soil with to eventually flow into the lower reaches of the stream which, in the case of Loess Plateau, is the Yellow River (Yang, Shou Ye, et al., 2012). Even though constructing a real terraced field is unrealistic, a terrace field model could be done in order to simulate the effect of preventing soil erosion on the hill side.

A.1 Constructing the Model：

In this paper the level terrace, which is a commonly adopted types of terrace field that is easier to simulate, is selected as the prototype of model. The model doesn't have to be exactly measured and designed as agricultural engineer do, but it serves the basic functions through after placing terraces of descending height as shown in the setup picture below (Figure 3). Wax paper boxes are used and taped together to form a descending level of terraces that would simulate the formation terraced farming. To prevent the whole thing from collapsing after getting wet, plastic membranes are used to cover each layer of terrace. There are 4 levels of terraces to act as platform for holding the soil, and at the bottom a basket is placed for the purpose of collecting run-off samples after irrigation.

The irrigation method used here is to simulate the natural rainfall. This is done by poking holes on a 2 liters' empty bottle and allow the water inside to drop natural on the experimental soils on the first terrace. The standard specifications of my model are shown in **table 1 below.**

Figure 3. Demonstration of Terraced Model

Table 1. Terrace Field Model Standard Specs.

Specs. Items & Units	Measurement
Single Terrace Height (cm)	20.5
Single Terrace Width (cm)	20.5
Single Terrace Length (cm)	30
Gross Soil Mass (gram)	2400
Gross Irrigation Water Volume (Gram)	1000
Gross Soil Volume (Liter)	10
Soil Volume per Terrace (Liter)	2.5

A.2 Methodology:

*** Gross Soil Loss Test:**

The gross soil loss test is done on the sample of run-off collected in the collecting basket. After the simulated rainfall is finished, there will be a 10-minute time interval for the water to finish running down the slope or series of terraces. After ten minutes the run-off sample collected in the basket would be measured using electronic balance (± 0.1 g) to find the total mass of run-off sample collected. This process is done on both models. When measuring the mass of the run-off sample, there is no previous time given for the soil to dry out, so the data of gross soil loss test is actually the combination of water absorbed and soil sample. Still, this doesn't affect comparability between terraced and slope model since both data contains the water mass.

*** Gully Formation and Morphology:**

This series of data consists of width and height of gullies formed on the surface of soil sample on both models. During ten minutes' interval given to for water stream, gullies are clearly recognizable on the surface of the soils. Both width and height of gullies on the soil surface are measured with rulers (± 0.05cm) For the terraced model, there are numerous gullies formed on each level of terrace, but during the collecting part, the width and height of different gullies on one layer of terrace are summed up to form a integrative data, which makes it more accountable to compare with that of the slope model. In the raw data table of gully formation and morphology, only width and height are included but not the number of gullies formed. This is because number of gullies formed on each terrace are likely to be random since the force of simulated rainfall is not controllable in this study.

*** Nutrients Level Test:**

This sample for nutrients concentration test requires run-off solution and testing kit that utilizes colorimetry for ammonia nitrogen and phosphorus. 15ml of tested sample are taken from the run-off solution from terraced and slope model, and the test tube containing the sample are put in centrifuge because the run-off sample is too muddy, which makes colorization difficult to identify. After ten minutes of centrifuging, testing kit chemicals are used in the solution, and 15 minutes are waited for the colorization to be prepared. After 15 minutes, the test tube containing the tested sample are compared against the colorization chart given by the kit under the bright light for an accurate result. This procedure is done on both ammonia nitrogen and phosphorus.

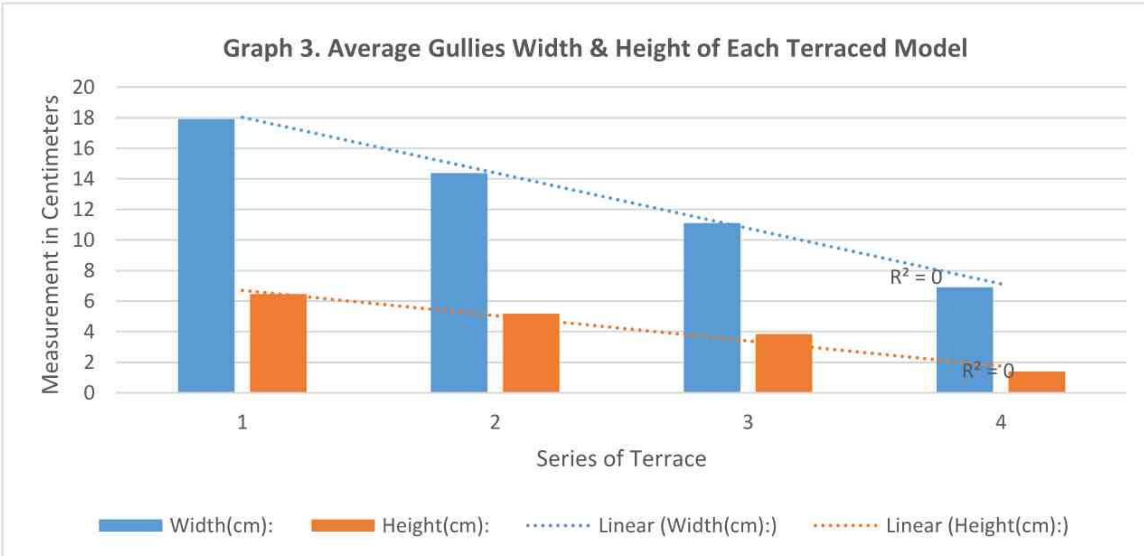
A.3 Result and Analysis:

A.3.1. Gully Formation and Morphology:

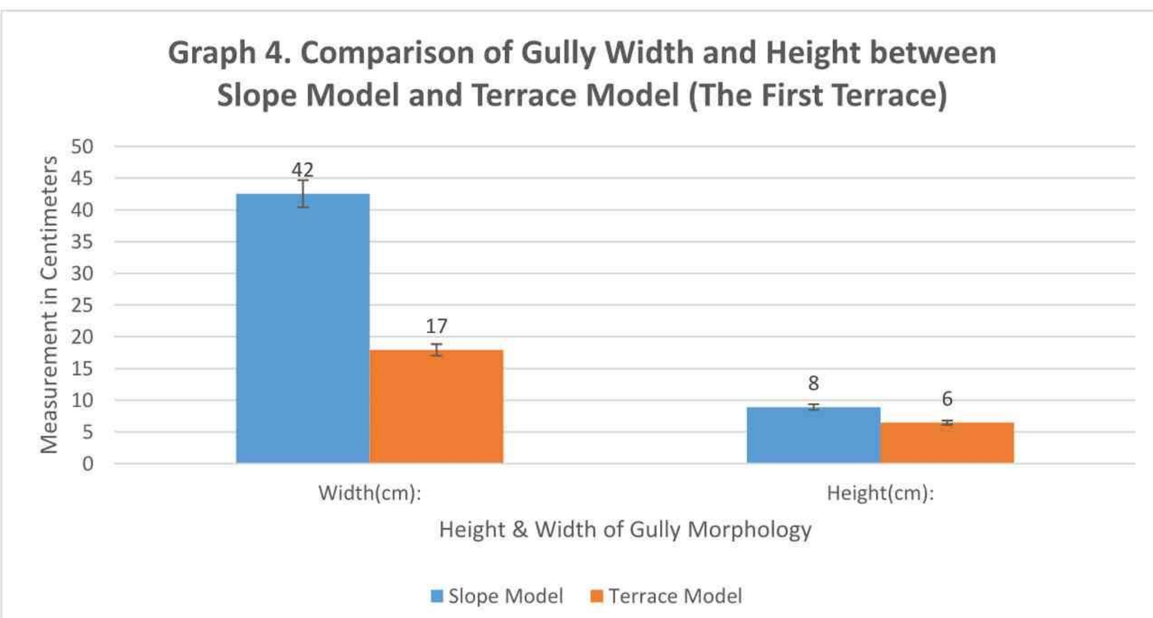
When measuring the gully formation and morphology on the terraces, only width and height of the gullies are taken into consideration of my investigation since the length of the gully would be same as the length measured of the platform of each terrace. As shown in table 2, for the terrace field model, both width and height of the gullies are the highest on the first layer of terrace (17.92cm & 6.47cm), which means that gully erosion is most severe on the first layer of terrace as compared to following layers. This may due to the reason that the first layer of terrace withstands the full speed and pressure of rainfall simulation without other medium buffering for it, while the descending layer of terraces have the upper terraces slowing down the velocity of the water, thus decreasing the force of the stream gradually. This may explain why on average both height and width of gully formed will decrease as the terraces go down, indicated by the downward trend line shown on graph 3. (Gully Morphology Picture and raw data table can be seen in Appendix). Based on the result graph 3, it can be seen that the width and height of gullies formed on terrace decrease at the same time on descending layers, which could indicate that there is a positive correlation between these two factors.

Table 2. Terraced Farming Gully Data

Average:	First Terrace	Second Terrace	Third Terrace	Forth Terrace
Width(cm):	17.92	14.38	11.12	6.9
Height(cm):	6.47	5.18	3.85	1.4



The data then is used to make comparison with the slope model. Since there are four sets of data on gully formation of the terrace model, while the slope mode would only have one set of gully data collected due to its simplistic structure, only gully data from the first terrace of terraced model will be chose to compare with that of the slope model. This is because the first terrace platform and slope model experience similar rainfall condition that, while the other terraces may have the previous layer buffering or slowing down the water draining down the model, so only the gully data on the first layer of terrace is comparable with that on the slope model.



As shown on the graph 4, the slope model indicates greater measurement on both the height and width of the gully morphology. For the width of the gullies, the slope model outweighs the terrace model by 137.5% ((42.5-17.92)/17.92) and the heights of the gullies on slope model is greater than that of terrace model on scale of 37.7% ((8.92-6.47)/6.47). Error bars show the standard deviation.

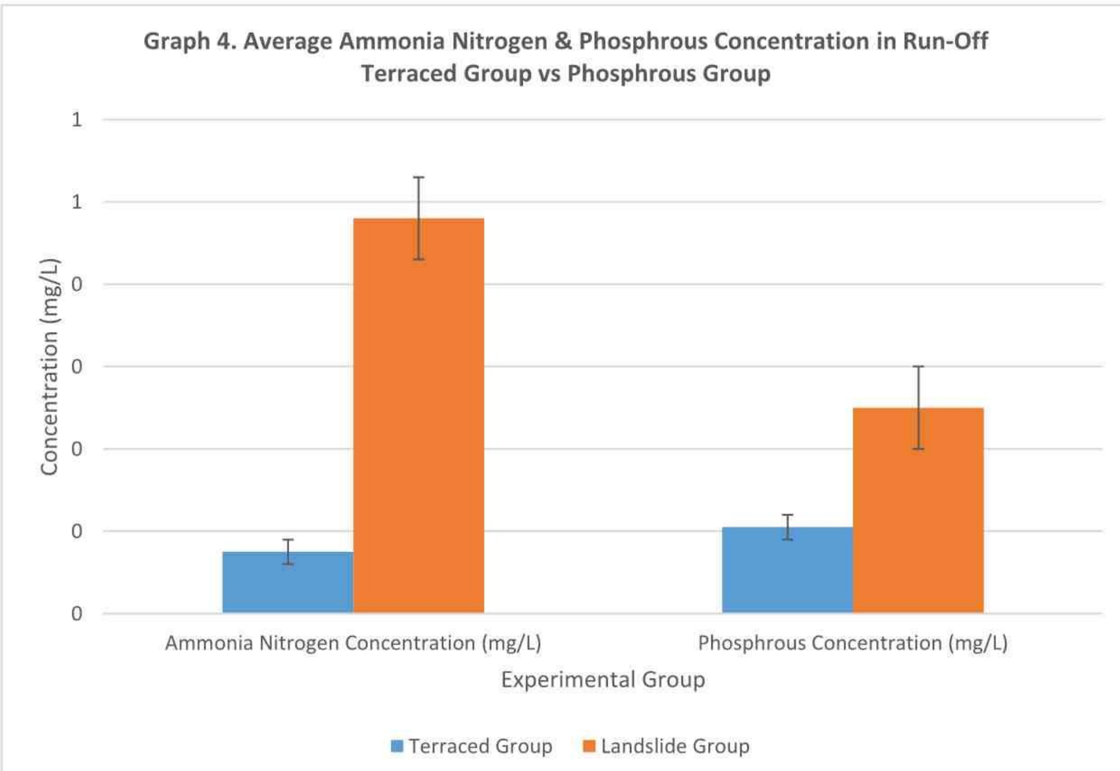
A.3.2. Gross Soil and Nutrients Loss in Run-off:

Table 3. Average Ammonia Nitrogen & Phosphorus Concentration in Run-Off
Terraced Group vs Phosphorus Group

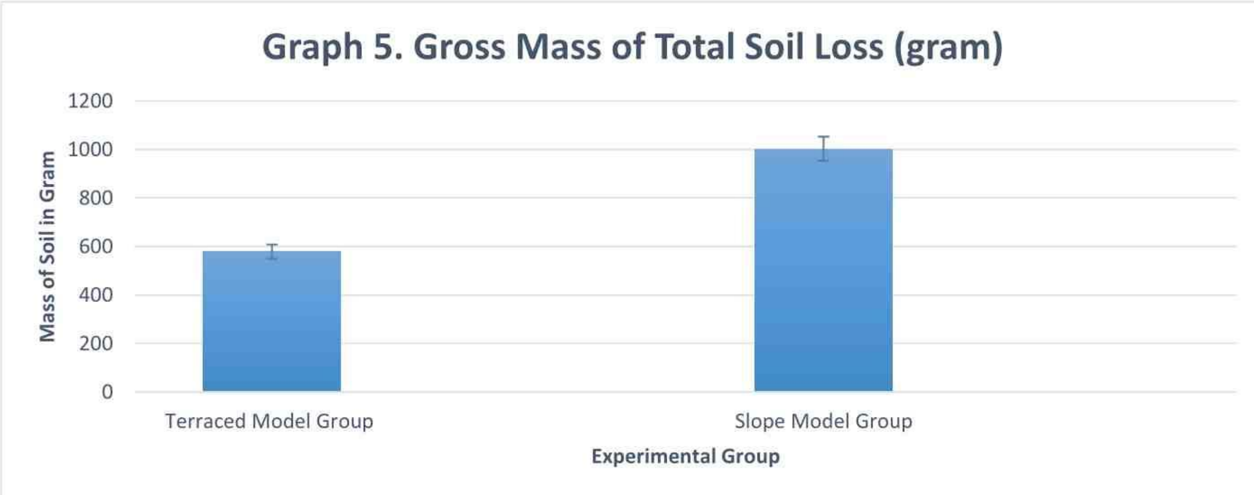
	Terraced Group	Landslide Group
Ammonia Nitrogen Concentration (mg/L)	0.65	0.96
Phosphorus Concentration (mg/L)	0.21	0.50

When examining the run-off sample in the last collecting baskets, ammonia nitrogen and phosphorus testing kit is used to measure the nutrients concentration in the run-off. The testing kit utilizes the colorimetric chart to compare with the coloration of solution tested. As shown on table 3, the average concentration of ammonia nitrogen and phosphorus (mg/L) is compared between the run-off collected in terraced model and slope model. On both the ammonia nitrogen and phosphorus concentration, the run-off collected from the slope model shows more concentrated nutrients level than terraced model. The slope model has 47.69% more concentrated ammonia nitrogen ((0.96-0.65)/0.65) and 138% ((0.5-0.21)/0.21) more concentrated phosphorus than the that of the terrace model's run-off.

To further analyze the difference on nutrition level in run-off, these data are integrated and compared with the data collection of gross soil loss for each model. As shown in the graph 4 and 5, both nutrients levels and soil loss indicate a greater value in slope group
than in terraced group, in which the gross soil loss, mixed with water mass, is 1003



grams
in slope group but 578.6 grams in terrace group on average, a 73.3% increase in gross soil loss. Based on the comparison between graph 4 and 5, it implies that concentration of nutrients (Ammonia Nitrogen and Phosphorus) may correlates with the mass of soil loss collected in the run-off basket. This point would be further examined in discussion of the data.



A.4 Discussion

*** Gross Soil Loss and Gully Formation:**

As shown in the data collected by the model, terraced model did decrease soil loss after simulated rainfall as compared to the slope model. From the run-off soil collected in the bucket below both the models, we could see that there is a substantial difference in the mass of soil that is eroded from the original sample, in which for terraced model the gross soil loss accounts for 24% of initial mass (2400 gram), while the soil loss of slope model makes up 41.7% of initial mass. Even though the mass of water absorbed by eroded soil is also included in the percentage calculation, the difference between soil loss fractions could also indicates how terraced model has decreased soil erosion better than slope model from the gross soil loss aspects. This could also be discussed with the observation and measurement of gully formations on each model. As shown on the terraced model, both the height and the width of gullies formed will decrease as the series of terrace descend. This is because the descending trend of terraces slows down the initial water velocity, leading to gradually decreasing force of water exerting to the soil. On the other hand, the slope model has nothing buffering the water velocity, so the simulated rainfall would flow naturally along the bare soil on it, causing severer gullies composed of larger width and depth. Since gullies are the vacancy of original soil matter that is caused by running water through the surface, so larger the gullies, the greater the total soil loss. This may account for the reason why slope model has greater soil loss.

*** Nutrients Level:**

As there is sign of association between soil loss and nutrients level as stated in analysis part, it is likely that the higher concentration of ammonia nitrogen and Phosphorus collected in Slope Model's run-off is due greater amount of soil contained in the run-off. Due to the methodology used to test the concentration of nutrients, testing solution taken from the run-off will have more concentrated soil matters than that of terrace model, which is discussed previously in the section of soil loss and gully formation. Therefore, the higher concentration of ammonia nitrogen and phosphorus in slope model may be explained by the result that slope model have much higher soil loss than terrace model. The testing kit used in nutrition test is within the microscale since the soil used in the model is not treated with nitrogen or phosphorus fertilizer. However, it is likely that the real concentration of ammonia nitrogen and phosphorus would possibly exceeds the data collected since large amount of soil loss of slope model may add up to increasing concentration of nutrient within the run-off. Thus, even though there is significant difference of nutrient concentration between slope model and terraced model, there might be greater differences if larger scale measurement is adopted in during data collection.

*** Overall Conclusion:**

Based on the comparison and interpretation of result collected from terrace and slope model, it is clear that through simulation of different types of land use the terrace model demonstrates milder gully erosion, less gross soil loss, and less concentrated nutrients contained in the run-off. All of the three factors above act as the key determinants of soil erosion in agricultural land in Loess Region in China. Thus, compared to the slope model, which intends to simulate the unregulated land-use of farmers living at Loess regions, the terrace model shows both qualitative and numerical evidence that descending layers of terrace may slow the water flow by rainfall, which saves great fraction of soil matter that would likely be carried away by water streams. This would consequently reduce the loss of essential nutrient for crops like ammonia nitrogen and phosphorus. Thus, the terrace structure of farmland may prevent the soil erosion and restore the soil fertility at a more efficient and effective way than slope model.

This provides an insight to the grain production of Loess Plateau since the soil fertility is improved by terrace farming. Even though it is shown on figure 6 (Liu, Yi et al., 2012), under the afforestation plan of GPTP (LiDing, Chen, et al 2007), farmland of loess plateau decreased 10.80% while grassland increase 6.60% and woodland rise for 4.90% (in thousand km2) (Liu, Yi, et al, 2012), the grain production doesn't decrease but rather keeps growing from the first year of GPTP to 2008 as shown in figure 7. According to the studies of Liu, Yi, et al (2012) Therefore, based on the result collected by the simulation, it may imply that even there is a reduction in farmland area, a more efficient and scientific use of land such as terrace farming could have positive effect on gross grain production due to higher soil productivity and protection against soil erosion. Therefore, farmer's income is not sacrificed as they are required to transform farmland, which is their main income source, into grassland and woodland. Meanwhile, the soil erosion damage is avoided to a certain extent.

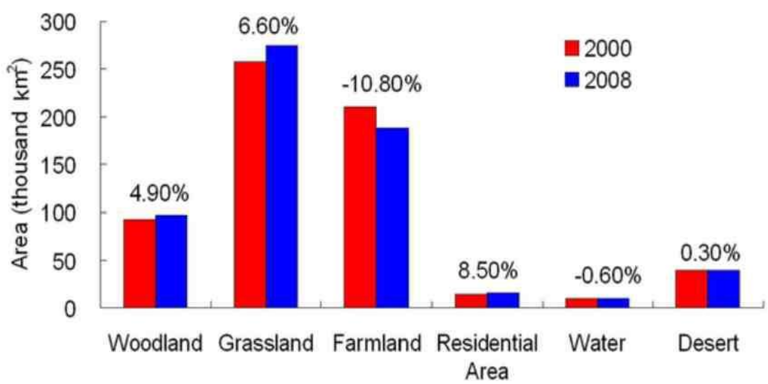
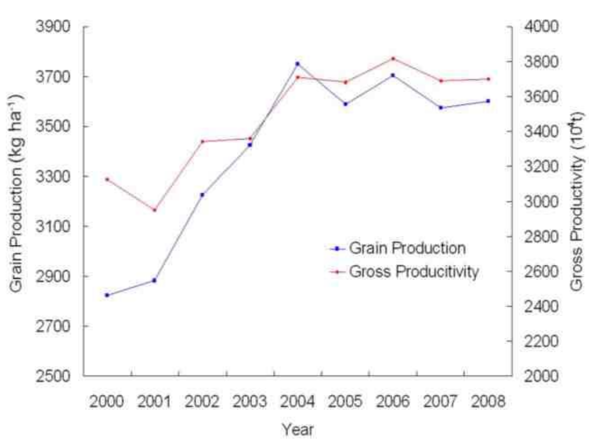


Figure 6. Coverage of each land cover type in Loess Plateau, in 2000 to 2008 Liu, Yi. et al (2012)



A.5. Evaluation & Further Research

* Use of Model:

The terrace model and slope model provide a simplistic version of the farmland structure in Loess Plateau regions of China. However, the methodology of this research may cause uncertainties. During repeated trails, same amount of soil mass is used for every trial, and soil that is adopted again is collected and rearranged without enough time for drying. That is to say that the wetness and level of water contained in the sample soil is kept constant, which would confound the result collected from both models. Even though the significant data difference could be concluded from comparing these two models, my discussion would be more valid with the wetness of soil kept constant.

Also, from the data collected, the discussion part mainly stated that it is more likely that terraced model would prevent severe soil erosion due to milder gullies formation and fewer soil loss after simulated rainfall, and it would restore a better soil fertility than slope model based on the nutrients data collected in run-off. However, when discussing the implication of result collected from terrace model, the slope degree factor (slope degree =35° for terrace model) is not taken into accounts. This is critical when reaching a conclusion for this research because studies suggest that for Loess Regions, hill slope greater than 8° are very difficult for local farmers to construct (Ye and Yang, 2002), which means the cost from building a terrace may outweigh the returns from reduction. Therefore, it is hard to fully generalized my terrace model result to the realistic situation on Loess Plateau regions of China. Still, the comparison between models sheds light to the solution of soil erosion and maintenance of soil fertility.

Besides the using terrace farming to replace the natural slope land on the hilly loess regions. Different types of irrigation systems and vegetation rehab approaches could also be studied in order to complete a meta-analysis and cross-comparison between these approaches to study their effect in solving soil erosion. On both terraced model and slope model, the simulated rainfall actually functions in the similar way of flood irrigation of farming technique (Adachi, S. (2007) in which all of the water used for irrigation would be firstly receive by the first series of terrace, followed by naturally descending of water flow under force of gravity. Studies has shown that the more efficient irrigation method would also increase the productivity of land while preventing the soil erosion, also with vegetation rehabilitation, less farmland would be exploited, leading to less soil erosion happened on Loess Region.

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Candidate personal code:

Extended essay - Reflections on planning and progress form

Candidate: *This form is to be completed by the candidate during the course and completion of their EE. This document records reflections on your planning and progress, and the nature of your discussions with your supervisor. You must undertake three formal reflection sessions with your supervisor: The first formal reflection session should focus on your initial ideas and how you plan to undertake your research; the interim reflection session is once a significant amount of your research has been completed, and the final session will be in the form of a viva voce once you have completed and handed in your EE. This document acts as a record in supporting the authenticity of your work. The three reflections combined must amount to no more than 500 words.*

The completion of this form is a mandatory requirement of the EE for first assessment May 2018. It must be submitted together with the completed EE for assessment under Criterion E.

Supervisor: *You must have three reflection sessions with each candidate, one early on in the process, an interim meeting and then the final viva voce. Other check-in sessions are permitted but do not need to be recorded on this sheet. After each reflection session candidates must record their reflections and as the supervisor you must sign and date this form.*

First reflection session

Candidate comments:

We discussed the plan for the investigation. We are at the planning stage of the investigation. I had a few ideas for my EE and one of the ideas interested my supervisor very much was the terraced farming investigation in the field of soil science. However since the supervisor told me that the topic should be a topic that I am mostly interested in, in the beginning I hesitated to follow the topic through the next 6 months. So I decided to come up with some alternatives such as an investigation into genetics using an online database. In order to give the supervisors suggestion a chance, I started to read some background reading into soil science and also I also recalled my experience in the group 4 project which also focused on soil science and felt that this was a doable topic for my extended essay.

Date: August 30, 2018 Supervisor initials:

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Interim reflection

Candidate comments:

The first few months of research seemed to go well and all of the set ups are successfully constructed. I started my first draft of my extended essay and started the first part of the pre lab in the greenhouse that we built. I initially trialed inside descending layers inside of the greenhouse, and at the beginning of my plan I wanted to plant some plants to also test the nutrition levels, and I encountered some difficulties. I ran into problems with the irrigation system and availability of space. After this experience I reflected on my model and decided to construct a new model to better reflect the conditions found in terrace farming. I discussed this with my supervisor and I reflected further on whether I can focus my research on soil science.

Date: November 30, 2018

Supervisor initials

Final reflection - Viva voce

Candidate comments:

So one of the challenges that I faced is that I found it difficult to manage the practical aspects' time allowance, as I underestimated the amount of time needed to collect data with my model. This was further compounded by my time commitments outside of the class which meant that I had to do some of the data collection in small bursts rather than in a more sustained manner. The sustained manner would have helped me reflect more consistently and to record things that occurred to me during the periods in which I was not actively pursuing the EE. One of the more pleasant aspects was to share the process of research with my teacher in a topic that we both had an interest before. I really enjoyed the conversations and learnt where my weaknesses were as a beginning research students and IB learner, as well as some of the areas in which I could actually do some great research.

Date: March 7, 2019

Supervisor initials: