西安理工大学
联合培养博士研究生资助申请表

姓 名	陶汪海	性别	男	学号	1160410043	
出生年月	1989 年 8 月	婚否	否	政治面貌	群众	
联系方式	座机:					

所在学院	水利水电学院	学科名称	农业水土工程
攻读方式	√全脱产 □在职	外语水平	CET 4
申请留学国别	USA	申请留学院校	Pennsylvania State University
申请留学学科	Soil physics	申请留学期限	1 年
国内导师	王全九	国外导师	Henry Lin

研究题目	Mathematical model of soil erosion and nutrient loss during over hillslope		
研究方向	Agricultural water and soil resource	开题时间	未开题

	题目	刊物名称（发明专利、著作）	发表时间	完成人（前三）	备注
已经取得的高水平科研成果情况	Mathematical model of sediment and solute transport along slope land in different rainfall pattern conditions	Scientific Reports	2017.03	Wanghai Tao;Junhu Wu;Quanjiu Wang	

申请承诺	本人保证所有申请材料客观、真实，若填报失实，本人将承担全部责任，主动放弃资助 另附中英文《研修计划》和《国外院校邀请函》、国外导师简历、已取得科研成果证明等材料 签字：陶汪海 2017年 9 月 28日
导师推荐意见	对申请人的学习成绩、研究能力、出国期间的学业安排、学习计划、安全保障及回国计划等方面的约定进行说明。 该生学习刻苦认真，努力钻研，取得了一些创新性成果。出国期间学业安排合理，学习计划周密，按期回国完成学业。现已取得很好成果，通过出国学习、钻研，将具有很强竞争力。同意推荐。 签字：[illegible] 年 月 日
同行专家推荐意见	（另附）
学院学位评定分委员会推荐意见	论证选题与研究前景，对已经取得的研究成果进行评价，明确是否推荐资助。 同意推荐 主席签字：[illegible] 2017年 9 月 28日
研究生院意见	签字： 年 月 日

申请材料一式二份，另一份可复印，经分会主席签字后交研究生院学位办。

2016级
1160410043

附件二

Research Plan for PhD Mobility Program 博士研究生留学计划

Name	Wanghai Tao 陶汪海		
Gender 性别	Male	**Date of birth (yy/mm/dd)**	1989/8/28
College 学院	Xi'an University of Technology	**Major 学科**	Agricultural soil water engineering
Domestic supervisor 导师姓名	Quanjiu Wang	**Hosting foreign country 留学国家**	USA
Hosting foreign institution 留学单位	Pennsylvania State University	**Hosting faculty or department 留学院系**	Department of Ecosystem Science and Management
Hosting foreign supervisor 国外导师	Henry Lin	**Area of research 研究领域**	Soil physics
Duration of study 留学时间		12 months (from 2018/4/1 to 2019/4/1)	

RESEARCH PROJECT 研修计划

TITLE： 研究题目 **Mathematical model of soil erosion and nutrient loss during over hillslope** 坡面土壤侵蚀及养分流失数学模型

MAIN SUBJECTS: 研究方向 **Agricultural water and soil resource**

THE CURRENT RESEARCH CONDITION AND LEVEL OF THE RESEARCH PROJECT AT HOME AND ABROAD: 国内外当前研究现状和水平

Soil erosion and nutrient loss are detrimental to agricultural products, food security, and the sustainability of ecosystem services[1]. Crops can only absorb half of the nutrients contained in the soil, and the remaining nutrients may be lost during rainfall[2]. In recent years, the increased use of chemical fertilizer and corresponding nutrient loss from sloping farmland (owing to agricultural activities) have received increasing attention[3]. Several studies have, through artificial and natural rainfall, determined the mechanism of rainfall erosion. These studies revealed that runoff erosion and nutrient loss processes are affected by the topography, soil properties, and rainfall characteristics[4]. The mechanism of erosion, to a certain extent, depends on the characteristics of the soil. For example, in one case, sandy loam experienced greater nutrient loss than silty clay loam, and nutrient loss in the runoff increased with increasing initial soil water content[5]. Other studies have indicated that the concentration of solute in the runoff increases with increasing slope length and gradient[6]. Moore[7] evaluated the effect of soil crust on the erosion process and found that the crust can reduce the erosivity of the soil. Moreover, Wang[8] assessed nitrogen, phosphorus, and potassium transport with runoff and found that soil and water losses increased with increasing gradient. Xing[9] reported that runoff rates and runoff-associated TN-loss rates decreased with increasing slope length, whereas sediment and sediment-associated TN losses increased. Majid[10] found that rain-induced erosion was transport-limited at gentler slopes, whereas at steeper slopes, this erosion was governed by detachment-limited conditions. Reid[11] indicated that runoff and sediment production varied significantly with vegetation patch type. Rainfall has a significant effect on the soil fertility of the top layer, because nutrient loss and soil erosion occur mainly in the top of the soil[12]. The effect of rainfall characteristics on soil erosion has been extensively investigated. Ran[13] concluded that rainfall characteristics have a considerable effect on runoff generation and soil erosion. In semi-arid regions, which are characterized by occurrences of low volume (i.e., annual amount) high-intensity rainfall, variations in precipitation patterns may increase local runoff and soil erosion[14]. Flanagan[15] found that the runoff rate of storms, with maximum intensity occurring in late stages, was greater than that of uniform-intensity storms or storms with maximum intensity occurring during the initial stages; in addition, soil loss from late-peaking storms was greater than that associated with early-peaking storms. Frauenfeld[16] reported that rainfall intensity patterns had no effect on the total runoff or infiltration, but the total erosion associated with variable rainfall was significantly greater than that associated with uniform rainfall. Parsons[17] designed five simulated rainstorms, each with a distinct intensity pattern, which all delivered the same total kinetic energy to the soil surface. Although the resulting total runoff was the same, the amount and size distribution of the eroded sediment varied with the pattern.

Rain-induced erosion research began in early 20th century[18]. Zingg[19] first began to research the relationship between rain-induced soil erosion and land slope and length, then Smith[20] expanded the relationship to incorporate conservation practices. In the following study, many models were developed to analyze the process of rainfall-induced erosion[21]. The Universal Soil Loss Equation and its revisions are the most popular empirical water erosion model applied in the world[22, 23]. Crawford[24] first developed a physical model (Stanford Watershed Model), which capable of modelling the entire hydrologic cycle and the entire watershed, then the modified model (Hydrological Simulation Program Fortran)[25] which include water quality processes. Physically-based models are normally based on the conservation equations for water mass and sediment yield[26]. The basic equation used to describe detachment and transport processes from surface runoff is the continuity equation for sediment transport[27], and Rose[28] determined that the rate of soil detachment by overland flow and the rate of soil detachment by impacting raindrops.

The process of soil-nutrient release into runoff is quite complex. Raindrop strikes, runoff scour, soil erosion, and diffusion all have an effect on this release. Donigian[29] hypothesized that rainwater mixes with soil and solute in a shallow thin mixing layer located in the soil surface. Ahujia[30] used ^{32}P as a tracer to analyze solute movement on the surface layer of soil, and concluded that the effect of the mixing layer is limited to depths of 2–3 mm. In subsequent work, Ahujia[31] found that the complete mixing layer is unsuitable for describing soils that have high infiltration capacity, and proposed an incomplete mixing model for describing solute transport in unsaturated soils. In addition, a series of models based on the theory of an incomplete mixing layer has been established by other researchers[32-34]. Chemical transfer from the soil to the surface runoff was attributed to accelerated diffusion, resulting from soil-depth variations in the chemical concentration of the soil. Hence, the conventional convective-dispersion equation could be used to describe solute transport. Wallach[35] developed a physically-based diffusion and transport model to describe the transfer of chemicals from the soil solution to the surface runoff. Ahuja[36] developed a convective-dispersion model by comparing the effects of ordinary molecular diffusion and accelerated diffusion on solute transfer from the soil to the runoff. Raindrop splash and diffusion play an important role in solute transport, as revealed by a solute transport model of raindrop splash (based on the soil erosion model), developed by Gao[37].

土壤侵蚀和养分流失会对农业生产、食物安全和生态系统的可持续性产生不利影响[1]。农作物只能吸收一部分土壤中的养分，剩下的养分很有可能会在降雨作用下而流失[2]。今年来，人们愈加重视对农业生产过程中越来越多的化学肥料使用及坡耕地养分流失问题[3]。已经有大量学者通过人工降雨或自然降雨试验研究了降雨过程中的土壤侵蚀机理。这些研究表明降雨过程中的泥沙和养分运移受到地形、土壤特性和降雨特征等因素的影响[4]。降雨侵蚀作用的大小在一定程度上取决于土壤特性，例如，沙壤土中养分会比粉质壤土中的养分更容易流失，土壤含水量的增大会导致养分流失程度的加剧[5]。还有研究指出，坡度和坡长的增加同样会导致径流中养分浓度的增大[6]。Moore[7]研究了土壤结皮对侵蚀过程的影响，结果发现土壤结皮可以有效降低土壤的受侵蚀程度。此外，Wang[8]研究了径流中氮、磷和钾的运移特征，发现坡度的增大会导致水、土及养分流失的增加。Xing[9]同过野外降雨试验分析了坡长对径流及泥沙中总氮的流失影响，发现坡长的增加会导致径流强度及径流中总氮的减小，然而泥沙及泥沙中的总氮流失量增大。Majid[10]认为降雨引起的土壤侵蚀在小坡度时主要受到运移能力限制，而在大坡度时主要受到剥蚀能力限制。Reid[11]指出总产流量和产沙量受到植被覆盖类型的显著影响。降雨对土壤表层的肥力有着显著影响，这是由于养分流失和土壤侵蚀主要发生在土壤表层[12]。Ran[13]认为降雨特征对产流和土壤侵蚀过程有着较大影响。在年降雨量较低，降雨集中且雨强较大的半干旱地区，雨型变化可能会导致更多的地表径流和土壤侵蚀[14]。Flangan[15]认为峰值雨强出现在降雨后期的降雨事件，比峰值雨强出现在降雨前期的降雨事件有着更大的径流强度。同时发现，峰值雨强出现在降雨后期的降雨侵蚀量要大于峰值雨强出现在降雨后期的土壤侵蚀量。Frauenfeld[16]认为雨型对同径流量或入渗量没有显著影响，但是雨强变化的降雨过程产生的泥沙量将显著大于恒定雨强。Parsons[17]设计了五种不同的雨型，且保证每种雨型的降雨到达地表的总动能是相同的。结果表明，虽然总径流量是几乎相同的，但是侵蚀泥沙的量及粒径分布是受雨型影响的。

对降雨侵蚀作用的研究最早开始于 20 世纪初[18]。Zingg[19]首先开始研究降雨侵蚀与坡度及坡长之间的关系，之后 Simith[20]将这种关系应用到水土保持措施当中。在后续研究中，为了分析降雨侵蚀过程建立了很多降雨侵蚀模型[21]。美国通用土壤流失方程及其修正方程是全世界范围内使用最多的经验模型[22,23]。Crowford[24]首先建立了土壤侵蚀的物理模型，可以用于模拟整个流域的水文循环过程[25]。物理模型通常是基于水和泥沙的质量守恒方程建立的[26]，用描述土壤剥蚀及运移过程的基本方程即泥沙输移连续性方程[27]。Rose[28]分别给出了降雨过程中径流冲刷侵蚀率及雨滴击溅侵蚀率的计算方法。

土壤养分向径流中释放是一个十分复杂的过程。雨滴打击、径流冲刷、土壤侵

蚀及扩散作用都会对这种释放过程产生一定程度的影响。Donigian[29]假设降雨水与土壤及溶质在土壤表层的一个混合层中相混合。Ahujia[30]用 ^{32}P 作示踪元素分析了溶质在土壤表层的运移过程，并认为有效混合层深度只有 2-3 mm。在后续研究中，Ahujia[31]发现完全混合理论不适用与入渗能力强的土壤，同时提出了不完全混合理论用于描述溶质在非饱和土壤中的运移过程。有很多学者基于不完全混合理论建立了不同条件下的溶质运移模型[32-34]。由于随着土壤深度的变化土壤中的溶质浓度是不同的，因此溶质从土壤中到地表径流可以看作是一个加速扩散过程。所以，传统的对流弥散方程可以用来描述降雨条件下土壤中溶质的运移过程。Wallach[35]提出了一种基于扩散作用物理模型用来描述化学溶质从土壤溶液向地表径流传递的过程。Ahujia[36]通过比较土壤溶质向地表径流传递过程中分子正常扩散与加速扩散作用提出了对流扩散模型。从 Gao[37]提出的基于侵蚀过程的溶质运移模型中可以看出，雨滴击溅和分子扩散在溶质运移过程中起着重要作用。

References:

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THE AIM AND EXPECTATION OF THE RESEARCH:
研究的目的及期望

Solute transfer to the soil surface runoff and runoff erosion are influenced by rainfall characteristics. However, the influence of rainfall patterns on runoff erosion and nutrient loss has rarely been investigated. Therefore, the objective of this study is to develop a mathematical model that describes runoff erosion and nutrient loss under different rainfall conditions.

溶质向地表径流的传递和土壤侵蚀均受到降雨特征的影响。然而，雨型对侵蚀及养分流失过程的影响却较少被提及。因此，本研究主要是为了建立一个可以描述不同降雨条件下降雨侵蚀及养分流失过程的数学模型，以期为水土资源的保护提供理论依据。

THE EXPERIMENTAL METHODS AND DATA ANALYSIS METHODS (*where required*): 实验方法和数据分析方法

Simulating the processes of soil erosion and nutrient loss under different rainfall conditions by establish rainfall plots. Using the experimental data to verify the theoritical mathematical model.

通过在野外建立降雨小区，模拟不同降雨条件下的土壤侵蚀及养分流失过程。利用野外试验数据验证理论数学模型

Timetable 时间表

Date 日期	**Activity 研究进展**
2018/4-2018/5	Designing the experiment and establishing the experimental plots 设计实验并建立实验小区
2018/6-2018/9	Conducting experiments 进行实验
2018/10-2018/11	Data analysis 分析实验数据
2018/12-2019/2	Writing papers 撰写论文
2019/3-2019/4	Final Report 最终报告

THE LEVEL AND ADVANTAGE OF THE HOSTING FOREIGN INSTITUTION ON THIS PROJECT: 留学单位在此项目研究上的优势

1. Advanced instruments and new methods of measurements and analyses 先进的一起设备和测试分析方法
2. High theoretical level 理论水平高

SIGNATURE OF DOMESTIC SUPERVISOR: 国内导师签名

Date(yy/mm/dd):

SIGNATURE OF HOSTING FOREIGN SUPERVISOR:国外导师签字

Date(yy/mm/dd): 2017/9/27

PENNSTATE

Dept. of Ecosystem Science and Management
The Pennsylvania State University

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Sept. 27, 2017

Wanghai Tao (male, born on 1989/8/28)
Xi'an University of Technology
Xi'an, P R China

Dear Wanghai,

Thank you for contacting me regarding your interest in coming to my laboratory at the Pennsylvania State University as a joint Ph.D. student from April 1, 2018 to April 1, 2019. I understand that, if your application is approved, you will have financial support from China to cover your stipend and travel expenses to the U.S. I hereby express my interest and willingness to host you for this purpose and will be glad to supervise your research while you are at Penn State.

Based on our communications, your technical and English skills have met the requirements of Penn State and are sufficient for your study and research here. I am glad that you have already conducted some related research in China. I hope you will advance your Ph.D. research in the areas of mathematical modeling of soil erosion and nutrient loss in hillslope through innovative research and publications in high-quality journals. I will be happy to guide your research and work with you on manuscripts preparation for publications.

As commonly done for international visiting scholars and students, Penn State will initiate the processing of paperwork that will allow you to obtain a visa. This can be done after you have notified me of the approval of your financial support. Once you arrive here, we will supply you with necessary equipment and supplies for the proposed research, including office desk, computer accessories, Internet access, library services, and many other resources available to our visiting scholars and students. Note that under this arrangement you will not be enrolled as a Pennsylvania State University student and not be receiving a formal degree from Pennsylvania State University. In such case, we can appoint you as a Visiting Scholar and no tuition will be required. Penn State always encourages international research and education collaborations. I am sure your visit will enrich your experience and help enhance your research capacity as well as promote our international collaborations.

Should you have any questions or need additional information, please feel free to contact me. I look forward to welcoming you to Penn State.

Sincerely Yours,

Henry Lin
Professor of Hydropedology/Soil Hydrology

附件三

国外导师基本情况

导师姓名	Henry Lin	专业技术职称	正高级	职务	教授
所在单位	Pennsylvania State University				
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著作：

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TI Mathematical model of sediment and solute transport along slope land in different rainfall pattern conditions
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DT Article
ID SOIL-EROSION PROCESSES; SURFACE RUNOFF; CHEMICAL-TRANSFER; IMPACT; INTENSITY; CROPLAND; DEPTH; CHINA; YIELD; WATER
AB Rainfall erosion is a major cause of inducing soil degradation, and rainfall patterns have a significant influence on the process of sediment yield and nutrient loss. The mathematical models developed in this study were used to simulate the sediment and nutrient loss in surface runoff. Four rainfall patterns, each with a different rainfall intensity variation, were applied during the simulated rainfall experiments. These patterns were designated as: uniform-type, increasing-type, increasing-decreasing - type and decreasing-type. The results revealed that changes in the rainfall intensity can have an appreciable impact on the process of runoff generation, but only a slight effect on the total amount of runoff generated. Variations in the rainfall intensity in a rainfall event not only had a significant effect on the process of sediment yield and nutrient loss, but also the total amount of sediment and nutrient produced, and early high rainfall intensity may lead to the most severe erosion and nutrient loss. In this study, the calculated data concur with the measured values. The model can be used to predict the process of surface runoff, sediment transport and nutrient loss associated with different rainfall patterns.
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