出國報告(出國類別:研討會)

作物生長模擬研究國際交流

服務機關 ： 行政院農委會　農業試驗所

姓名職稱 ： 陳琦玲研究員

派赴國家:美國

出國期間 : 107 年 11 月 1 日至 107 年 11 月 9 日

摘要

為期五年的台美科技合作計畫”氣候變遷之作物反應評估與減排調適策略研擬計畫”(2016 年 5 月至 2020 年 12 月)，至今為第三年，對於作物模式之應用已有成果。而今(2018)年美國農藝、作物與土壤學會於 11 月 4-7 日在美國馬里蘭州的巴德爾摩舉辦共同舉辦的國際研討會 (Tri-Societies meeting for the American Society of Agronomy, the Crop Science Society of America and Soil Science Society of America)，正以”在氣候變遷下加強生產力 (Enhancing Productivity in a changing climate)“為大會主題，因此以”應用 MAIZSIM 模式評估氣候變遷對台灣中部玉米生產之衝擊 (Impact assessment of climate on maize production in central Taiwan by MAIZSIM)”為題，發表於此國際研討會中，報告目前利用玉米模擬模式(MAIZSIM)以及台灣中部玉米試驗資料評估氣候變遷之影響結果，展現台美科技合作之共同成果。在研討會中，有著各式各樣的作物模擬模式模擬與應用成果，有一位學者分析 28 種的作物模擬模式之不同適用的作物以及相對應輸入條件，並進行模擬優劣與應用比較。對於氣候變遷情境之模擬，除了氣候暖化外，還有針對極凍、水災、風災和乾旱等進行模擬研究，並進行因應對策議題之討論。台美科技合作計畫五年計畫中，除了玉米之外，亦測試模擬大豆生產的 CLYCIM 模式，並進行應用於台灣環境之可行性，本此出國亦與計畫主持人和執行人討論進一步之合作方向。

目錄

本文

一、 目的

參加 2018 年 11 月 4 日至 11 月 7 日，為期四天於美國麻里蘭州的巴德爾摩(Baltimore)的巴德爾摩會議中心(Baltimore Convention Center)舉行 2018 年由美國農業學會、美國農作物學會和美國土壤科學協會共同合辦的農業作物年會(American Society of Agronomy (ASA) & -Crop Science Society of America International (CSSA) Annual Meeting)。這次年會共吸引了 2500 位來自不同領域的學者，產業界、政府機構和學術研究機構，還有在校的學生們共襄盛舉。這是跟農業、作物、土壤和相關科學研究各領域的專業人士們，互相瞭解最新的研究成果、與同行間見面學習、擴展最新知識互相交流的最佳機會；其中也包含了 2000 多場的口頭報告以及 300 多個海報展示，一系列的網路活動以及頒獎典禮。會場也展示了最新的科學檢測設備，服務以及諸多有用的參考資訊。

本此出國亦與台美科技合作計畫”氣候變遷之作物反應評估與減排調適策略研擬計畫”主持人和執行人討論進一步之合作方向。

二、 行程

日期	行程內容
11/1	啟程，由桃園機場前往美國紐約約翰甘迺迪機場(JFK)
11/2	(假日)
11/3	紐約至華盛頓克區杜勒斯機場(IAD)
11/4	前往「2018 農業作物年會」研討會會場，參加研討會
11/5	「2018 農業作物年會」研討會
11/6	「2018 農業作物年會」研討會
11/7	「2018 農業作物年會」研討會
11/8-9	回程，華盛頓克區杜勒斯機場(IAD)至桃園機場(+1)

三、　議程 (摘錄與業務相關所參加之議程)

日期:2018/11/04

Sunday, November 04, 2018　01:00 PM - 04:00 PM
Program : Committee Meeting　，Agmip Investigator Meeting
Baltimore Convention Center　- Room 323
Overview /概要: Update on AgMIP activities on ET (Evapotranspiration) intercomparison, North American Regional Project, and Model Improvements 更新 AgMIP 在蒸發量(ET)相互比較方面的活動以及北美地區計畫和模式改善 (AgMIP : The Agricultural Model Intercomparison and Improvement Project 農業模式比較和改進計畫

Sunday, November 04, 2018　06:00 PM - 07:00 PM
Program : Keynote Plenary Sessions　，　ASA and CSSA Opening Keynote ASA : American Society of Agronomy 美國農業學會 CSSA : Crop Science Society of America 美國農作物學會
Baltimore Convention Center　- Ballroom I-II
The Sustainable Intensification of Agriculture: Progress and Principles for Redesign 題目: 永續集約化農業:再設計的發展與原則
作者: Jules Pretty
Abstract/摘要: Sustainable intensification is defined as a process or system in which yields are increased without adverse environmental impact and without the cultivation of more land. It emphasizes ends rather than means, and does not predetermine technologies, species mix, or particular design components. Its expansion has begun to occur at scale across a wide range of agroecosystems. The benefits of both scientific and farmer input into technologies and practices that combine crops and animals with appropriate agroecological and agronomic management are increasingly evident. Jules Pretty's opening keynote presentation, “The Sustainable Intensification of Agriculture: Progress and Principles for Redesign”, draws on the three stages of transitions towards sustainability: i) efficiency; ii) substitution; and iii) redesign. Sustainable intensification of agriculture will be a continuous journey of adaptation and improvement, driven by a wide range of actors in the agricultural knowledge economy. 永續集約化農業的定義是在這過程或系統中，增加作物的產量時，不產生不利環境的影響也不增加種植的土地。它強調的是目的而不是手段，也不預先決定技術，混種或是特定的設計組成。它已經開始廣泛的擴展至大範圍的農業生態系。科學家以及農民將作物與動物與適當的農業生態和農業管理結合的技術和做

法，其好處越來越明顯。 在 Jules Pretty 的公開演說中提到，”永續集約化的農業:就是可再設計的進展和原則，作為轉向永續的三個階段，i)有效率的 ii)可替換的和 iii)可重新設計的。永續集約化農業將會是一個持續不斷適應和改善的過程，由農業知識經濟的眾多參與者所推動著。 As we develop clearer targets, progress toward redesign could be a gamechanger with wide social benefits. 隨著我們訂定更明確的目標，重新設計的發展過程將可能帶來更為廣泛的社會效益。	
06:00 PM	Introduction Remarks
06:15 PM	21-1 The Sustainable Intensification of Agriculture: Progress and Principles for Redesign
07:00 PM	Adjourn

日期:2018/11/05

Monday, November 05, 2018 09:30 AM - 11:30 AM	
Program : ASA Section : Climatology and Modeling	
Baltimore Convention Center - Room 325	
Overview/概述: Process-based crop models focus on predicting plant physiological and developmental processes in the context of the soil-plant-atmospheric continuum. While the use of these models composes the majority of agriculture decision support applications, alternative modeling approaches exist that may provide other unique insights.This symposium will bring together expert modelers from outside the 'traditional' process-based approach, and will include topics ranging from function-structural plant models to gene network approaches. 模擬作物變化過程的作物模式聚焦於預測土壤-植物-大氣環境下植物生理和其生長過程。雖然這些模式的使用構成大多是農業決策支持的應用，但模式應用可能提供其他獨特的見解。這次研討會彙整各專家所帶來”非傳統”以生長過程為基礎的模式和包括功能結構植物模型到基因網絡等主題。	
09:35 AM	42-1 Forging a Causal Chain Around the Circadian Clock, from Genome Sequence to Field Traits.
09:55 AM	42-2 Co-Design of Gene-Based Ecophysiological Crop Models for Breeding and Management.
10:15 AM	42-3 The Biology of Biogeochemical Cycles: Are Ecosystem Process Models Ready to Explore a World of Genetically Modified Organisms?.

10:35 AM	42-4 Functional-Structural Modelling of Fruit Trees Using L-Systems.
10:55 AM	42-5 Adding a Third Dimension to Modeling Crop, Plant and Organ Growth and Development.
11:15 AM	Discuss

Monday, November 05, 2018 02:05 PM - 03:45 PM	
Program : ASA Section : Climatology and Modeling	
Baltimore Convention Center - Room 327	
Overview/概述: The thermal properties of agricultural land provide a wealth of information on the moisture and nutrient content of both plants and soil. Much of the progress made in various studies relating to soil-plant-nutrient-water interactions is attributable to these highly resolved temporal and spatial measurements.This symposium highlights the novel ways that thermal imaging is being used in research across a range of scales from in situ plant-level measurements, the implementation with UAVs, up to satellite imagery. 農地的熱量特性為植物和土壤的水分以及養分提供了豐富的資訊。關於土壤-植物-營養-水相互作用的各種研究，是因為在時間和空間的可以高度的被量測到。這次研討會強調熱影像在研究中所使用到的新方法,其尺度從現場植物水平測量到無人機的實現，再到衛星影像圖等一系列的範圍。	
02:05 PM	Introductory Remarks
02:10 PM	88-1 Thermal Imaging for Agronomy and Plant Breeding: Past, Present and Future.
02:45 PM	88-2 Agricultural Soil Organic Carbon Levels Estimation Using Ground-Based and Uav-Imagery Thermal Data.
03:05 PM	88-3 Determining Crop Water Response with UAS-Based Remote Sensing.
03:25 PM	88-4 Thermal Imaging-Based Sensors for Agricultural Applications. (audio File & recorded presentation)
03:45 PM	Adjourn

日期:2018/11/06

Tuesday, November 06, 2018 08:30 AM - 10:35 AM
Program: ASA Session: Climatology and Modeling
Baltimore Convention Center - Room 325

Overview/概述:
Over the past decades, agro-ecosystem models have been continuously improved. If the model is appropriately parameterized and calibrated, soil water, temperature and nutrient dynamics and plant growth, water and nutrient uptake, and related processes can be simulated with a high level of accuracy. However, are models able to represent processes site-specifically? What field measurements do we need to take to improve models for site-specific applications. The objective of this symposium is to convey an overview on state-of-the-art in modeling site-specific soil and related biomass development processes, to stimulate ideas and research in the field of Agroclimatology and Agricultural System Model.
過去幾十年來，農業生態模式持續不斷的改善。如果模式有著適當的的參數化和校正，土壤水分、溫度和養分流動以及植物生長、水分和營養吸收相關過程，將可有較高的精準度。然而，模式可以因地而異具體的表現出來嗎?有哪些是我們需要測量的，以改善模式因地而異的應用。本次研討會的目的是對特定土壤和生物量相關發展過程中最新的模式概述進行交流，以激發農業氣候學和農業系統模式領域的想法和研究。

08:30 AM	Introductory Remarks
08:35 AM	134-1 Models Can be Useful to Study Spatial Variability and Its Effects on Plant Processes at a Range of Scales.
08:55 AM	134-2 Crop Models in Space and Time: Progress in Modelling Spatio-Temporal Crop Patterns
09:15 AM	134-3 Simulating the Impact of Spatially Variable Field Conditions on Crop Growth.
09:35 AM	134-4 Simulating Spatially Variable Irrigation Recommendations for Precision Irrigation Management.
09:55 AM	134-5 Modeling Yield Variability across Spatial Scales
10:15 AM	134-6 Model Sensitivity to Spatial Variability: Capabilities and Challenges
10:35 AM	Adjourn

Tuesday, November 06, 2018 01:30 PM - 04:10 PM
Program : ASA Section : Climatology and Modeling
Hyatt Regency Baltimore Inner Harbor - Lombard & Camden
Overview/概述:
This is a general session for research topics of interest to the Climatology and

Modeling Section. 這是一般對於研究氣候學和模式有興趣的研究主題會議。	
01:30 PM	Introductory Remarks
01:35 PM	194-1 An Improved Algorithm to Predict in-Field Dry-Down of Maize and Soybean Grains and Genotype-By-Environment Analysis.
01:50PM	194-2 Using Cycles to Predict Soybean Yield in Different Production Systems and Environments.
02:05 PM	194-3 Impact Assessment of Climate Change on Maize Yield in Central Taiwan By Maisim.
02:20 PM	194-4 Maize Yield Under a Changing Climate: The Hidden Role of Vapor Pressure Deficit.
02:35 PM	194-5 Modelling Economic Optimum Nitrogen Rate for Corn in Southeast Iowa.
02:40 PM	Break

論文發表（口頭報告）摘要	
報告時間	11 月 6 日 14:05-14:20
題目	Impact assessment of climate change on maize yield in central Taiwan by MAISIM

Yin-Jen Wu[1] Hung-Yu Dai[1] Chu-Chung Chen[1] Dennis Timlin[2] Chi-Ling Chen[1]

[1]Taiwan Agricultural Research Institute, Council of Agriculture

[2]Agricultural Research Service, United States Department of Agriculture

Crop growth is affected by weather, soil properties and agricultural managements. Mechanical model is a useful tool to simulate the crop growth in the complicated environment and help on making appropriate management decisions. The objectives of this study are to 1) compare the results of model-MAIZSIM (2dsoil) on simulating the growth of maize and the field data in central Taiwan and to 2) simulate the impact of climate change on maize yield. The field experiments include five varieties of sweet maize and four varieties of field maize cultivated with the same fertilizer management under different planting periods at two sites in central Taiwan between 2015 and 2017. The field data are used for the validation of model. The weather data under global warming is simulated and used for predicting the yields for next 10 years. As results, firstly, the growth of field maize can be simulated better than that of sweet maize. The correlation coefficient (r) between

simulated and observed yields for field maize (TNG1) is about 0.8. The growing degree days (GDD) of TNG1 is around 2050 and the maximum number of juvenile leave is 17. Secondly, the predicted yields do not change obviously for next 10 years. In conclusion, more filed data need to be collected for the calibration of the model to improve the applicability of model-MAIZSIM (2dsoil) in Taiwan.

Tuesday, November 06, 2018 01:30 PM - 03:35 PM	
Program : ASA Section : Climatology and Modeling	
Hyatt Regency Baltimore Inner Harbor - Room 319	
Overview/概述: This is a general session for research topics of interest to the Climatology and Modeling Section. 這是一般對於研究氣候學和模式有興趣的研究主題會議	
02:50 PM	185-5 Effect of Elevated Temperature and Nitrogen Interactions on Yield and Yield Components of Wheat.
03:05 PM	185-7 Multi-Location Climate Comparison of Potato Crop Models Preliminary Results.
03:20 PM	Adjourn

日期:2018/11/07

Wednesday, November 07, 2018 09:00 AM - 10:45 AM	
Program: ASA section: Climatology and Modeling	
Baltimore Convention Center - Room 317	
Overview/概述: There is a rapid increase in agricultural remote sensing, making use of new technologies and communications systems. A Modeling and forecasting algorithms are finding new sources of calibration and validation as well, from satellites to aircraft to UAVs and proximal sensors. Questions remain on how can remote sensing technology help make producers more efficient, profitable and sustainable? The Symposium focus on advances in how this information can be incorporated into agricultural decision making. 利用新技術和通信系統於農業遙測方面迅速擴展。一種模式和預測的演算法也在尋找新的校正和驗證方法，從衛星、無人機和近端感應器。問題是遙測技術如何幫助生產者提高效率、增加效益和永續性。研討會的重點是如何將這些訊息納入農業決策的研擬。	
09:00 AM	Introductory Remarks
09:05 AM	265-1 Remote Sensing in Agriculture: Achieving the Potential from This

	Technology for Agriculture.
09:25 AM	265-2 Remote Sensing Based Statewide Actual Evapotranspiration Mapping Program (CalETa) for Water Resources Management.
09:45 AM	265-3 Analysis of Reflectances Using up-Looking Incident Light Sensors for Remote Sensing with Unmanned Vehicles.
10:05 AM	265-4 Forest Service Perspective on Suas and UAS As an Operational Monitoring System.
10:25 AM	265-5 The Promise and Challenges of Unmanned Aerial Vehicles for Calibrating Remote Sensing Data for Agricultural Models in the Long-Term Agroecosystem Research Network: A Case from the Southeastern USA.
10:45 AM	Adjourn

Monday-Wednesday, November 07, 2018 02:30 PM – 04:30PM
Baltimore Convention Center - Exhibit Hall A-C
Overview: Poster review 海報賞讀

Wednesday, November 07, 2018 05:00 PM - 06:00 PM	
Program : Keynote Plenary Sessions ， ASA and CSSA Closing Keynote	
Baltimore Convention Center - Ballroom I-II	
Overview: ASA and CSSA Closing Keynote 美國農業學會與美國農作物學會年會閉幕主題演講	
05:00 PM	Introductory Remarks
05:05 PM	337-1 Growing a Revolution: Bringing Our Soil Back to Life
06:00 PM	Adjourn

四、 心得

為了可以持續有高品質的產量，用整合的方式來優化不同的生長條件式是很重要的，而作物模擬模式用來分析這些最佳條件和作物性之間的關係是有效的工具。本次研討會在作物模式的發展與多元工具之應用有許多值得國內參考與精進之處:

(一) 擴大不同氣候變遷模擬情境之模擬

以往作物模式較針對緩慢變化之氣候變遷(如逐漸增溫等)進行模擬，本次研討會則已有針對極端天候，如豪雨、凍害、乾旱等各種嚴峻條件下，進行

對作物生長與收成總量的影響，擴大不同氣候變遷模擬情境之模擬，可針對其衝擊，提早研擬對應決策，以減緩損失，確保糧食安全。

(二) 不同載具感測器的應用

隨著新技術和通信系統於農業遙測方面迅速擴展，無論從衛星、無人機和近端不同載具感應器的演算法與應用亦蓬勃發展，如利用無人機拍攝照片，研判作物病蟲害的程度，再參酌氣象資料，搭配無人機噴灑農藥，可提高效率與節省成本。此外，模式跟感應器結合在作物監測和表型分析上亦相當有效率，且較傳統調查方式省時省力。。

(三) 模擬模式校正

作物模擬模式可以反應出作物成長的空間變數，但也過去幾十年來，農業生態模式持續不斷的改善。藉著適當的的參數化和校正，土壤水分、溫度和養分流動以及植物生長、水分和營養吸收相關過程，將可有較高的精準度。但因目前尚無一個模式是完全機制式的，依然包括相當的經驗公式，因此仍出現因地而異的不佳模擬結果。提供當地的試驗資料以調整(校正)模式中細部的參數的設定仍是重要的。

(四)模式精進

1) 3D 模式發展: 從早期簡單描述一維空間模式 1D 進展 2D，而現在的三維空間，模擬模式將單株果樹或是作物，從種子萌芽開始，以 3D 立體的方式呈現，可擴大應用範圍。

2)遙測資訊應用: 遙測可以精確且快速的對面積較大的田區進行頻繁的觀測，蒐集田間作物動態的生長情況的空間分布資料，與作物模擬模式中各個階段的結果作比對，藉以探討影響模式參數設定。

3)發展影像樹生長模擬: 植物方面與影像合成研究有利用形態學來設計植物分枝的形式，有些利用微粒系統來設計植物的生長模式，而不再只是看著數字來想像作物的模擬過程，而是有圖片影像來輔助模擬過程。

4)發展番茄生長型態模擬模式: 建立番茄生長非線性模擬機制，其中參數有溫度、日照長度、二氧化碳濃度、光照射角度、光合作用的運作機制。

(五)永續集約化(Sustainable Intensification, SI)農業

於研討會中第一天主題演講中提及的永續集約化農業，概念並沒有特別闡明或是具體的方法。按照目前全球人口和糧食的消費趨勢，到了 2050 年，世界將會需要比現在多 60%的糧食量。由於耕地有限，大部分新增的產量將會是來自可持續的農業集約化。可持續(永續的)集約的農業提倡少花錢多做事的政策。其著眼於整個景觀、土地和生態系統，優化資源的利用和管理。農民必須在相同的農地上，相對地投入較少卻要產出更多的糧食。而這種轉變是可能的也是必要的。

FAO 農糧組織 (聯合國糧食及農業組織，Food and Agriculture Organization of the United Nations)提供援助政策以提高農業生產率、限制化學汙染管理生物多樣性和生態服務系統以及加強生計。農糧組織的節約和成長策略提出一種提高生產力也可持續性的新模式。該組織提倡獎勵改進作法的獎賞辦法，召開國際以及地區會議，並且鼓勵促進農業生態創新的政策。以下有幾個關鍵的政策訊息:

(1)致力於利用有效的資源提高生產力、糧食和營養安全。

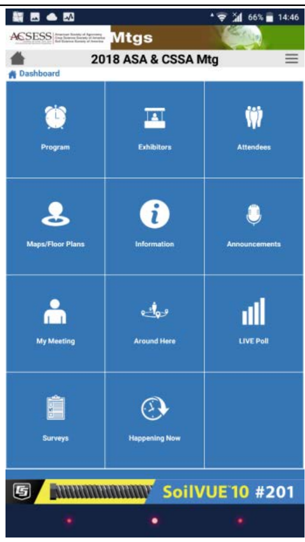
(2)呼籲透過生態系統，利用大自然對作物生長的貢獻來實現綠色革命。

(3)透過整合農作系統，智能資源的連結系統，像是水稻跟魚類、作物與牲畜的的合作，提升營養流動藉此提高產量的政策；優質的飼料和均衡的動物飲食；改善整個價值鏈能源的使用；利用訊息和通信技術加強創新觀念的傳播與應用。

(4)有效利用資源的政策對於 5 億發展中國家的家庭尤其重要，因為它們促進有利的農業制度，在面臨資源短缺和環境影響的挑戰也極具重要性。

五、建議

(一) 研討會議程行程表，提供兩種無紙化方式，1)可以登入網頁瀏覽，將有興趣的議題加入”My own schedule”，系統便會提醒，也可以藉由 google calendar 將譯成分享給其他人，方便查閱，2)手機以及平板的部分，藉由掃描 barcode 安裝議程 APP，除了搜尋議程外，查詢大會公告事項，還可以在選定的議程內輸入筆記，甚至於開幕茶會時，利用 APP 跟與會者互動，在這科技突飛猛進的時代，實在是相當方便的設計。之後如果有辦國際研討會，可以也這樣設計，降低用紙量較環保。

 	
1)APP 版本登入畫面	2)利用 email 帳號登入後畫面，大會各種資訊

(二)與美國農部 USDA ARS(United States Department of Agriculture，Agricultural Research Serivce)的 Dr. Vangimalla Reddy 和 Dr. Dennis Timlin 討論持續合作的意願與方向:

1)美國農部 Adaptive Cropping System Laboratory 研發作物模擬模式，其模式發展原理與應用，及其模式發展經驗分享。

2)行政院農業委員會農業試驗所，配合模式作物參數修正，進行相關試驗，以提升作物模擬準確度。

3)預計邀請 Dr. Reddy 和 Dr. Timlin 明年 2019 來台演講及授課，2020 年希望農試所可以再派員赴美國農部學習。

(三)氣候變遷資訊: 聯合國 IPCC 已提供 AR4 和 AR5 兩種氣候變遷資料，AR6 亦已完成，未來可應用於作物模擬模式進行前述不同情境氣候變遷的影響模擬。

(四)應用遙測資料進行作物空間模擬之驗證: 作物生長模式通常針對特定坵塊進行單點模擬，應用遙測資料可取得作物生長勢或病蟲害危害之空間分佈，可了解空間變異，或估算特定坵塊之代表生長勢，以與生長模式模擬結果進行比較，有助於模擬準確度之分析。

(五)從本次研討會學者之發表顯示 DSSAT model 仍然是模式模擬研究之主流模式，建議本所因應氣候變遷計畫可應用 DSSAT 進行氣候變遷下作物生長模擬及因應對策研擬工具。

六、摘錄翻譯部分研討會摘要

題目: Functional-Structural Modelling of Fruit Trees Using L-Systems 利用 L 系統之果樹功能結構式模式
作者 : Ted M. DeJong
Dynamic simulation of the growth and physiology of trees is a complex problem that requires modelling the assimilation and distribution resources to individual organs of a tree while simultaneously growing the architecture of trees in three-dimensional space in response to the availability of resources, under specific environmental conditions and over multiple years. The L-PEACH model uses L-systems to approach this problem. It simultaneously simulates the architectural development and carbohydrate dynamics (assimilation, transport, distribution, storage and remobilization) and water use of growing peach trees. L-PEACH combines the supply/demand concepts of carbon allocation with an L-systems model of tree architecture to create a distributed supply/demand system of carbon allocation in a

three dimensional, growing, virtual tree. The L-PEACH model is expressed in terms of modules that represent plant organs. Organs are represented as a set of elementary sources and sinks for carbohydrates and the whole plant is modeled as a branching network of modules (i.e. organs) connected by conductive elements.The model provides realistic simulations of peach tree growth and development over multiple years.

This work has been extended to simulate the growth and development of almond trees to demonstrate the utility of the modelling approach for other species. Converting the L-PEACH model to an L-ALMOND model initially required merely substituting the peach parameters for each of the different organ types (modules) to values appropriate for almond, based on data from field experiments. However, additional development of a function for simulating stem/spur mortality based on within-canopy shading was required to better simulate self-pruning in tree canopies that are not manually pruned. The modelling approach used in the L-PEACH and L-ALMOND models can be adapted to virtually any annual or perennial crop species and is instructive for advancing integrated understanding of developmental and physiological factors that determine crop growth and yield.

動態模擬樹木生長和生理的的模式，是一個複雜的議題，其需要建立樹木中各個器官的同化和分配資源的模型，並同時模擬在特定環境及資源有效性下三維空間樹結構的多年生長。L-PEACH 模型即是利用 L-系統來處理這個問題。它可同時模擬桃樹的結構發展和碳水化合物動態(吸收、運送、分配、儲存和再活化)以及水分利用的狀態。L-PEACH 將碳分配-供給/需求的概念與樹結構的 L 系統模型相結合，建立一個三維空間、生長和虛擬樹木中碳分配-供給/需求的系統。

L-PEACF 模式是用植物器官的模組來表示。植物器官是碳水化合物的基本源頭的集合，整個植物生長被模擬為一個由傳導元件所連結的分支網絡模組。該模式已發展多年，提供了桃樹擬真的生長模擬過程。這模式也擴展到杏仁樹的生長與發展，證明對其他物種也是有用的。將 L-PEACH 模式轉換成 L-ALMOND 模式，起初只需要依據田野調查資料，將不同類型的桃樹參數替換成杏仁樹的值。然而，為了發展更好的功能來模擬莖幹/距死亡的函數，需要為一個樹冠層陰影為基礎，但其樹冠層最好是天然落枝而不是自人工修剪的。用於 L-PEACH 和 L-ALMOND 的模式，其模擬模式可套用於一年生或是多年生的作物物種；對於促進決定作物生長和產量的生理因素，有整合理解的發展的意義在。

註：Lindenmayer 系統，簡稱 L 系統，是由荷蘭烏特勒支大學的生物學和植物學家，匈牙利裔的林登麥伊爾（Aristid Lindenmayer）於 1968 年提出的有關生長發展中的細胞交互作用的數學模型，尤其被廣泛應用於植物生長過程的研究。

L-system 是一系列不同形式的正規語法規則，多被用於植物生長過程建模，但是也被用於模擬各種生物體的形態。L-system 也能用於生成自相似的分形，例如疊代函數系統。(資料來源，維基百科
https://zh.wikipedia.org/wiki/L%E7%B3%BB%E7%B5%B1)

使用 L-系統 生成的 3D 雜草

題目	: Adding a Third Dimension to Modeling Crop, Plant and Organ Growth and Development 導入三維空間(3D)至作物、植物、器官生長和發展之模擬
作者	: Leo Marcelis

For sustainable production of high quality products, it is important to optimize all the different growth conditions in an integrated way.

為了可以持續有高品質的產量，用整合的方式來優化不同的生長條件式是很重要的。

Crop simulation models are powerful tools to analyse these optimal conditions in relation to characteristics of the plant.

作物模擬模式用來分析這些最佳條件和作物性之間的關係是有效的工具。

Nowadays a wide range of simulation models exist for crops ranging from simple descriptive models to complex mechanistic models that consider a large number of plant processes.

目前作物模擬模式類型很廣泛，從簡單的描述型模式到考慮大量植物生長過程的複雜機制的模式。

The last two decades the simulation of 3-D structure of a crop has been incorporated in a number of process-based models, resulting in functional structural plant models (FSPM).

過去的二十年間，對作物三維空間結構的模擬已經被納入到多數以過程為基礎的模式中，進而產生了功能結構植物模式(FSPM)。

Scaling from organ to plant and from plant to crop level and vice versa are important aspects in understanding behavior of a crop.

從器官到植物，從植物到作物的尺度縮放，反之亦然;這是瞭解作物行為重要的方

向。

Simulation models for plant growth and quality typically use the climate as measured at a central position as input.

植物生長和產量的模擬模式通常是在中心位置測量氣候資訊作為輸入的資料。

However, the response of the plants as well as biotic factors such as fungal diseases (e.g. mildew, botrytis) are more related to the microclimate, which might deviate from the average climate.

然而，植物和真菌疾病等(像是黴菌，灰黴屬菌類)生物因子的影響與微氣候更相關，可能會偏離平均氣候。

For instance shoot apex temperature may be 4ºC higher or lower than air temperature under rather moderate environmental conditions.

例如，在適度的環境條件下，作物芽頂溫度可能比氣溫或高或是低 4 度。

Microclimate affects crop growth and development as well as crop architecture.

微氣候影響作物的生長和發展，就像作物的結構一樣。

In its turn crop architecture influences microclimate, resulting in complex interactions between microclimate, crop architecture, plant growth, and disease infection.

反過來說，作物結構影響微氣候，導致微氣候、作物結構、植物生長和疾病感染之間的複雜相互作用。

This presentation will describe some approaches for mechanistically simulating growth, development and 3D-plant architecture of crops, such as tomato, lettuce and roses, in response to their environment.

本報告將呈現一些模擬作物生長、發展和作物 3D 結構的方法，像是番茄、萵苣生菜和玫瑰，反應它們的環境。

It will be discussed how models help us in exploring new avenues, and how the combination of models and sensors is powerful in both crop monitoring and phenotyping.

它將討論模式如何幫我們探索新的方法，以及模式跟感應器結合在作物監測和表型分析中是如何的有效。

題目: Models Can be Useful to Study Spatial Variability and Its Effects on Plant Processes at a Range of Scales 作物模式可以用來研究空間變異性以及在不同尺度上對植物生長過程的影響
作者 : Dennis Timlin 、David H. Fleisher Vangimalla Rr. Reddy
The spatial variability of soil properties can affect crop development and yield at a

range of scales, from the root zone between plants to variation in topographic properties.
在某一尺度範圍內，土壤屬性的空間變異，從植物之間根系到地形性變化影響作物生長和產量。
Most crop models are 1D representations of plant and soil processes.
大部分的作物模式都是用一維空間來表示植物和土壤過程。
Here we will show how a model with two dimensional soil processes can be used to study the effects of variable soil properties between plants on plant dynamics.
這裡，我們將顯示如何用一個二維空間來研究植物之間不同土壤屬性對植物的動態影響。
In the second application we will show how a simple plant model can be used to evaluate soil water holding capacity on a landscape scale.
在第二個應用中，我們將展示一個簡單的植物模式可以用來估算景觀尺度上土壤的含水量
We will extend these results to show how we can bridge the large and small scale variability.
我們將延伸這些結果以展示我們如何能夠跨越不同大小尺度的差異。
Another application takes advantage of the fact that spatial and temporal variability of yields often mirror each other.
另一個應用的優點則是可呈現產量於時空上的變異。
We can use time series of crop model results to investigate yield stability and how nitrogen and water management impacts it.
我們可以利用時間序列在作物模型的結果，來瞭解產量的穩定性和氮以及水分如何影響產量。

題目 : Model Sensitivity to Spatial Variability: Capabilities and Challenges
模式對空間變異的敏感度 : 能力和挑戰

作者 : Kurt C. Kersebaum 、Evelyn Wallor 、Ole Wendroth

Process-oriented agro-ecosystem models are increasingly applied to assess crop effects of management options or impacts of climate change on agricultural production, food security and ecosystem services.
機制農業生態系模式越來越多應用在評估管理決策的影響，或是氣候變遷對農業生產、糧食安全和生態服務等的衝擊。
The aggregation of initial soil and climate information is a widely used approach for performing simulations at larger scales such as regions, nations or even globally.

彙集初始的土壤和氣候資訊是一種廣泛用來操作模擬模式的方法，用在較大尺度，像是某地區，國家甚至全球。

Since site conditions and soil properties have a strong influence on crop production and multiple ecosystem services, the ability of models to respond to different site conditions is essential for high quality impact assessment through the use of modelling tools.

由於各地環境條件和土壤屬性對產量以及多種生態系統服務影響甚鉅，模擬模式對不同環境條件的模擬能力，是使用模式工具時進行高品質評估時的關鍵。

While spatial variability complicates model calibration if the underlying spatial structure of inputs is unknown, the knowledge of these structures also provides a chance to evaluate the sensitivity of a model's response to variable inputs in a field, which often contains most of the variability of a whole landscape.

如果輸入的空間結構是未知的，那麼空間變異性使得模式的校正變得複雜；而這些結構的知識提供未來評估模式對某方面的輸入影響的敏感度，該領域通常包含整個尺度大部份的變異。

Data from precision agriculture offer the opportunity to test models regarding their sensitivity to site conditions.

精準農業的資料提供了測試模式對特定條件的敏感性的機會。

However, the model performance on a specific field depend on the complexity of determining factors and the capability to consider them in a model

然而，特定領域的模式模擬能力取決於變數的複雜性以及模式中處理變數的能力。

Besides soil properties variable boundary conditions, such as shallow groundwater, lateral water and matter movement or shading by topography may play a role in the formation of spatial productivity levels.

除了土壤特性的邊界條件，像是淺層地下水、側向水和物質移動或是地形陰影等均在空間生產力扮演角色。

Examples will show the importance of different factors at different fields as well as at the regional scale.

不同的例子將顯示不同田區和區域尺度規模的重要性

A comparison of 11 models applied to spatially variable data will demonstrate differences in model responses looking also at the consistency of model outputs across crop and soil state variables.

對 11 種應用空間變數模式進行比較，顯示模式間的差異，同時亦顯示模式對作物與土壤變數之反應的模擬結果的一致性。

The impact of data aggregation of high resolution data, e.g. from yield monitoring on model calibration will also be investigated. 研究中亦分析彙集高解析度資料，如以產量監測進行模式校正的影響。

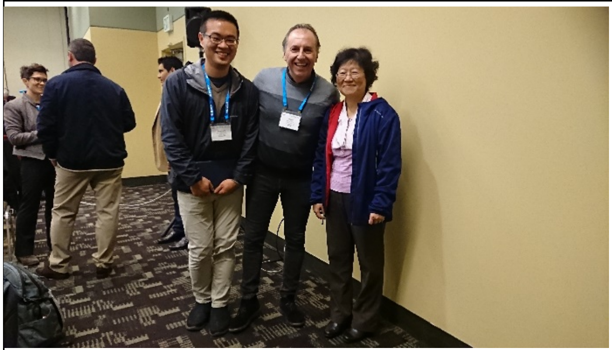
七、攜回資料

1. MicaSense Accuracy Quality：Leading the industry in imagery, analytics, and sensors；MicaSense,lnc.
2. Beautiful Soils：2019 Soils Planner；United States Department of Agriculture.
3. Mapping Our World of Soils；Soil Science Society of America.
4. Soils Overview Unit；Soil Science Society of America.
5. Envi Analytics Answers You Can Trust；Harris Technology to Connection, Nformand Project.
6. Envi OneButton Utilize UAS and Aerial Data To Enable Better Business Decisions；Harris Technology to Connect, Information and Project.
7. Comstock Publishing Associates：The East Country Almanac Tales of Valley and Shore, Jules Pretty.

附錄、研討會照片

會場-巴德爾摩會議中心(外觀)

報到



與密西根州立大學 Bruno Basso 教授合照

與 Dr. Reddy 合照

Dr . Timlin 報告

與 Dr. Timlin 合照

助理研究員陳柱中報告

與美國農部研究室人員合照