出國報告（出國類別：開會）

出席
「2009 年水田及水環境國際研討會」
出國報告書

服務機關：行政院農業委員會、臺灣大學生物環境系統工程系、中央大學海洋與水文科學研究所、宜蘭大學森林暨自然資源學系、立德管理學院觀光系、農業工程研究中心

姓名職稱：林國華技正、童慶斌主任、劉振宇教授、譚義績教授、李明旭副教授、阮忠信助理教授、郭勝豐教授、張斐章主任、譚智宏組長

派赴國家：印尼

出國期間：98 年 10 月 6 日至 10 月 10 日

報告日期：99 年 3 月 1 日

摘要

2009 年 10 月 7 日至 9 日假印尼 BOGOR 農業大學（Bogor Agricultural University；INSTITUT PERTANIAN BOGOR；IPB）International Conference Center 所舉辦之「2009 年水田及水環境國際研討會」(PAWEES 2009 International Conference on Promising Practices for the Development of Sustainable Paddy Fields)及第 7 屆「水田及水環境年會」(The 7th Annual Conference of the International Society of Paddy and Water Engineering)，係由國際水田與水環境學會所每年主辦召開，第 1 屆於 2003 年日本京都召開，2004 年於韓國 Ansan、2005 年於臺灣臺北、2006 年於日本 Utsunomiya（櫪木宇都宮市）、2007 年於韓國首爾、2008 年於臺灣臺北。國際水田與水環境學會是由日本農業土木學會、臺灣農業工程學會及韓國農業工程學會組成之國際性學術組織，透過舉辦本研討會，讓台灣、日本、韓國及全球其他國家之水資源、農田水利、農業環境專家學者，針對如何提升全球季風區水田生產、生態、生活及文化功能之技術，進行研究成果之經驗分享、學術探討與人員交流。希望透過研討會之舉辦，凝聚臺灣、日本及韓國維持水田文化之共識，攜手建構水田在水資源、環境保護、生態維繫的多功能核心價值。

「2009 年水田及水環境國際研討會」主題包括：(一）提高土地、水和人力等資源在水稻田的生產力（Enhancing Land、Water、and Labor Productivities in Paddy Fields Cultivations）、(二）利用有機生產方式，復原自然資源（Application of Organic Rice Farming and Uses of Local Varieties and Their Impacts to The Restoration of Natural Resources)、(三）農村價值與舒適性於水田永續發展之功用（Function of Rural Values and Amenities on Supporting Sustainable Paddy Field Development）等 3 大部分，其中主題一收錄論文 17 篇、主題二收錄論文 8 篇、主題三收錄論文 9 篇，另論文集中亦收錄日本及印尼學生論文共 32 篇。

專題演講由美國康乃爾大學食品和農業發展國際學院（The Cornell International Institute for Food, Agriculture and Development (CIIFAD)），Norman Uphoff 教授以「The System of Rice Intensification (SRI):A Win-Win Opportunity for Water-Saving Rice Production」(水稻強化栽培體系—稻米生產與節約水資源的雙贏契機）爲題，介紹 SRI 水稻栽培方法之優缺點及全球各地

推動之情形與未來展望。

第 7 屆「水田及水環境年會」,會中頒發國際水田與水環境學會 International Award,臺灣方面有本會農田水利處蔡處長明華獲獎;另台灣大學生物環境系統工程系劉振宇教授則獲頒 PWE Best Reviewer Award。另年會討論的主題爲(一)農業工程師專業教育認證制度遠景。(二)亞太經合組織(APEC)農業工程師計畫與國際工程師聯盟現況。(三) PWE 期刊發行情形報告。(四)水稻種植區之工程師作業手冊發行進度報告。(五)討論 PWE 期刊與 PAWEES 之協定書修正案。會議結束後,並由台日韓三國共同發表 BOGOR 宣言(PAWEES 2009 BOGOR STATEMENT),作爲未來 PAWEES 成員國共同努力之方向。

本次會議主辦單位安排 Nagrak 水稻有機 SRI 栽培試驗中心(Organic SRI Center;NOSC)及 Bogor 植物園(Bogor Botanical Garden)等處進行技術參訪,由現地參訪中,對於印尼在接受外國專家的專業技術指導下,對於水稻栽培技術之提升、改善農民收益及生態環境保育作爲之成果有更深之體驗,可做爲台灣未來農業用水調配與農業相關建設發展之參考。

出國報告審核表

出國報告名稱：出席「2009 年水田及水環境國際研討會」		
出國人姓名（2 人以上，以 1 人爲代表）	職稱	服務單位
林國華	技正	行政院農業委員會
出國類別	□考察 □進修 □研究 □實習 ■其他 研討會 （例如國際會議、國際比賽、業務接洽等）	
出國期間：98 年 10 月 6 日 至 98 年 10 月 10 日		報告繳交日期：99 年 3 月 1 日

計畫主辦機關審核意見

■1.依限繳交出國報告

■2.格式完整（本文必須具備「目的」、「過程」、「心得及建議事項」）

■3.無抄襲相關出國報告

■4.內容充實完備

■5.建議具參考價值

■6.送本機關參考或研辦

□7.送上級機關參考

□8.退回補正，原因：□不符原核定出國計畫 □以外文撰寫或僅以所蒐集外文資料爲內容 □內容空洞簡略或未涵蓋規定要項 □抄襲相關出國報告之全部或部分內容 □電子檔案未依格式辦理 □未於資訊網登錄提要資料及傳送出國報告電子檔

□9.本報告除上傳至出國報告資訊網外，將採行之公開發表：

□辦理本機關出國報告座談會（說明會），與同仁進行知識分享。

□於本機關業務會報提出報告

□其他_____

□10.其他處理意見及方式：

審核人	一級單位主管	機關首長或其授權人員
	蔡明華 0304 0830	蔡明華 0304 0830

說明：

一、各機關可依需要自行增列審核項目內容，出國報告審核完畢本表請自行保存。

二、審核作業應儘速完成，以不影響出國人員上傳出國報告至「政府出版資料回應網公務出國報告專區」爲原則。

目錄

壹、目的

2009 年 10 月 7 日至 9 日假印尼 BOGOR 農業大學（Bogor Agricultural University or INSTITUT PERTANIAN BOGOR；IPB）International Conference Center 所舉辦之「2009 年水田及水環境國際研討會」(PAWEES 2009 International Conference on Promising Practices for the Development of Sustainable Paddy Fields)及第 7 屆「水田及水環境年會」(The 7th Annual Conference of the International Society of Paddy and Water Engineering)，係由國際水田與水環境學會（International Society of Paddy and Water Environment Engineering，簡稱 PAWEES）每年主辦召開，由台灣、日本及韓國三國輪流主辦，第 1 屆於 2003 年日本京都召開，2004 年於韓國 Ansan、2005 年於臺灣臺北、2006 年於日本 Utsunomiya（櫪木宇都宮市）、2007 年於韓國首爾、2008 年於臺灣臺北，本年度則由日本輪值主辦。國際水田與水環境學會是由日本農業土木學會、臺灣農業工程學會及韓國農業工程學會組成之國際性學術組織，透過舉辦本研討會，讓台灣、日本、韓國及亞洲、歐美其他國家之水資源、農田水利、農業環境專家學者，針對如何提升全球水田生產、生態、生活及文化功能之技術，進行研究成果之經驗分享、學術探討與人員交流。希望透過研討會之舉辦，凝聚臺灣、日本、韓國及其他種稻國家，維持水田文化之共識，攜手建構水田在水資源、環境保護、生態維繫的多功能核心價值。

稻米為國人主要糧食，水稻亦為我國種植面積最廣之農作物，而農田灌溉良窳攸關農業生產與農民生計。台灣農田水利事業始於 17 世紀，迄今已逾 300 年，而農田水利組織，經過長期的發展，不僅現有之營運組織頗具規模，現有之灌溉工程設施亦頗為完善，因此就灌溉技術、用水調配及營運管理組織是世界上少數最成功的國家。行政院農業委員會農田水利處為全國各農田水利會之中央主管機關，隨著國內外情勢轉變，未來農業與農田水利建設如何兼顧農田三生功能、稻米文化、產業發展，以及合理調配水資源乃是施政上的重大挑戰。

本次研討會主題包括：1.提高土地、水和人力等資源在水稻田的生產力（Enhancing Land、Water、and Labor Productivities in Paddy Fields Cultivations）、2.利用有機生產方式，復原自然資源（Application of Organic

Rice Farming and Uses of Local Varieties and Their Impacts to The Restoration of Natural Resources)、3.農村價值與舒適性於水田永續發展之功用（Function of Rural Values and Amenities on Supporting Sustainable Paddy Field Development）等 3 大部分，其中主題一收錄論文 17 篇、主題二收錄論文 8 篇、主題三收錄論文 9 篇，另論文集中亦收錄日本及印尼學生論文共 32 篇。從各國發表論文中可勾勒出各國在 SRI 相關技術之研發、維護水田多功能、水資源管理、農村規劃及水質管理等議題上最新研究成果與未來發展方向，可做爲我國將來相關政策規劃之參考。大會專題演講邀請美國康乃爾大學食品和農業發展國際學院（The Cornell International Institute for Food, Agriculture and Development (CIIFAD)）Norman Uphoff 教授以「The System of Rice Intensification (SRI)：A Win-Win Opportunity for Water-Saving Rice Production」（水稻強化栽培體系—稻米生產與節約水資源的雙贏契機）爲題，介紹 SRI 水稻栽培方法之優缺點及全球各地推動之情形與未來展望，SRI 水稻栽培方法是在馬達加斯加發展的一項新技術，目前正在全球稻米生產國家推廣。該栽培方法乃藉由改變作物、土壤、用水與營養管理，提高稻米生產力，而且所需要使用的灌溉用水也較傳統漫灌少，因此面對未來全球氣候變遷之挑戰，發生乾旱之次數將增加，農業用水之使用勢必將更爲短缺，面對調整 21 世紀的農業生產策略時，SRI 的經驗與想法將提供了新的思考方向。

基於我國爲 PAWEES 創始會員國之一，並藉由積極參與相關國際活動，以汲取國際水田多功能、水資源與水質管理、水稻栽培等科技與技術之前瞻論點與最新經驗，有助於加強專業相近的各個國際性及區域性學術團體間的跨領域合作，共同進行分享在水田與水環境工程相關之最新資訊與知識，同時透過非政府間學術交流活動，向國外宣傳台灣先進科技與技術研發成果，建立參與國際活動管道，拓展我國外交空間。本會於接獲台灣農業工程學會組團參與印尼 BOGOR「2009 年水田及水環境國際研討會」之邀請後，簽奉核定指派農田水利處林國華技正出席並代表蔡處長明華領取 PAWEES 2009 年 International Award（因頒獎日值立法院開議期間，蔡處長明華未克出席親自領獎），與臺灣大學生物環境系統工程系童慶斌主任、劉振宇教授、譚義績教授、中央大學海洋與水文科學研究所李明旭副

教授、宜蘭大學森林暨自然資源學系阮忠信助理教授、立德管理學院觀光系郭勝豐教授、農業工程研究中心張斐章主任、譚智宏組長等共同組團參加，出國期間自民國 98 年 10 月 6 日至 10 日止，爲期 5 日。

貳、過程

本次會議日本及印尼主辦單位規劃之行程爲：DAY 1：10 月 7 日於印尼 BOGOR 農業大學 International Conference Center（IICC）召開「2009 年水田及水環境國際研討會暨 PAWEES 第 7 屆年會」、DAY 2：10 月 8 日於 IICC 召開「2009 年水田及水環境國際研討會暨 PAWEES 第 7 屆年會」、DAY 3：10 月 9 日爲技術參訪，參訪地點爲 Nagrak 水稻有機 SRI 栽培試驗中心（Organic SRI Center；NOSC）及 Bogor 植物園（Bogor Botanical Garden）。詳細行程如下列表 1。

表 1　出席 2009 年水田及水環境國際研討會行程表

10 月 6 日 （星期二）	去程（台北→印尼雅加達、BOGOR 市）
10 月 7 日 （星期三）	參加「2009 年水田及水環境國際研討會暨 PAWEES 第 7 屆年會」
10 月 8 日 （星期四）	參加「2009 年水田及水環境國際研討會暨 PAWEES 第 7 屆年會」
10 月 9 日 （星期五）	技術參訪，地點： 1. Nagrak 水稻有機 SRI 栽培試驗中心。 2. Bogor 植物園。
10 月 10 日 （星期六）	返程（印尼 BOGOR 市、雅加達→台北）

一、2009 年水田及水環境國際研討會暨 PAWEES 第 7 屆年會概述

(一)研討會議程

2009 年水田及水環境國際研討會於 10 月 7、8 日舉行，會場地點爲印尼 BOGOR 農業大學 International Conference Center，議程詳如附件 1。BOGOR 市位於印尼首都雅加達南方約 60 公里處，面積約一萬一千八百五公頃，由於地表高程爲 190~330 公尺，年氣溫大約爲 21.8℃~26℃，相對溼度約爲 70%，年總降雨量約 3,500mm~4,000mm，爲著名之雨都（The Rainy City），農業耕作面積約佔 10%；至於 BOGOR 市主要經濟活動爲貿易、旅館和餐館約 31.27%、製造業約爲 26.44%、金融、租賃和服務公司約 12.35%、農業則爲 0.4%。

本次研討會出席人員包括印尼、日本農業土木學會、臺灣農業工程學會及韓國農業工程學會相關學者專家，另外美國、越南、印度、馬來西亞、東帝汶等國亦有派員參加，總出席人數約 200 人，所有演講論文並已編纂爲論文集。

研討會主題包括：1.提高土地、水和人力等資源在水稻田的生產力、2.利用有機生產方式，復原自然資源、3.農村價值與舒適性於水田永續發展之功用等 3 大部分，其中主題一收錄論文 17 篇、主題二收錄論文 8 篇、主題三收錄論文 9 篇，另論文集中亦收錄日本及印尼學生論文共 32 篇，臺灣發表之論文爲宜蘭大學森林暨自然資源學系阮忠信助理教授所撰「Evaluation of The Agro-Ecological Complexity, Case Study of Rice Paddies in Ilan, Taiwan」(如附件 2)。

大會專題演講邀請美國康乃爾大學食品和農業發展國際學院（The Cornell International Institute for Food, Agriculture and Development (CIIFAD)）Norman Uphoff 教授以「The System of Rice Intensification (SRI)：A Win-Win Opportunity for Water-Saving Rice Production」（水稻強化栽培體系—稻米生產與節約水資源的雙贏契機）爲題，介紹 SRI 水稻栽培方法之優缺點及全球各地推動之情形與未來展

望(如附件 2)。

(二)水田及水環境年會

第 7 屆「水田及水環境學會年會」於 10 月 7 日上午及 8 日下午舉行，會場地點爲印尼 BOGOR 農業大學 International Conference Center，10 月 7 日上午年會由 PAWEES 主席 Dr. Tsuyoshi Miyazaki 主持，議程如附件 1，本年我國獲頒之獎項爲：1. International Award－行政院農業委員會農田水利處蔡明華處長獲獎。2.The PWE Best Reviewer Award－台灣大學生物環境系統工程系劉振宇教授獲獎。因頒獎日值立法院開議期間，蔡處長明華未克出席親自領獎，由行政院農業委員會農田水利處林國華技正代爲領獎並代爲宣讀感謝辭，感謝辭全文如附件 3。

10 月 8 日下午舉行第 8 次水田農業地區農業工程教育認證制度與亞太經合組織(APEC)農業工程師計畫國際會議，會議討論之主題共分爲五大項：1.農業工程師專業教育認證制度遠景。2.亞太經合組織(APEC)農業工程師計畫與國際工程師聯盟現況。3.PWE 期刊發行情形報告。4.水稻種植區之工程師作業手冊發行進度報告。5.討論 PWE 期刊與 PAWEES 之協定書修正案，議程如附件 1。主要參與討論之國家爲 Japanese Society of Irrigation, Drainage and Reclamation Engineering (JSIDRE), Korean Society of Agricultural Engineers (KSAE) and Taiwan Agricultural Engineers Society (TAES)、印尼 Bogor Agriculture University 及 PAWEES 其他會員國。

討論議題一共有日本、韓國、台灣、印尼及馬來西亞等國進行國家報告，台灣部分由臺灣大學生物環境系統工程系張斐章教授以該系進行之工程教育評鑑概況與未來發展方向向與會者說明。討論議題二由日本、韓國及台灣等國進行國家報告，台灣部分由臺灣大學生物環境系統工程系譚義績教授以該校協助經濟部水利署進行水災災害防救業務情形與淹水潛勢分析等向與會者說明。討論議題三由日本、韓國及台灣等國進行國家報告，台灣部分由臺灣大學生物環境系統工程系劉振宇教授報告，PWE 期刊之編輯作業自 2009 年 1 月起台灣從韓國手中接棒，劉振宇

教授以 2009 年 PWE 期刊編輯作業組織、程序及投稿、出刊情形與 2010、2011 年台灣輪值期間 PWE 期刊預定刊登論文篇數與計畫出刊日期等向與會者說明。討論議題四由日本 Matsuno 教授進行工程師作業手冊發行進度報告，該項工作結合日本、台灣及韓國等專家共同研商多年，已初具雛形，名稱暫定爲「水田灌溉系統在環境管理之介紹」，分爲五章共約 300 頁，分別爲簡介、水稻田灌溉及排水原理、水田多功能介紹、水田灌溉系統管理、水田管理案例研析等。另該參考書將優先以英文版發行，未來則會出版日文、韓文及中文等版本。討論議題五由日本 PWE 期刊主編 Nakano 教授報告 PWE 期刊編輯情形、與出版商 Springer-Verlag 之合約，另由日本 Matsuno 教授報告 PAWEES 之協定書案。水田與水環境國際期刊（PWE），自 2003 年創刊，7 年來共發表 145 篇文章，水田與水環境國際期刊於 2006 年 12 月已向美國科學資訊研究所(Institute for Scientific Information, ISI)申請登記，並可望在 2009 年 12 月被收錄在該機構的科學引文索引（SCI）理工類（E）期刊名單中，如此可提升 PWE 之能見度。

(三)大會宣言（PAWEES 2009 BOGOR Statement）

研討會後，出席人員就本次會議在 PAWEES 組織發展、農業工程師教育認證、技術研發及國際合作上所達成的共識，發表大會宣言，如附件 4。

圖 1 PAWEES 年會頒獎典禮，我國由張斐章教授代表主持

圖 2 林國華技正代蔡明華處長領取 International Award

圖 3 臺灣大學劉振宇教授獲頒 The PWE Best Reviewer Award

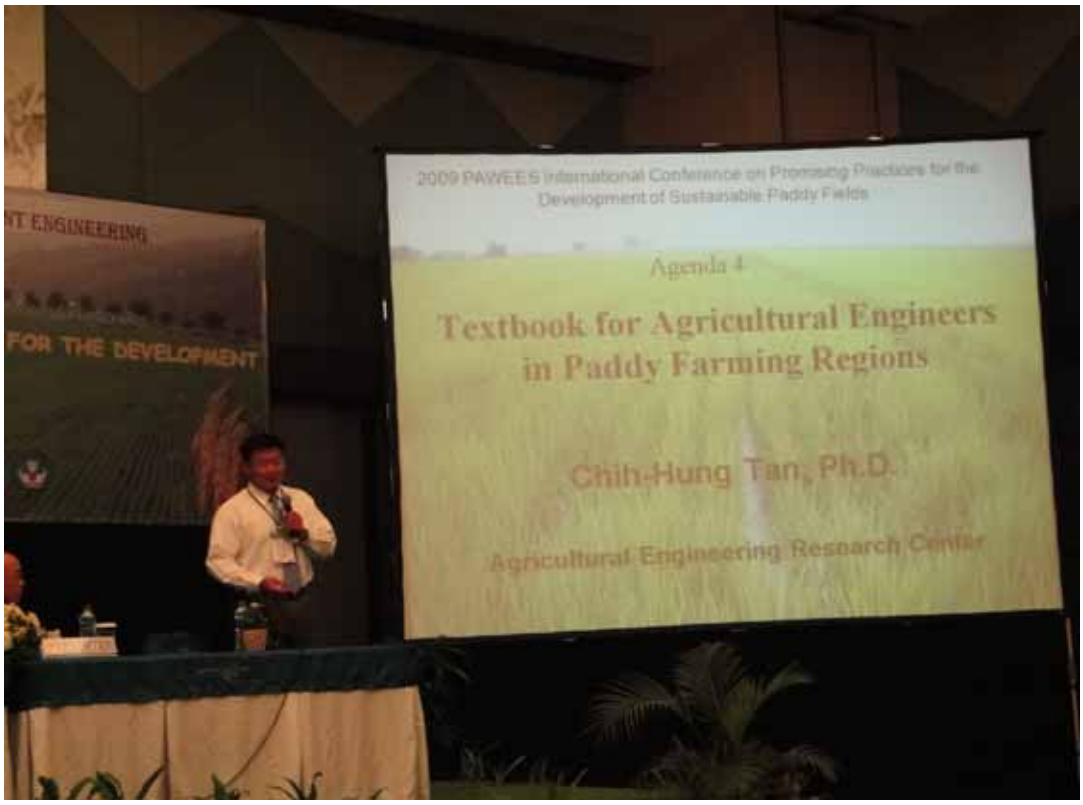

圖 4 農工中心譚智宏博士報告台灣農業工程參考書情形

圖 5 PAWEES 年會討論情形

圖 6 台灣代表團於會場合影

二、研討會論文簡述

研討會論文主題一：「提高土地、水和人力等資源在水稻田的生產力」收錄論文 17 篇、主題二：「利用有機生產方式，復原自然資源」收錄論文 8 篇、主題三：「農村價值與舒適性於水田永續發展之功用」收錄論文 9 篇，另論文集中亦收錄日本及印尼學生論文共 32 篇，專題演講由美國康乃爾大學食品和農業發展國際學院（The Cornell International Institute for Food, Agriculture and Development (CIIFAD)）Norman Uphoff 教授以「The System of Rice Intensification (SRI)：A Win-Win Opportunity for Water-Saving Rice Production」（水稻強化栽培體系—稻米生產與節約水資源的雙贏契機）爲題，介紹 SRI 水稻栽培方法之優缺點及全球各地推動之情形與未來展望。茲摘錄較具代表性的論文簡介如下：

(一)專題演講

◎The System of Rice Intensification (SRI)：A Win-Win Opportunity for Water-Saving Rice Production

－作者： Norman Uphoff（美國康乃爾大學）

－論文重點：SRI 水稻栽培方法是在馬達加斯加（Madagascar）發展的一項新技術，目前正在全球稻米生產國家推廣並尋求世界各個稻米生產國家的認同。該方法之原理爲藉由改變作物、土壤、用水與營養管理，使現有的所有稻米品種都會因此變成具有較高生產力的品種，可以在較短時間內獲得較高產量，並且僅需要使用較少的灌溉用水。此外，有許多缺乏灌溉設施的國家與地區，也出現了依賴降雨形態的水稻強化栽培體系方式，意味著水稻強化栽培體系（SRI）並不侷限使用於灌溉生產系統。而且，水稻強化栽培體系也可以應用於提升其他作物之產量，亦可見其應用層面的廣度。對過去幾個世代的人們來說，一般相信採取持續漫灌的耕作方式，可獲得較好的稻米產量與品質。然而，經由水稻強化栽培體系的試驗所獲取的科學數據，顯示了水稻

並非大眾所認知的水生作物。當水稻長時間生長於需氧土壤中時，水稻將更爲健康且對病蟲害更有抵抗力，甚至可以抵抗像颱風等風災的侵襲而不至於倒伏，並且可以更爲耐旱，忍受極端溫度與其他來自氣候的壓力。這些功效主要是來自於較好且較深的根系生長，以及大量、多樣且活躍的土壤生物群。SRI 對於如何改變作物管理技術已經有進一步的了解，包括改變用水管理可增進到米的產量與品質。水稻強化栽培體系爲農夫們創造了減少灌溉用水支出的誘因，因爲他們如果採用水稻強化栽培體系，便可使用較少的灌溉用水卻能獲取較高的稻米產量。

SRI 六個基本概念爲：1.提早插秧時間以維護秧苗生長潛勢（目前亦有實驗直播法）。2.避免損傷秧苗根部。3.提高秧苗之株距。4.保持土壤適當的水分但不長期浸水。5.儘可能維持通氣狀態。6.加強土壤之有機質。SRI 推廣區域已逐年擴展，1999 年之前僅在馬達加斯加辦理，其後逐漸在亞洲、非洲及拉丁美洲等地區推廣，迄今 2009 年止全球已有 36 個國家在辦理 SRI 推廣試驗工作。另依據 SRI 在全球各地試驗結果顯示，SRI 栽培方法可增加產量 50~100%、減少灌溉用水約爲 25~50%、降低生產成本約 10~20%、提高稻米碾製率 15%，減少破碎米粒、減少化學肥料使用量、由於根部系統發展狀況良好且土壤通氣情形較佳，抗病蟲害亦較佳。

在農業水資源的供應因爲氣候變遷、能源價格高漲以及人均耕地日漸減少等衝擊，而變得更加不可靠且更受擠壓時，如何減少灌溉用水需求量已十分迫切且危急。當我們必須重新調整 21 世紀的農業生產策略時，水稻強化栽培體系的經驗與想法提供了新的思考方向。

(二)主題一：提高土地、水和人力等資源在水稻田的生產力

◎Irrigation Effects on Vulnerability of Rice Yield in Thailand and Japan

－作者：Hajime Tanji.、Hirohide Kiri、Shintaro Kobayashi（日本）

－論文重點：與只靠雨水供給的耕作形態比較，灌溉有助於大量提高稻米產量，但有關產量脆弱度的評估尚缺乏研究。泰國稻米產量的數據有四種，包括主要生產季節接受灌溉稻田產量(MIr)、主要生產季節不受灌溉稻田產量 (MNon)、第二季接受灌溉稻田產量(SIr)、以及第二季不受灌溉稻田產量(SNon)等。統計泰國的各項數據，Mir、Mnon、Sir、SNon 的變異係數分別爲 0.10、0.07、0.12 以及 0.07。

比較接受與不受灌溉的數據，在主生產期間，每公頃的灌溉地增加了 948 公斤的產量，在第二季期間則增加了 357 公斤的產量。假設產量的變異係數爲 t 分配，比較一公頃不受灌溉稻田之平均產量與接受灌溉稻田產量的 90%信賴區間之最低值，兩個數據相差質在主要生產季以及第二季時分別爲 829 和 81 公斤。相較主要生產季，灌溉在第二季只提高了 1.8%的生產量，比較微不足道。

在估計灌溉對日本稻米產量的影響上，作者假設灌溉的面積將隨著時間擴大，把每縣的這 21 年來的產量依照年段分爲 6 個數據集來做變異係數的計算與比較，分別是(1958-1972)、(1963-1983)、(1968-1988)、(1973-1993)、(1978-1998) 和 (1983-2003)。在產量變異係數上有成長的包括了青森,、岩手、宮城、福島、栃木、長野、奈良、愛媛、福岡、佐賀、長崎、熊本以及大分縣。除了以上 13 個縣，日本其他縣的稻米產量變異係數和產量不穩定的脆弱度逐年段下降。

作者以產量的變異係數(Coefficient of Variance(CV))爲產量不穩定的脆弱度 (vulnerability)做一個度量，藉以分析泰國以及日本的稻米產量數據，進而比較灌溉以及沒有灌溉下的產量不穩定的弱點。

◎Development of Repair Methods to Extend the Functional Life of Irrigation Canals

－作者：MORI Takehisa、TOKASHIKI Masaru、MORI Mitsuhiro、NAKAYA Tetsuo（日本）

－論文重點：現今日本約有 40 萬公里長的灌溉與排水渠道，其大多數都是建造於多年以前，現階段多因年久失修而無法發揮以往的功能。從節省經費及有效利用資源的觀點來看，發展整修及恢復這些排水系統功能的技術遠強過重新建設。

灌溉與排水渠道主要由水泥建造而成，損壞集中於因連接處與底部表面的磨損引起的水滲漏。用來填補灌溉排水渠道接合處的材料必須可以承受水泥的冷縮熱脹，而填補表面磨損的材料必須具有高耐磨損性以及與原本材料的高密合性。我們爲填補接合處發展出一種高彈性的橡膠材料，也爲河道底部的磨損發展出聚合物水泥。同時，我們也爲耕農發展出利用這些材料來修理小型農業灌溉與排水渠道的簡易方法。

◎Evaluation of the System of Rice Intensification(SRI) Techniques under the Temperate Climatic Condition in Japan

－作者：Tejendra Chapagain、Eiji Yamaji（日本）

－論文重點：爲了調查水位高度、水稻秧苗日數以及插秧間距對作物生長、生產力和資源節約的影響，本研究於 2008 年的稻米耕作期(5 至 9 月)，在日本千葉進行了實地實驗。本實驗應用前述控制因子，首先以水位高度爲主要因子分成兩種實驗類型，分別採不同乾濕期距的間歇灌溉與持續性漫灌，再以水稻秧苗日數以及插秧間距兩項因子作爲輔助因子，以分裂區集設計出 8 個不同實驗狀態。

比較其中兩個實驗狀態組合下的水稻產量，其一爲採間歇灌溉、幼齡的秧苗以及較寬的插秧間距的組合，另一個爲

持續灌溉、較老齡的秧苗以及較窄的插秧間距，實驗結果顯示間歇灌溉能可節省約 28.77%的灌溉用水，而且在不會減少糧食產量(每公頃 7.4 噸對 7.37 噸)。灌溉用水的生產力在間歇灌溉下的實驗狀態組合明顯高於連續灌溉下的組合，採用水稻強化栽培體系技術之灌溉用水的生產力爲每公升 1.74 克重稻米，原有之灌溉方式則爲每公升 1.23 克。

此外，研究結果也明顯地顯示間歇灌溉能減少病蟲害的發生率，縮短水稻生長期，並維持作物的挺直以便於採收。此外，幼齡的秧苗與較寬的插秧間距都能對水稻分蘖力、稻穗長度以及稻穀飽和等方面產生提升的協同效應，進而增加稻米的總生產量及品質。然而，要總體了解哪種灌溉形態的稻米產量較好，仍須考量不同的土壤特性、氣候條件與間歇灌溉最佳的灌溉時段、時期與周期。

◎ Simulating yield response of rice to climate change Using FAO-AquaCrop

－作者：Sang-Ok Chung（韓國）

－論文重點：本研究使用 FAO-AquaCrop 模式模擬氣候變遷對水稻產量的影響。水稻產量模擬所輸入的氣候變化情景是先前氣候變遷研究的 SRES A2 及 B2 模擬結果，到了 2050 年及 2080 年之情景。按照先前氣候變遷模擬的預測，2050 年和 2080 年的降雨量將比 1961-1990 年基期年雨量增高很多。在 A2 的情景下，2080 年的水蒸發量將隨著大幅度的溫度升高而增加，2050 年及 2080 年蒸發散量則將隨著二氧化碳濃度升高而減少。在沒有氣候變遷的基準情景下，預計每公頃的水稻產量爲 6.2 公噸，一立方公尺水的稻產量則爲 2.1 公斤。在氣候變遷的情景下，預計水稻產量將增加 50%，水資源的生產力將增加 62%~110%。在 A2 模擬結果在 2080 年代的情景下，大氣中將有很高的二氧化碳濃度，預計水稻產量和水資源的生產力也將隨之大幅度增加。

◎Flood reduction Function of Paddy Rice Fields under Different Water saving Irrigation Techniques

－作者：Joko Sujono（印尼）

－論文重點：除了水稻生產外，水田也具有涵養水資源以及調洪減災等等諸多外部機能。爲提高稻米產量和節水，節水灌溉(WSI)技術已被廣泛用於水稻種植。

本文討論水田在不同節水灌溉技術下的減洪效果。本研究在水稻實驗田的雨季耕作過程中蒐集水量平衡上的每日數據，包括降雨量、滲流量、蒸散量以及水田堤壩的溢堤量。結果顯示，水田可以有效的減洪，並可蓄存超過 40%的降雨量。

然而，水田的減洪效果與採用哪種節水灌溉技術有著顯著關係。半旱式耕作技術的減洪效果最佳，在不影響水田生產力的情況下，能儲存總降雨量(636 mm)的 55.7%(365 mm)。

(三)主題二：利用有機生產方式，復原自然資源

◎ Introducing System of Rice Intensification in Timor Leste – Experiences and Prospects

－作者：George Deichert、José Barros、Martin Noltze（東帝汶）

－論文重點：在這幾年來東帝汶在農業策略上特別關注稻米的生產，每年總產量估計大約爲 27,000 公頓。但是，當地稻米產量尚不足以供應現階段超過 100 萬且持續成長的人口，每公頃農地的產量估計約爲 2 公噸。

農業與漁業部不斷致力於增加水稻田的耕作面積以及產量，在 2007 年農業與漁業部開始在東帝汶的 Bobonaro 和 Covalima 的兩個地區推廣水稻強化栽培體系(SRI)。但在更早之前，Bobonaro 和 Covalima 兩個地區已開始實行作物整合管理(Integrated Crop Management)。

農業與漁業部藉由政府農業推廣事業的管道來推廣水稻

強化栽培體系。在兩年的時間內，每期作採用水稻強化栽培體系的農民人數已由原本 50 多人增加到 1300 人，而每公頃農地的產量也從 3 公噸提高到 5 公噸(約提升 60%)。

農業與漁業部已簽署水稻強化栽培體系爲東帝汶提升稻米生產的三大國家策略之一。本文特別介紹監控水稻強化栽培體系各個單元之機制，勾勒出水稻強化栽培體系將來在東帝汶推廣上的前景與挑戰，也將水稻強化栽培體系與其它增強稻米生產的方法做一個比較，並且討論政府農業推廣事業人員在水稻強化栽培體系推廣上所需的具備條件。本文也特別的探討如何在有多種發展部門與公共慈善事業資助的環境中激發農民以自助的方式採用水稻強化栽培體系。

◎Promising Rice Farming Techniques for Sustainable Rice Production in Vietnam, Future Prospects

－作者：Mai Van Trinh、Pham Quang Ha、Nobumasa Hatcho（越南）

－論文重點：本文討論越南近幾年稻米產量的諸多限制因素，例如價格競爭、經濟危機、其它經濟發展目標與自然資源上的競爭、疾病和自然災害，尤其是氣候變遷對稻米生產的影響。爲了永續的確保整個國家的食品供應量，國家計畫應設定長期土地使用計畫和生產目標。國家也應著重發展稻米耕作技術以應變將來環境變遷的影響，例如因海平面上漲的土地損失、溫度的上升、乾旱和其他極端事件所引起農業損失。爲了使稻米生產達到最佳化，可實地應用下列開發技術，包括增加耐熱、耐鹽、耐酸與耐乾旱等稻米種類的耕種；在增加肥料使用效率並考慮營養鹽的循環；加強農物產量、儲藏及運輸上的管理以減少農作物損失和自然災害的負面影響。

(四)主題三：農村價值與舒適性於水田永續發展之功用

◎Evaluation of The Agro-Ecological Complexity，Case Study of Rice

Paddies in Ilan，Taiwan

－作者：阮忠信（台灣宜蘭大學）

－論文重點：本文選取位於台灣宜蘭的四個水田區，評估其在人類經濟活動形成的農場規模、自然系統的生物多樣性和維持能值持續耕種等三個情境下的農業生態複雜性。四個水田區皆採用不同的耕作方法，第 1 區爲傳統農業耕作方式（三星地區），第 2 區爲鴨間稻體系（三星地區），第 3 區爲稻米循環耕作（蘇澳地區），第 4 區爲鴨間稻體系（蘇澳地區）。結果顯示，非傳統耕作方法由於市場價格較高能獲得更好的利益。在蘇澳地區的研究點，其生物多樣性表現較優，可能由於這些水田的土地較鬆軟並且環境更自然。而在單一的農場規模下，生物多樣性可能不容易產生。稻米循環耕作體系下的能值持續發展指數則高於其他方式，表示循環系統內資源重複利用對於持續發展是相當重要的，假如非傳統的耕作方法可以擴展到更多自然景觀設計的區域，其結果將是有利的，水田的持續發展應與人爲市場、水田景觀和耕作方式相互結合。

◎Climate Change Adaptation on the Sustainability of Paddy Field Area in the Upstream of Cidanau Watershed

－作者：M Yanuar Purwanto（印尼）

－論文重點：印尼近年經常發生旱災和水災等極端氣候事件，可見印尼已明顯受到氣候變遷的影響。將來對於水稻產地如何永續適應氣候變遷的研究方面，水稻田灌溉水量的改變是一個重要的分析課題。

在供應面上，影響灌溉水量變化的主因是降雨量變化。由於灌溉用水主要來自河川取水，降雨量及溪流流量的變異程度對水稻種植有相當大的影響。鑑於上述情況，評估用水供需的方法應予調整。在模擬水資源供需與進行旱澇風險研究時，皆應考量各項氣候變遷的可能影響情形。所採取的氣

候變遷調適措施應該建立在壓力累積與產量等指標上。

本研究針對小型水庫應用水稻強化栽培體系(SRI)提出進一步的分析，探討其調適氣候變遷的可行性。此水庫寬 13 米，長 200 米，深 7 米。水庫供水灌溉約 234 公頃稻田，同時也供水給農村工業和家庭使用。

三、技術參訪

(一)Nagrak Organic SRI Center（NOSC；水稻有機 SRI 栽培試驗中心）

本屆 PAWEES 2009 研討會大會議題爲「永續水稻田發展的可行作法」，討論主題包括強化土地、水、勞力等於水田生產、使用有機栽培與當地品種，與它對自然環境的影響等。配合大會主題，主辦單位特別安排水田觀摩活動，地點爲位居 Nagrak 有機稻米栽培中心(Nagrak Organic SRI Center)，該地點位於西爪哇的 Nagrak 村，距離雅加達約 90 公里，有新鮮空氣和令人心曠神怡的風景。Nagrak 有機稻米栽植中心是一個地區性的培訓中心，主要在推廣有機水稻種植與 System of Rice Intensification(SRI；水稻強化栽培體系)的栽植方法。該中心提供之主題有：SRI 理念和基本制度、SRI 的有機示範的做法、介紹土壤生態、環境友好的可持續農業、土壤物理性質 、土壤生物學、土壤化學、有機材料分解過程、自製生產的堆肥、當地微生物等。

SRI 是一套透過改變管理植物，土壤，水和養分的水稻種植方法，來提高生產力。與台灣現行水稻種植方法，主要的不同在於：1.灌溉僅維持土壤濕潤，田間無湛水，每一期作應可節省可觀水量；2.土壤透氣度提高，促使水稻根系充分發展；3.插秧的間距擴大，每一位置僅插一株秧苗；4.由於田間無湛水，雜草容易滋生，需要更多的人力管理；5.採用有機栽培方法，以自製的天然肥料施肥，並不噴灑農藥，強調自然方法；6.由於有機栽培方法與微潤的土壤，田間具有更豐富的生物多樣性。

Nagrak 水稻有機 SRI 栽培試驗中心，規劃多區水稻栽培試驗場地，種植不同品種之水稻、不同種植株距、不同灌溉方法等，進行現地試驗，同時亦利用農業有機材料（動物及植物）、農家廚餘等，設置有機肥料生產試驗場，提供作爲有機稻作施肥時使用。主辦單位並安排參訪人員實地進行田間插秧體驗，俾充分認識 SRI 栽培方法。

(二)Bogor 植物園（Bogor Botanical Garden）

Bogor 植物園座落於 Bogor 市中心，緊鄰總統行宮（殖民時期的總督府），荷蘭殖民時期之爪哇總督 Gustaaf Willemn 建立此庭園，於 1817 年由出生於德國之荷蘭裔植物學教授 Casper George Carl Reinwardt 將此處轉型成國家植物園，用以栽植與研究印尼其他區域的植物及其種子，經過長期近兩百年的經營，此植物園成爲世界上重要的植物園與植物研究中心，爲擴大該植物園區之功能性，印尼政府於 1962 年 6 月改名爲國立生物學研究院。全園面積廣達 87 公頃，是世界上最大的熱帶植物園，入園費 10,000Rp（約台幣 30 元）。

園內劃分爲蓮花池、棕櫚屬、蔓生植物、竹林、藤類、蘭花科、仙人掌科、羊齒類等種植區，園內有池沼、庭園、小丘等，園區面積寬廣，景色怡人。目前植物園共計植栽超過 15,000 種樹木與植物，植物的栽種沿著園區內的溪流與蓮花池，形成生態豐富並優雅的景觀。棕櫚科的植物栽種超越 400 種，主要沿著道路或在草坪上，有著美麗的熱帶植物景象。園區中有超過 50 種的鳥類，也有多種蝙蝠棲息於樹林間。此外，蘭花溫室區蒐集了有超過 3000 種的蘭科植物，亦是此植物園的特殊典藏。

雖然 Bogor 植物園內軟硬體設施維護仍有待提升（河川水質不佳、廁所髒亂且須收費（約台幣 3 元）、園區內垃圾充斥、解說牌不足、欠缺導覽手冊等），相較於區外的街景，植物園算是都市中的世外桃源，亦呈現出印尼不同社會階層的差異性。我們一行人來到植物園區，透過當地專業的解說員瞭解此植物園中重要的植物與特色。Bogor 雨水豐沛，植物園內巨樹參天，熱帶的樹林常見有巨大的板根，甚至超越人的高度。園區中，有許多遊客進行遊憩的活動，此植物園兼具研究、教育與遊憩的性質。數年前，APEC 高峰會在印尼舉辦時，即曾利用此園區之場所。

圖 7　Nagrak 有機稻米栽培中心試驗田區佈置

圖 8　參訪人員進行 SRI 田間插秧體驗

圖 9　Bogor 植物園區配置圖

圖 10　Bogor 植物園區一景－熱帶樹林巨大的板根

參、心得與建議

1.水稻栽培在同屬亞洲季風地區之日本、韓國及台灣等已有久遠歷史，水田灌溉所產出外部效益亦經相關之研究確認，隨著加入 WTO 後，水稻種植面積逐年降低，台灣、日本及韓國三國均面臨水田三生功能流失的問題，未來我國應繼續加強研究，透過國際技術合作建立統一之評價方法，明確評估其經濟價值，並宣導對水田保存維護之重要性。

2.台灣爲 PAWEES 創始會員國之一，在台灣外交日益困難之際，此學術平台提供台灣與世界各國學界及政府間交流的管道，台灣在此組織之能見度亦高，未來，我國仍應持續提升參與組織活動之積極度，以與世界各國建立長期合作對話管道，維護國家整體外交利益。

3.本屆研討會大會議題爲「永續水稻田發展的可行作法」，討論主題包括強化土地、水、勞力等於水田生產、使用有機栽培與當地品種，與它對自然環境的影響等。多篇發表論文研究領域爲探討 SRI 栽培方法在世界各地辦理之情形與成果，而在主辦地印尼等東南亞水稻國家，SRI 栽培方法也得到相當良好的效果。

4.依據美國康乃爾大學 Norman Uphoff 教授專題演講，SRI 不需要利用現有之品種，即能達到比傳統灌溉方法獲得更高之產量，且用水量用水也節省了 25 至 50%，如搭配使用就地取材製造之有機材料（堆肥、糞肥或任何腐爛的植物），其農產品單價將更提升，農民收益也會增加。依據實際參與的農民們表示，當 SRI 的方法正確地被使用時，水稻能有效地抵抗病蟲害，因此能減少農藥的使用，甚至不需要噴灑農藥來保護農作物。

5.由 Nagrak 有機稻米栽培中心之參訪，目前在印尼試驗田區之栽培方式尚需使用大量的勞動人力，特別是在插秧、除草及用水管理上。然而台灣之農業人口日益老化、工資昂貴，此栽培方法是否會造成生產成本增加，宜再深入探討，並設計更爲省工之栽培機械設備，以符台灣之農業生產環境。

6.由於台灣水資源日益匱乏，農業灌溉用水常被要求應設法降低，依據國外研究報告顯示，SRI 栽培方法確能達到省水栽培水稻之目的。目前台灣尚無引進此種栽植方法，建議可先由研究單位於西部水資源供應較爲貧脊之

桃園、石門、新竹、苗栗及嘉南農田水利會等灌區內，擇適當之區位進行先驅性試驗與評估。若如此方法可行，可再推廣至一般農戶，以節省日益稀有的水資源，增加區域水資源調度空間，以及維持水田農業之永續性。

附 件 一

Day – 1 (October 7, 2009)

Time	Activities	Speaker/fasilitator
08.00-08.30	Registration participant	OC
08.30-09.00	Opening Ceremony	
	1. Welcome Speech 2.Welcome Speech 3. Opening Address	Budi I. Setiawan (OC) Tsuyoshi Miyazaki(PWE President) Herry Suhardiyanto (Rector of IPB)
09.00-10.30	Awarding Ceremony	Shen-Hsien CHEN Yoshisuke Nakano Tsuyoshi Miyazaki (PWE President)
10.30-11.00	Coffee Breaks	OC
	Keynote Speeches	Iswandi Anas (Moderator)
11.00-12.00	1.Rationality of the System of Rice Intensification in China（取消）	Zhu Defeng (China National Rice Research Institute)
	2. The System of Rice Intensification: A Win-Win Opportunity for Water Saving in Rice Production	Norman Uphoff (CIIFAD, USA)
12.00-13.00	Lunch break and press conference	
13.00-13.30	Poster Session	

Day – 1 (October 7, 2009)

Time	GROUP I: Enhancing Land, Water, and Labor Productivities in Paddy Fields Cultivations
13.30-15.00	Chairman : Masaru Mizoguchi
	Irrigation Effects on Vulnerability of Rice Yield in Thailand and Japan (Hajime Tanji)
	Analysis of Sprinkler Irrigation System Application For Dry Land Rice and Horticulture (R. Ismu Tribowo)
	Computer Based Automatic Irrigation System for Dry Land Agriculture (Isrofi Farhi)
	Development of Repair Technology to Extend The Functional Life of Irrigation Canals (MORI Takehisa)
15.00-16.30	Chairman : Chih-Hung Tan
	Evaluation of the System of Rice Intensification (SRI) under the Temperate Climatic Condition in Japan (Tejendra Chapagain)
	Simulating Yield Responses of Rice to Climate Change Using FAO-Aquacrop (Chung, Sang-Ok)
	Information Technology (IT) Field Monitoring in a Japanese System of Rice Intensification (J-SRI) (Virgilio Julius P. MANZANO, Jr,)
	Mathematical Modeling on Nitrogen Dynamics of Paddy Field Waters in Red River Delta, Vietnam (Shinji Fukuda)
16.30-19.00	Break
19.00-21.00	Dinner Party
Time	**GROUP II : Application of Organic Rice Farming and Uses of Local Varieties and Their Impacts to The Restoration of Natural Resources**
13.30-15.00	Chairman : Jin-Soo Kim
	The performance of organic SRI on some acidic Malaysian soils: some preliminary results (Anizan Isahak)
	Introducing System of Rice Intensification in Timor Leste – Experiences and Prospects (George Deichert)
	Promising Rice Farming Techniques for Sustainable Rice Production in Vietnam, Future Prospectus (Mai Van Trinh)
	System of Intensification - A Boon in Gengetic Inceptisol(Ratikanta Ghosh)

15.00-16.30	Chairman : Ratikanta Ghosh
	A Comparative Study on The Effect of Organic and Inorganic Sources of Nutrients on Productivity of Local and High Yielding Cultivars of Rice and Soil Fertility in Sub-Tropical Region of India (Dhananjoy Dutta)
	Molecular Analyses of Particulate Methane Monoxygenase Gene (*Pmo*) in Soil of System of Rice Intensification and Its Ecological Significance (I Made Sudiana)
	Assessment and Impact Analysis of System of Rice Intensification (SRI) in Basmati Rice (Jang Bahadur Singh)
	Impact of SRI Vs Conventional Methods on Rice Productivity at Farmer's Field (L.R. Singh)
16.30-19.00	Break
19.00-21.00	Dinner Party

Day – 2 (October 8, 2009)

Time	GROUP I: Enhancing Land, Water, and Labor Productivities in Paddy Fields Cultivations
09.00-10.45	Chairman : Eiji Yamaji
	Water Management: Key Issue in Preventing Pesticide Pollution from Paddy Fields (Thai Khanh Phong)
	Effect of Water Management on Greenhouse Gas Emissions and Microbial Properties of Paddy Soils in Japan and Indonesia (Abdul Hadi)
	Flood Reduction Function of Paddy Rice Fields under Different Water Saving Irrigation Techniques (Joko Sujono)
	Development of Agricultural Purification System for Supplying Clean Irrigation Water (Choi, Kyung-Sook)
	Water productivity and yield of summer rice under different irrigation regimes and nutritional levels in eastern regions of Indian subcontinent (Aftab uz Zaman)
10.45-12.15	Chairman : Nora H. Pandjaitan
	SRI Improves Single Plant Yield But Not The Yield Per Unit Area (Jiji Joseph)
	Ubiquitous Monitoring of Agricultural Field in Asia for Safe Agricultural Production Management (Masaru MIZOGUCHI)
	Characteristics of Runoff and Nutrients from an Agricultural Area with Low-Land Paddy Fields (Tasuku Kato)
	Effect of Age and Number of Seedlings on Paddy Growth in Continuous and Intermittent Irrigation Method (Yamaji Eiji)
12.15-13.15	Poster Session and Lunch Break
13.15-16.00	Pawees Agenda*
16.00	Closing Ceremony

Time	GROUP III : Function of Rural Values and Amenities on Supporting Sustainable Paddy Field Development
09.00-10.45	Chairman : M Yanuar J. Prwanto
	Investigation on the Impact of Rice Root-knot Nematode, Meloidogyne graminicola Golden & Birchfield and iIs eco-friendly management (A. Pramanik)
	Life Cycle Assessment of Paddy Fields from The Viewpoint of GHG Measurement (Yukari Motomura)
	Evaluation of The Agro-Ecological Complexity, Case Study of Rice Paddies in Ilan, Taiwan (Chung-Hsin Juan)
	Estimate of Methane Emission from Indonesia Rice Field under Different Water Environments (Hidayat Pawitan)
10.45-12.15	Chairman : M.S.M. Amin
	Development of Improved Infrastructure and Technology for Rice Production in Africa (Motomu UCHIMURA)
	Sustainable Weed Management in Dry Direct Seeded Rainy and Summer Season Rice (P. K. Mukherjee)
	The Role of Social Capital in Community Development Lessons Learned from Kamikawa Town, Japan (Shogo Nakamura)
	Climate Change Adaptation On The Sustainability Of Paddy Field Area In The Upstream of Cidanau Watershed (M. Yanuar J Purwanto)
12.15-13.15	Poster Session and Lunch Break
13.15-16.00	Pawees Agenda*
16.00	Closing Ceremony

Pawees Agenda*

8th International Conference on Educational Accreditation System and APEC Engineers Project for Agricultural Engineering in Paddy Farming Regions

Date: 8 October 2009

Venue: IPB International Conference Center (IICC), Bogor City, Indonesia

Time	Agenda	Chair person
13:15-13:20	Opening address: Prof. Won Myoung Suh	Prof. Budi I. Setiawan

13:20-15:45	Agenda I- Perspective on Professional Accreditation of Engineering Education Japan： Prof. Toshihiro Morii Korea: Prof. Joongdae Choi Taiwan: Prof. Fi-John Chang Indonesia: Prof. Asep Sapei Malaysia: Prof.Amin	Prof. Chen-Wuing Liu
	Agenda II – Present Situation of APEC Engineer Project and International Engineering Alliance Japan： Korea: Prof. Sun Joo Kim Taiwan: Prof. Yih-Chi Tan	Prof. Toshihiro Morii
	Agenda III-Progress and Issues on PWE Publication Japan：Prof. Yoshisuke Nakano Korea : Prof. Soon Jin Hwang (Jin-Yong Choi*) *Substitute speaker Taiwan: Prof. Chen-Wuing Liu	Prof. Joong Dae Choi
	Agenda IV –Publication of Textbook for Engineers in Paddy farming Region Japan：Prof. Yutaka Matsuno Korea：Prof. Jin-Soo Kim Taiwan: Dr. Chih-Hung Tan	Prof. Asep Sapei
	Agenda V- Confirmation and Amendment of Agreements for PWE publication and PAWEES PWE: Prof. Yoshisuke Nakano PAWEES: Prof. Yutaka Matsuno	Prof. Yih-Chi Tan
15:45-16:00	Bogor Statement Prof. Budi I. Setiawan	Prof. Yutaka Matsuno
16:00-	Closing Remarks	

Day – 3 (9 October 2009):

Time	Activity
07.30-12.00	Leave IICC to NOSC by bus
	Arrive at NOSC (Nagrak Organic SRI Centre)
	Program in NOSC
12:00-13:00	Lunch
13:00-15.00	Leave NOSC to Bogor Botanical Garden (BBG)
	Program in BBG with professional guide
17:00	Free

附 件 二

KA.2

The System of Rice Intensification: A Win-Win Opportunity for Water Saving in Rice Production

Norman Uphoff

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Abstract

The System of Rice Intensification (SRI) is an innovation coming from Madagascar which is gaining acceptance in most of the rice-producing countries around the world. By changing the management of plants, soil, water and nutrients, rice plants of almost all varieties (genotypes) are induced to become more productive phenotypes, producing higher grain yields in shorter time with less requirement for irrigation water. Moreover, in a number of countries and regions where irrigation facilities are not available, ***rainfed versions*** of SRI are emerging, which means that SRI applications are not limited to irrigated production. Also, it is being found that the productivity of ***other crops*** can be enhanced by extrapolating the concepts and methods of SRI to their cultivation methods. So SRI principles appear to have wide relevance. For generations, it has been believed and practiced that rice crops will perform best in soil that is continuously flooded (hypoxic). However, SRI experience and scientific evaluations are showing that rice is not an aquatic plant as widely assumed. When grown under mostly aerobic soil conditions, rice plants are healthier and more resistant to pests and disease; they resist lodging and storm damage, even typhoons; they are more tolerant of drought conditions, extreme temperatures and other climatic stresses. These benefits are associated with better and deeper root growth, and more abundant, diverse and active soil biota. We understand better how changing crop management practices, including water management, can improve the vigor and productivity of rice plants. SRI methods create incentives for farmers to reduce their current extractions of irrigation water, because they can attain higher yields and more net income ***by using less water*** in conjunction with the other recommended SRI practices. Reducing the demand for irrigation water is becoming more and more urgent and critical as the freshwater supplies for agricultural production become more constrained and unreliable with changing climate and other conditions affecting food production such as rising energy prices and less land per capita. At a time when there is need to reformulate agricultural production strategies for the 21st century, SRI experience and ideas are opening up new directions.

1. Introduction

The System of Rice Intensification (SRI) developed in Madagascar some 25 years ago by Fr. Henri de Laulanié, S.J., after two decades of working with Malagasy farmers on improving their rice crops, is gaining increasing acceptance by farmers in some three dozen countries and by rice scientists in the major national rice research institutions in Asia. It remains controversial in some circles, however. This paper will review some of the most extensive and reliable data sets on SRI results, to give readers an overview of the kind of results which can result from changes in management practices. It will also consider scientific evaluations of SRI that are now getting published in peer-reviewed journals.

It is hoped that when the growing body of evidence concerning SRI is considered carefully, the current controversy can be superseded by systematic efforts to expand the empirical knowledge base on which SRI rests. It is expected that the concepts and methods of SRI will be utilized to the extent -- and wherever -- they can demonstrably improve the productivity and incomes of rural households. We anticipate that SRI effects will reach beyond the farm and benefit consumers and the environment more generally.

What we refer to as 'the SRI effect' has been reported now from 36 countries, Timor Leste being the most recent country from which higher productivity has been seen. This 'effect' can be characterized summarily as getting more productive ***phenotypes*** from any given rice variety, i.e., ***genotype***. The SRI effect can be seen and counted in obvious things like:

- Increased numbers of tillers per plant, and larger numbers of grains per panicle
- Larger size and brighter color of root systems, indicating less senescence (aging, degradation)
- Darker-green leaf coloring, indicative of higher chlorophyll content and more potential for photosynthesis, documented in trial results reported below
- Delayed senescence of the flag leaf and other leaves, and
- Resistance to lodging caused by wind and/or rain

The principles underlying SRI are reasonably simple, supported by scientific evidence such as:

- Roots under continuous flooding lose transport capacity for nutrients and water as 30-40% of their cortex is sacrificed for the formation of air pockets (aerenchyma) (Kirk and Bouldin, 1991).
- Juxtaposing aerobic and anaerobic soil conditions enhances soil N (Magdoff and Bouldin, 1970), and N availability is reduced in soils that are continuously flooded, i.e., hypoxic (Olk et al., 2004).
- Rice plants give 40-70% higher yield when (the same amount of) N is provided in both nitrate and ammonia forms, which occurs with intermittent flooding, compared to having only the latter, which predominates under continuously flooded conditions (Kronzucker et al., 1999).
- Root systems' functioning is adversely affected by the senescence of rice plants' lower leaves which is accelerated by close spacing (Yoshida, 1981)

- Photosynthesis is enhanced by having leaves that are more upright (Sinclair and Sheehy, 1999) and when the number of plants per hill is reduced (San-oh et al., 2006),

There are many subjects that could be considered in relation to SRI. But the integrating theme in this paper will be the conservation and more productive use of irrigation water in the paddy sector, given the interests of the organizers of this conference (PAWE). The proposition of this paper is that SRI methods -- by raising factor productivity for the land, labor, water and capital used in irrigated rice production – can make it attractive to paddy farmers to curtail their use (indeed, often overuse) of water.

When farmers reduce their water applications while making other changes in crop management, as recommended for SRI, they have repeatedly found that they can achieve higher yields with more net income. This makes using less water more proftable for farmers. Moreover, adopting SRI methods can substantially reduce farmers' risk of economic loss (Uphoff, 2007).[1] Risk is a major consideration for practically all farmers. The win-win outcome referred to in the title is that farmers can get higher production and incomes at the same time they can reduce their water requirements, which is good for everyone, plus other benefits like risk reduction and higher quality grain.

2. Country Evaluations

To date, resources have never been available for those interested in SRI to do the kind of comparable, standardized evaluations that would have been desirable. This is partly because opponents of SRI have objected to SRI even being studied, deciding a priori that this would be a waste of resources (Sinclair, 2004; Sinclair and Cassman, 2004). Perhaps because the results reported with SRI management were so impressive and attractive, persons who sought to get systematic evaluation of SRI were characterized and dismissed as proponents of universal adoption of SRI methods, which was quite incorrect.

A first principle of SRI has always been that its methods should be tried out in any agroecological environment -- before any widespread utilization -- to see how they perform under location-specific conditions. Further, it should be ascertained what, if any, adaptations or modifications of general recommendations should be made to get the best synergy between the crop's genetic potential and its soil and above-ground environment for growth. Resistance from some within the scientific community to even having SRI taken seriously has limited the willingness of governments, foundations and donor agencies to support collaborative evaluation of SRI methods with those who know the most about them.

In Table 1, results are summarized of evaluations done in eight countries, most in Asia, which produce almost three-fourths of the world's rice. A consequence of lacking resources for systematic

[1] This conclusion is based on studies by GTZ in Cambodia (Anthofer, 2004) and IWMI in Sri Lanka (Namara et al., 2008), with random samples of 500 farmers in 5 provinces and 120 farmers in two districts, respectively.

evaluations is that the overall assessment of SRI's potentials and limitations have had to be based on a great variety of evaluations, undertaken by a diverse set of institutions.[2] However, that such different assessments all pointed in the same direction should give more credibility to the results.

The yield increases vary widely, from, in one evaluation an 18% lower yield compared to what are considered best management practices (Latif et al., 2005), to more than a tripling of yield. Half are in the 30-50% range, but the average is about 67%. For farmers, of course, profitability is more important than yield, and this is too often not considered in agronomic evaluations. The income increases reported from Bangladesh, Cambodia, China, Tamil Nadu, Indonesia and Sri Lanka averaged 90%, while some other reports were of increases in multiples, not increments. In Indonesia (Lombok), one calculation was of a 5x increase; in Myanmar, rainfed farmers got 8x more net rice income than before; and in the Gambia, the net increase was 9x (references are given in Table 1).

These very large and unprecedented increases are achieved, first, because farmers' net incomes from rice production are now usually so low that any increments are very great in percentage terms; but further, when costs are reduced at the same time that yields are increased, the net gain is very large.[3]

A number of countries less prominently engaged in rice production have also been taking up SRI methods in recent years, such as Afghanistan, Bhutan, Iraq, Iran, and Mali (Table 2). These are not usually thought of as prime rice-growing areas and have used SRI methods under conditions quite different from most of those in the Table 1 countries. In Afghanistan, the Aga Khan Foundation has introduced SRI methods in Baghlan Province in the mountainous north; in Mali, the NGO Africare has started SRI trials and demonstrations in the Timbuktu region on the edge of the Sahara Desert. The results reported in Table 2 are still in the early stages, but the average increment of 3 tons/hectare with

[2] The institutions involved in funding and/or conducting the evaluations summarized in Table 1 below include: agricultural universities in China and in Andhra Pradesh and Tamil Nadu states of India; international agricultural research centers (the International Rice Research Institute, IRRI, in Bangladesh, and the International Water Management Institute, IWMI, in India and Sri Lanka); non-governmental organizations (BRAC and other NGOs in Bangladesh; Metta Development Foundation in Myanmar); government agricultural research agencies (the Bangladesh Rice Research Institute, and the National Agricultural Research Institute in the Gambia); private sector organizations (Syngenta in Bangladesh, and Nippon Koei in Indonesia); and a donor agency (GTZ in Cambodia).

[3] The one evaluation with negative results (Latif et al., 2005) was based on a small data set (N=20) in Bangladesh – just 1.5% of the total number of on-farm comparison trials conducted under an IRRI-funded evaluation (Muazzam Hussain et al., 2004). Seedling age and spacing were more than is recommended for SRI, and all trials received the same fertilization so the benefit of SRI's recommendation for organic fertilization was negated. Most important, the weeding (by hand or herbicides) did not contribute to the soil aeration that is recommended for SRI. Even this incomplete use of SRI methods gave yields only 15% less than what Latif considered best management practices, and no consideration was given to SRI's saving of water and cost. The most cited evaluations that have claimed to refute SRI did not follow a protocol that its proponents would recognize (Sheehy et al., 2004) or considered as SRI the results from trials that used as few as half of the SRI recommendations (McDonald et al., 2006). These kinds of idiosyncracies in methodology have fueled the controversy associated with SRI in recent years.

reduced inputs of seeds, water, chemical fertilizer, and sometimes labor, suggests that rice production could become quite successful in these areas.

2.1. Water

In terms of water savings, most evaluations found that these larger rice harvests were achieved with 40 to 50% less water, because fields are no longer kept continuously flooded. The amount of water saving depends on factors like soil characteristics and the degree of water control that was feasible, but also on the extent to which water was previously used unnecessarily profligately in the misguided belief that rice plants benefit from being provided with more water rather than less (see Guerra et al., 1998).

The main constraint for wider SRI use is probably that many farmers are not cultivating under conditions where they have much control over water issues, e.g., field-to-field distribution. Cooperation among farmers can mitigate this constraint, but often there may be shortcomings in physical facilities and their operation that deters farms from cultivating their rice crop 'with a minimum of water,' as Fr. Laulanié (1993) recommended.

Farmers working with the Decentralized Irrigation Management Improvement Project (DISIMP) in Eastern Indonesia have found that they can cope with field-to-field irrigation to use SRI methods by constructing drainage channels within their rice paddies and by growing their rice on raised beds within these (Sato and Uphoff, 2007).The results from Indonesia reported in Table 1 indicate that this is reasonably successful. In some countries, farmers are starting to use sprinkler irrigation with their SRI crop as a water-saving option. We should expect that there will be considerable experimentation and innovation in the years ahead for learning how to grow rice under mostly aerobic soil conditions.

Table 1. Country results from evaluations of system of rice intensification (SRI) methods

Country/Evaluation	Yield increases	Water saving	Other benefits reported	Data base for evaluation
BANGLADESH: Evaluations done under grant from IRRI/BD programme[^] (1) ---------- Bangladesh Rice Research Institute (2)	30% average increase ---------- 18% less yield than best management practices, 14% more than farmer practice	Not measured	Costs of production lowered by 7%; net income per hectare increased by 58% --- 13% more labor than BMP, and 18% more labor than FP	On-farm comparison trials (N=1,278) over two years, 2002-04 ---------- On-farm comparison trials (N=20) in 2003
CAMB ODIA: GTZ, German Technical Cooperation (3)	41% average increase in yield	Volume not measured; most farms were rainfed[**]	Income increases averaged 74%; SRI was labor-neutral on average, with lowered risk of net economic loss	Random sample (N=500) of SRI users vs. non-users in 5 provinces in 2004
CHINA/Sichuan Province: China Agricultural University (4)	Comparisons made with farmer practice: 47.7% higher in 2003; 12.1% higher in 2004, a more normal year	45%	Cost of production 7.5% lower; net income increased more than 100%; labor saving reported as greatest benefit	Random sample (N=82) from 398 SRI users in 2004; up from 7 SRI users in 2003, a drought year
GAMBIA: National Agricultural Research Institute (5)	6.2 vs. 1.8 t/ha in replicated trials, average for 3 spacings; 7.3 vs. 2.5 t/ha at 20x20 cm spacing	45%	Cost of production 3% lower; net income \$446 vs. \$50 ha^{-1}; water productivity increased from 0.10 grams to 0.62 grams of grain/kg total water input	Replicated on-station trials comparing SRI with conventional practice, during 2000-02
INDIA/ Andhra Pradesh: ANGRAU (state agricultural university) (6)	38% increase (8.73 vs. 6.31 t/ha)	40-50%	AP: water productivity was raised from 0.57 g/m^3 of water to 2.05 g/m^3 of water	AP: supervised on-farm trials (N=1,525) in all 22 districts of the state during 2003-05
INDIA/ Tamil Nadu: Tamil Nadu Agricultural University (6)	28% increase (7.23 vs. 5.66 t/ha)	40-50%	TN: 8% lower labor input/ha; net income was increased from \$242/ha to \$519/ha	TN: supervised on-farm trials (N=100) in Tamira-parani Basin in 2004
INDIA/ West Bengal: International. Irrigation Management Institute, India Programme (7)	32% average increase in yield with partial adoption of methods and drought effects	Rainfed production	Net income/ha up 87%; 46 vs. 32 kg of rice per day of labor; 845 vs. 61 kg of rice per kg of seed; labor/ha reduced by 8%	Study of two villages with SRI adoption (N=110), one village having experienced drought in 2004
INDONESIA : Nippon Koei technical assistance team (8)	78% increase in yield over farmer practice; 7.7 t/ha vs. 4.4 t/ha	40%	Fertilizer use reduced by 50%, costs of production by 20%	On-farm comparison trials (N=12,133) over 9 seasons on total area of 9, 429.1 hectares, 2002-06

MYANMAR: Metta Development Foundation (9)	6.4 t/ha average on FFS plots and 4.2 t/ha on farmers' fields vs. 2.1 t/ha usual yield	Rainfed production	Increase achieved with no increase in cost of production; net income rose from 296 kg of rice to 2,584 kg of rice	Members of 30 farmer field schools (N=612) surveyed over 3-year period, 2002-04
SRI LANKA: International Water Management Institute, Sri Lanka Programme (10)	50% increase in yield, even with incomplete utilization of SRI practices	21% reduction in hours of irrigation	Water productivity up 90%; labor productivity up 50%; net income increased 112% on average for WS and DS; 7x less risk of net economic loss	Random sample (N=120) of SRI users vs. non-SRI users in 2 districts in 2003

^ Field trials were managed by three NGOs (BRAC, SAFE, POSD) and Syngenta Bangladesh Ltd.

^^Flooding at TP: 3% with SRI vs. 96% conventional; at vegetative growth stage, 22% instead of 64%; so significant reduction in water use.

Source:

(1) Muazzam Hussain, A.M. et al. (2004). Final Evaluation Report for Verification and Refinement of the System of Rice Intensification (SRI) in Selected Areas of Bangladesh (SP 36 02). Report to International Rice Research Institute, Dhaka, June. (http://ciifad.cornell.edu/sri/countries/bangladesh/bangpetfrep.pdf).

(2) Latif, M.A. et al. (2005). Validation of the System of Rice Intensification (SRI) in Bangladesh. ***Field Crops Research***, 93:281-292.

(3) Anthofer, J. (2004). The potentials of the System of Rice Intensification (SRI) for poverty reduction in Cambodia. ***2004 Deutscher Tropentag***, Berlin (http://www.tropentag.de/2004/abstracts/full/399.pdf).

(4) Li X.Y., Xu X.L. and Li H. (2006). A socioeconomic assessment of the system of rice intensification (SRI): A case study from Xinsheng village, Jianyang county, Sichuan province. In Zhu D.F., ed., ***The Theory and Practice of SRI***. Chinese Publishing Company of Science and Technology, Beijing, published for the China National Rice Research Institute, Hangzhou (in Chinese) [English: http://ciifad.cornell.edu/sri/countries/china/cnciadeng.pdf].

(5) Ceesay, M., W. S. Reid, E. C. M. Fernandes and N. Uphoff (2006). Effects of repeated soil wetting and drying on lowland rice yield with System of Rice Intensification (SRI) methods. ***International Journal of Agricultural Sustainability***, 4: l.

(6) Satyanarayana, A., T. M. Thiyagarajan and N. Uphoff (2006). Opportunities for saving water with higher yield from the System of Rice Intensification. ***Irrigation Science***, 38: 99-115.

(7) Sinha, S.K. and J. Talati (2007). Productivity impacts of the System of Rice Intensification (SRI): A case study in West Bengal, India. ***Agricultural Water Management***, 87: 55-60.

(8) Sato, S. and N. Uphoff (2007). A review of on-farm evaluation of system of rice intensification (SRI) methods in eastern Indonesia. ***CAB Review: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources***. Commonwealth Agricultural Bureau International, Wallingford, UK.

(9) Kabir, H. and N. Uphoff (2007). Results of disseminating the System of Rice Intensification with Farmer Field School methods in Northern Myanmar. ***Experimental Agriculture***, 43:4.

(10) Namara, R., D. Bossio, P. Weligamage and I. Herath. (2008). The practice and effects of the System of Rice Intensification (SRI) in Sri Lanka. ***Quarterly Journal of International Agriculture***, 47: 5-23

2.2. Labor

One of the main objections to SRI, by some evaluators and some farmers, has been an increased requirement of labor, at least in the initial stages when farmers are learning the new methods (Moser and Barrett, 2003). This has been found to be a transitional constraint, however, because labor requirements with SRI decline as farmers gain skill and confidence in using the alternative methods (Barrett et al., 2004). A number of evaluations have found that SRI practices are either labor-neutral (e.g., Anthofer, 2004; Sato and Uphoff, 2007) or labor-saving (Li et al., 2005; Sinha and Talati, 2008). Indeed, in both India and China, labor-saving with SRI is cited as one of its most attractive features for farmers (e.g., *Hindu*, 1/1/08; http://www.thehindu.com/2008/01/01/stories/2008010153180300.htm http://ciifad.cornell.edu/sri/countries/china/cnntutrep0807.pdf).[4]

While labor-intensity can be a barrier to adoption in the first instance, while farmers and laborers are on the low part of their learning curve, this is a passing problem. Further, a number of labor-saving methods and techniques have been (and will continue to be) developed to reduce labor requirements further, like the rakes and roller-marker designed to speed up marking SRI fields for transplanting, and mechanized transplanting machines or motorized weeders. It needs always to be kept in mind that, as SRI is not a technology but rather a system or a process, it is *a work in progress*, not finished yet. Critics object that SRI is 'a moving target' (for them to shoot at?), but this dynamism reflects the nature of SRI and of agricultural innovation itself.

Table 2. Results of SRI methods in the 2008 reports from other countries

Country	% Increase	Conv.	SRI	Agency and URL for 2008 Reports
Afghanistan	87	5.41	10.13	Aga Khan Foundation - on-farm supervised comparison trials (N=6) http://ciifad.cornell.edu/sri/countries/afghanistan/afgAKrptwithPhotos08.pdf
Bhutan	25[1]	6.92	8.63	College of Natural Resources, Royal University of Bhutan - on-station trials http://ciifad.cornell.edu/sri/countries/bhutan/bhuLhendupFinalRpt08.pdf; Renewable Natural Resources Research Centre, Bajo - on-station trials http://ciifad.cornell.edu/sri/countries/bhutan/bhGhimireBajoRpt08.pdf
Iran	64	3.5	6.0	Haraz Technology Development and Extension Center - on-station trials http://ciifad.cornell.edu/sri/countries/iran/iranrpt08.pdf
Iraq	72	4.66	7.03	Al-Mishkhab Rice Research Center - on-farm trials in 4 districts (N=16) http://ciifad.cornell.edu/sri/countries/iraq/IraqHameedRpt08.pdf
Mali	65	5.5	9.1	Africare Development Program, Timbuktu - on-farm comparison trials (N=53) http://ciifad.cornell.edu/sri/countries/mali/MaliAfricare%2008and09.pdf
Average	62	5.2	8.2	

[1] Average for 2 sets of evaluation trials

[4] In a video conference on SRI, September 11, 2009, organized by the World Bank Institute to assist Kenyan farmers who will begin SRI cultivation this season, the faculty member at Tamil Nadu Agricultural University introduced an Indian farmer who had reduced the number of laborers needed to transplant his paddy fields from 25 to 5 once he switched to SRI methods, with their 90% reduction in the number of seedlings to be transplanted. Labor shortages during this peak period of demand for labor to do transplanting create an additional incentive to take up SRI.

Table 3. Scientific evaluations by Chinese scientists of SRI methods

Initial evaluations: Published in the proceedings of an international conference, held in Sanya, China, April 1-4, 2002: ***Assessments of the System of Rice Intensification***, edited by N. Uphoff, E.C.M. Fernandes, Yuan L.P., Peng J.M., S. Rafaralahy and J. Rabenandrasana. Cornell International Institute for Food, Agriculture and Development, Ithaca, NY, 2002:
Tao L.X., Wang X. and Min S.K. (2002). Physiological effects of SRI methods on the rice plant, pp. 126-132 (http://ciifad.cornell.edu/sri/proc1/sri_29.pdf)
Wang S.H., Cao W.X., Dong J., Dai T.B. and Zhu Y. (2002). Physiological characteristics and high-yielding techniques with SRI rice, pp. 116-124. (http://ciifad.cornell.edu/sri/proc1/sri_27.pdf)
Yuan L.P. (2002). A scientist's perspective on experience of SRI in China for raising the yields of super hybrid rice, pp. 23-25. (http://ciifad.cornell.edu/sri/proc1/sri_06.pdf)
Zhu D.F., Chen S.H., Zhang Y.P. and Lin X.Q. (2002). Tillering patterns and the contribution of tillers to grain yield with hybrid rice and wide spacing, pp. 125-131 (http://ciifad.cornell.edu/sri/proc1/sri_28.pdf)
Subsequent evaluations (not a complete listing):
Chen, H.Z., D.F. Zhu, L.B. Rao, X.Q. Lin and Y.P. Zhang (2006). Effects of SRI technique on population quality after heading stage and yield formation in rice. *Journal of Huazhong Agricultural University*, 25: 483-487, with English summary.
Liang Y.M., Lin X.Q., Sun Y.F., Zhu D.F. and Shi G.A. (2004). Study on yield and its components of Xieyou 9308 under the system of rice intensification. *Chinese Agricultural Science Bulletin*, 20: 84-86.
Lin X.Q., Zhou W.J., Zhu D.F. and Zhang Y.P. (2004). Effect of water management on photosynthetic rate and water use efficiency of leaves in paddy rice. *Chinese Journal of Rice Science* 18: 333-338.
Lin X.Q., Zhou W.J. and Zhu, D.F. (2005). The photosynthetic rate and water use efficiency of leaves at different position at panicle initiation stage under the System of Rice Intensification (SRI). *Chinese Journal of Rice Science* 19: 200-206.
Lin X.Q., Zhou W.J., Zhu D.F. and Zhang, Y.P. (2005). Effect of AWD irrigation on photosynthesis and grain yield of rice (*Oryza sativa* L.). *Field Crops Research* 94: 67-75.
Lin X.Q., Zhou W.J., Zhu D.F., Chen H.Z. and Zhang Y.P. (2006). Nitrogen accumulation, remobilization and partitioning in rice (*Oryza sativa* L.) under an improved irrigation practice. *Field Crops Research* 96: 448–454.
Lin, X.Q., W.J. Zhou and D.F. Zhu (2005). The photosynthetic rate and water use efficiency of leaves at different position at panicle initiation stage under the System of Rice Intensification (SRI). *Chinese Journal of Rice Science* 19: 200-206.
Long, X., J. Ma, F.Y. Xu, H.Z. Wang, Q.L. Huang and Z.X. Yuan (2005). Study on the seedling-age and planting density in SRI. *Journal of Sichuan Agricultural University*, 23: 365-373.
Lu X.M., Q. Huang and H.Z. Liu (2006). Research of some physiological characteristics under the system of rice intensification. *Journal of South China Agricultural University*, 27: 5-7,
Tao, S.S and J. Ma (2003). Improvement of the system of rice intensification (SRI) and its application in medium hybrid rice of the double cropping system. *Hybrid Rice*, 18: 47-48.
Wang, S.H., Cao W.X., Jiang D., Tai D.B. and Zhu Y. (2003). Effects of SRI technique on physiological characteristics and population development in rice. *Chinese Journal of Rice Science*, 17: 31-36.
Xu, F.Y., J. Ma, H.Z. Wang, H.Y. Liu, Q.L. Huang, W.B. Ma and D.F. Ming (2003). The characteristics of roots and their relation to the formation of grain yield under the cultivation by system of rice intensification (SRI). *Hybrid Rice*, 18: 61-65.
Yu, A.Y, Z.Q. Wu, X.Q. Lin, G.P. Zhu, N.T. Zhou, D.L. Chen and Y.M. Shen (2005). Optimization of high-yield cultural practice under the system of rice intensification. *Chinese Agricultural Science Bulletin*, 21: 162-164.

Zhao L.M., L.H. Wu, Y.S. Li, X.H. Lu, D.F. Zhu and N. Uphoff (2009). Influence of the system of rice intensification on rice yields and nitrogen and water use efficiency with different application rates. *Experimental Agriculture*, 45: 275-286.

Zhong H.M., A.M. Huang, J.P. Liu, J.N. Li, F.B. Wu and F.P Ouyang (2003). Analysis on the yield-increasing effects and economic benefits of the system of rice intensification (SRI) in hybrid rice. *Hybrid Rice*, 18: 45-46.

3. Scientific Evaluations

The first scientific work on SRI methods was done by researchers in Madagascar and then China, starting with students in the Faculty of Agriculture (ESSA) at the University of Antananarivo, who were recruited and supervised by its director of research, Prof. Robert Randiamirisoa. They did extensive and detailed evaluations of SRI methods from 1997 to 2004, when Prof. Robert passed away. Because these students' theses were unpublished and in French language, only some of their findings have become known outside Madagascar (Randriamiharisoa and Uphoff, 2002; Uphoff and Randriamiharisoa, 2002; Randriamiharisoa et al., 2006).

Chinese scientists began evaluating SRI in 1999, starting at Nanjing Agricultural University. The next year trials began at the China National Hybrid Rice Research and Development Center. When these were successful, its director, Prof. Yuan Longping, famous as 'the father of hybrid rice,' gave impetus to scientific evaluations of SRI in China (Yuan, 2001). Unfortunately for the rest of the world, most of the resulting articles were written in Chinese language, however.

Several reports were presented in the proceedings of the first international conference on SRI, held in Sanya, China, in April, 2002, hosted by Prof. Yuan. Even though these and some other articles were published in English (see Table 3), for the most part the findings of Chinese scientists have been ignored in evaluations of SRI by other scientists, e.g., Sheehy et al. (2004), McDonald et al. (2006).

For several years, the only article in the agronomic literature that gave a favorable view of SRI was Stoop et al. (2002) in *Agricultural Systems*. Critical articles found more ready acceptance in journals such as *Field Crops Research*. In the last several years, however, there has been an increase in published articles on the results of using SRI methods based on agronomic or agroeconomic research, as seen in Table 4.

The number of persons with training to make measurements and employ methods that are standard for scientific investigation and reporting -- and who are interested in understanding SRI principles and practices -- has been growing. These include senior scientists like Dr. Zhu Defeng and Dr. Lin Xianqing at the China National Rice Research Institute in Hangzhou and Dr. Amod Thakur at the Water Technology Centre in Bhubaneswar, India. Younger researchers such as Dr. Abha Mishra at the Asian Institute of Technology in Bangkok, Thailand, and Tim Krupnik, doing PhD thesis research on SRI with WARDA in Senegal, are also contributing to more detailed and thorough understandings of how, why, when and where SRI management methods are able to evoke more productive

phenotypes from existing rice genotypes. This paper cannot report all of the findings that contemporary research is contributing to the advance of SRI knowledge and practice, so recent publications are listed in Table 4.

Table 4. Evaluations of SRI methods in the peer-reviewed literature

Agronomic Evaluations
Ceesay, M., W.S. Reid, E.C.M. Fernandes and N. Uphoff (2006). Effects of repeated soil wetting and drying on lowland rice yield with System of Rice Intensification (SRI) methods. *International Journal of Agricultural Sustainability,* 4: l.
Chapagain, T. and E. Yamaji (2009). The effects of irrigation method, age of seedling and spacing on crop performance productivity and water-wise rice production in Japan. Accepted by *PAWEES Journal*
Menete, M.Z.L., H.M. van Es, R.M.L. Brito, S.D. DeGloria and S. Famba (2008). Evaluation of system of rice intensification (SRI) component practices and their synergies in salt-affected soils. *Field Crops Research* 109: 34-44.
Mishra, A. and V.M. Salokhe (2008). Seedling characteristics and early growth of transplanted rice under different water regimes. *Experimental Agriculture* 44: 1-19.
Thakur, A.K., N. Uphoff and E. Antony (2009). An assessment of physiological effects of system of rice intensification (SRI) practices compared to recommended rice cultivation practices in India. Accepted by *Experimental Agriculture*
Thakur, A.K., S. Rath and A. Kumar (2009). Performance evaluation of rice varieties under system of rice intensification (SRI) compared to conventional transplanting system. Accepted by *Archives of Agronomy and Soil Science*
Thakur, A.K., S. K. Chadhlari, R. Singh and A. Kumar (2009). Performance of rice varieties at different spacing grown by the system of rice intensification in eastern India. *Indian Journal of Agricultural Sciences* 79: 441-447.
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4. Conclusions

The saga of SRI is not finished, so final or firm conclusions need to be deferred. The history of SRI is still being written as its concepts and methods are being extended to rainfed, uinirrigated rice production, and also to other variants of rice cultivation – direct seeding, zero-tillage, raised beds, mechanization, etc. So far, these extensions have had quite beneficial results. At the same time, SRI concepts and methods are being extrapolated now to other crops such as wheat, sugar cane,[5] and finger millet, even to legumes and vegetables. So while SRI insights and methods began with irrigated rice production, they are becoming more encompassing.

At the first (and so far only) international SRI conference, held in China in 2002, the consensus of the participants from 15 countries across Asia, Africa and Latin America was that SRI activity should proceed along two parallel tracks, which could be described as theory and practice, or science and application. The usual strategy for making advances in the agricultural sector in most of the 20th century was for scientists to first develop new knowledge and methods and then this would be transformed into finite technology which then be 'transferred' to farmers as end-users. There could be some feedback loops through extension personnel, but basically this operated as a one-way, sequential process.

With SRI, it was clear that we are not dealing with a standard kind of technology. For this reason we prefer the designation 'system' or 'methodology' -- to avoid encapsulating this still-growing and changing knowledge base into a set formula or prescription. SRI grew out of practice rather than science, although whatever was learned and done should be consistent with what can be understood and explained in scientific terms, possibly new or modified ones.

Accordingly, the best conclusion for now to affirm is that both scientists and practitioners should each proceed in tandem in their respective contributions to SRI. Each should be learning from and assisting the other to the extents possible. Farmers are playing a central and critical role in the ongoing evolution, improvement and extension of SRI applications. SRI is mapping out a new approach to agricultural improvement, and we are still in the process of learning how to make the most of this.

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Evaluation of the Agro-ecological Complexity, Case Study of Rice Paddies in Ilan, Taiwan

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Abstract

This paper investigated four Paddy Fields in Ilan, Taiwan to evaluate their agro-ecological complexity at the farm scale from the aspects of human economy, the biodiversity in natural systems, and sustainable energy (Emergy) to maintain the farming practices.

The four paddy field employed different farming practices, the conventional farming at Site 1 (Sanshing townshop), duck-rice system at Site 2(Sanshing townshop), recycle farming at Site 3 (Suao township), and duck rice system at Site 4 ((Suao township). The results showed that the non-conventional farming practices were better in economy because the market price was higher. The biodiversity at the study site in Suao township performed better. It might be resulted from the lands of those paddies were not consolidated and more natural. The property of the biodiversity might not be emerged yet at the single farm scale. The emergy sustainability index of the recycle system was higher than the others. It indicated to recycle materials inside the systems was important for sustainable development. If those non-conventional farming practices can be extended to a larger region with more natural landscape design, the evaluation should show a consistent agreement in favor of non-conventional farming practices. It implies that the sustainable development of paddy field should integrated with human market, landscape of paddy fields, and farming practices.

Keywords : Multi-functionality of Paddy, Agro-ecosystem, Ecological Complexity, Emergy analysis, Sustainability index

Introduction

A complex system is generally described as a network of many components whose aggregate behavior is both due to, and gives rise to, multiplescale structural

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and dynamical patterns which are not inferable from a system description that spans only a narrow window of resolution (Parrott, 2002). Generally speaking, ecological complexity means the diversity, self-organization processes and ordering of structure and function in different hierarchies in the ecosystem. Agricultural ecosystem is a complex system between the interface of human and nature, which includes dimension of human society and natural ecology. Complex system has the characteristic of entirety itself, so that in the long-term progress of system development, each dimension in system has to develop simultaneously, or it could be obstructive. Different from the agriculture management in the pass, which sees economic production as the main target, natural ecology dimension in agricultural environment has to be involved in the system under the premise of sustainable development. From the sustainable aspects, the rice paddies do not only provide places for rice cultivation but also environmental and human cultural services, such as land conservation, fostering of water resources, preservation of the natural environments), formation of scenic landscape, transmitting culture, rural amenity, maintaining revitalizing rural community. Those services provided by rice paddies are also depicted as the multi-functionalities of rice paddies.

Furthermore, the concept of ecological conservation focusing on legal protection area in the pass gradually extends to focus on illegal protection area. Therefore, the evaluation of long-term development of Agricultural ecosystem has to use Ecological complexity as a point of view to consider dimension of human society and natural ecology.

Complexity often takes the form of hierarchy (Wu, 1999). In the higher level of hierarchy (larger scale), the properties of the services (multi-functionalities) of agro-ecosystems gradually emerges when many farm lands, natural lands, villages in the lower level of hierarchy (smaller scale) are lumped. Those services are not obvious in the smaller scale as farm lands. The properties usually observed in the scale of farm lands are the sustainable farming practices in terms of economic benefits from the human aspect, the biodiversity from the natural aspect, and the wise use of resources and energy by the evaluation of the emergy at four sites from the long-term sustainability. “Emergy” was defined as “all the available energy that was used in the work of making a product and expressed in unit of one type of energy” (Odum,1996). The emergy of a type of material, product, or service indicates the historical energy inputs to form it, and usually is regressed to the fundamental

sustainable energy unit on earth, i.e. solar emergy joule (sej). The ideal farming practices should have the benefits of all three aspects.

This paper only presents the evaluation of the ecological complexity of rice paddies in the smaller scale of farm lands in Taiwan. The emerging environmental and cultural services in the larger scale are not considered, but expected to be develop and integrated in the longer term.

Site Description

This paper takes the samples of four Paddy Fields in Ilan, the northeastern Taiwan (Fig 1).

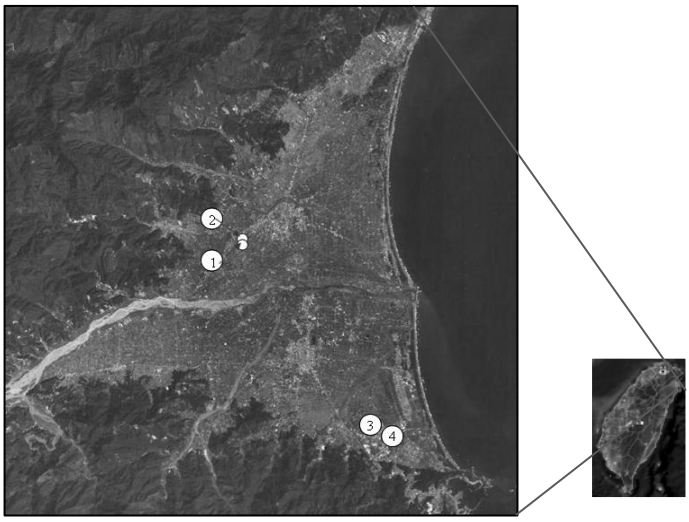

Fig 1. The study area

The farming practices at the four sample sites were different. Site 1, referred as General Paddy Fields in Sanshing was the conventional farming practice, i.e. using chemical fertilizers and pesticides. The farming practices at Site 2 and Site 4, referred as Duck-Rice Paddy Fields in Sanshing and Duck-Rice Paddy Fields in Suao were so-called duck-rice mixed systems which were recently introduced from Japan and southeastern Asia. The farming practice at Site 4, named by the farm owner as Natural Paddy Fields in Suao recycled the local organic wastes as fertilizers and created some natural environments around the field to balance the biodiversity for the pest control. The farming practice at Site 1 was the most popular way, where the other the other practices were considered more sustainable but only employed by very limited farmers.

Methods

The three evaluation procedures from different aspects were integrated to evaluate the emerged properties of the ecological complexity of the study sites.

The economic cost and income of producing rice at the farm lands and were evaluated to realize the benefits from the aspects of human systems. The biodiversity of amphibian and insects was investigated as a measure for the aspects of natural systems. In addition, the emengy of the farming practices was analyzed to understand the sustainability. The data for evaluation was collected in 2007.

Results

The results of the economic analysis for the four different practice was summarized as in Fig. 3. The results showed that net income of the non-conventional practices were higher, although their prime cost may be higher for the duck-rice farming practices. The higher net income was due to the market price for organic or natural rice products. The supports of organic or natural products from the human market apparently are the important driving force to encourage farmers to shift farming practices.

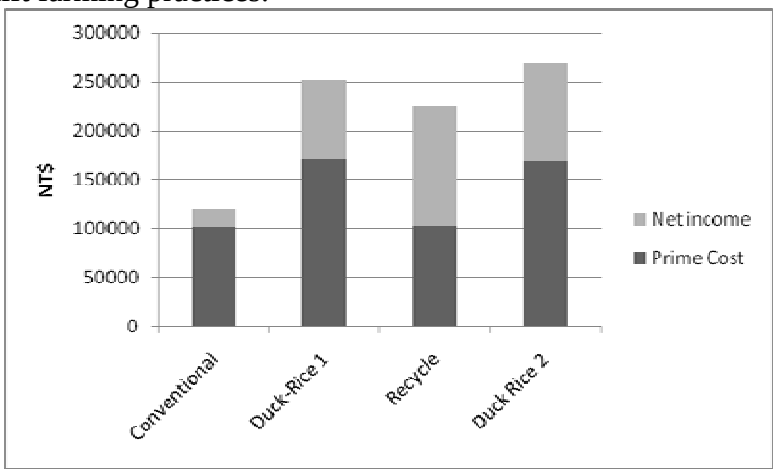

Fig 3. The economic evaluation of the four sites.

The biodiversity of the dragon fly species were investigated from May to Oct in 2007. The results were demonstrated as species richness, numbers of total counts, and Shannon diversity indices, as Fig 4, 5, and 6. The results indicated that the Recycle and Duck-Rice 2 systems have much better biodiversity in terms of species richness, numbers of total counts, and Shannon diversity index, where the Conventional and Duck-Rice 1 have similar but lower diversity. Since the area of the paddies of Conventional and Duck-Rice 1 have been land-consolidated, the banks of the paddies, the irrigation canals were made of concrete and there were very few natural lands surround them. It implied that the biodiversity might be more related to the landscapes of agricultural area than the farming practices. In other words, the properties of biodiversity tended to emerge in larger scale.

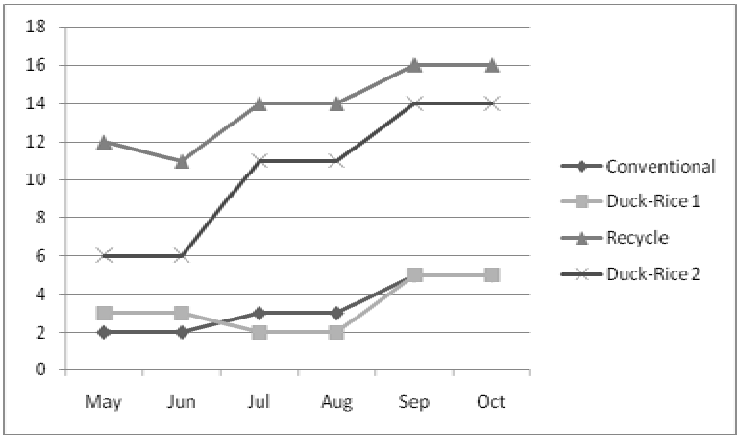

Fig 4. Species richness at the four study sites.

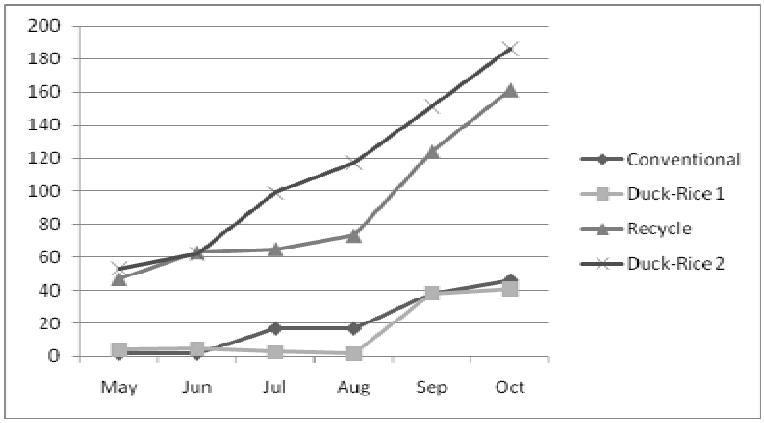

Fig 5. Total numbers of counts at the four study sites.

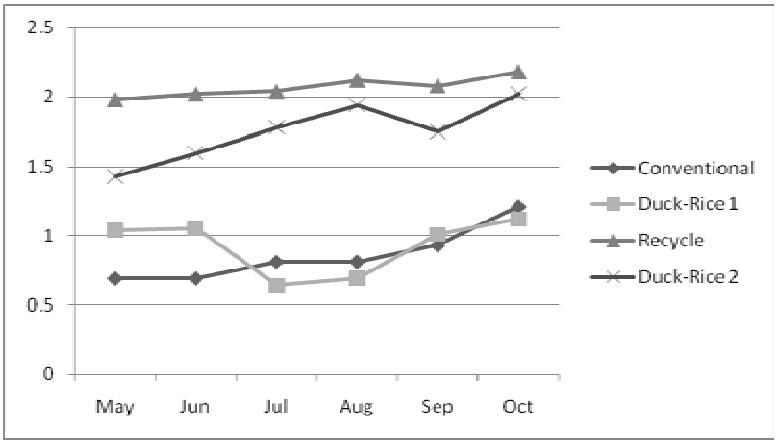

Fig 6. Shannon diversity index a the four study sites

The results of the emergy analysis in terms of common emergy indices were listed in the table 1. The sustainability index of the recycle farming practice was highest, that of the conventional farming practice was the second, where those of the duck-rice systems were the lowest. The fact that the recycle system recycled the local organic waste which was considered as the materials inside the system reduced the total inputs from the outside system. Although the duck-rice systems were usually regarded as sustainable farming practices, the results showed they were not. The duck-rice systems imported extra feeds for the duck in the paddies, and as a result they were not as sustainable as the other systems. If the duck-rice systems in the study

paddies were coupled with duck farms and supported from each other, then it should be more sustainable.

Table 1. The emergy indices at four study sites.

Emergy Index	Conventional	Duck-Rice 1	Recycle Duck-Rice 2	
Fraction of Renewable Energy	0.85	0.61	0.87	0.82
Emergy Yield Ratio	6.45	3.77	7.43	5.46
Environmental Loading Ratio	0.14	0.36	0.1	0.22
Emergy Sustainability Index	46.07	10.47	74.3	24.31

Conclusion

The results of three different evaluation procedures showed the different farming practices performed different benefits from different aspects. From the economic aspects, the non-conventional farming practices have higher net income than the conventional farming practice. From the natural aspects, the landscape of paddies in larger scale might be more important than the farming practices. From the emergy aspects, to recycle the materials inside the systems was the important key for the sustainable development. Since the evaluations were only at single farm scale, the results might showed differently in different farming practices. If those non-conventional farming practices can be extended to larger scale, such as a complete irrigation division with more natural landscape design, the evaluation should show consistent results in favor of those non-conventional farming techniques.

Acknowledgement

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附 件 三

Good Morning!

In August Typhoon Morakot heavily damaged Taiwan and resulted in tremendous casualty and loss of property.

Dr. Tsai is in command of the reconstruction of irrigation and drainage facilities to assist recovery operation in agricultural area.

Please accept his apology that he is unable to receive this honor in person.

Dr. Tsai appreciates this great honor very much and authorizes me to receipt the Award and deliver his thank you speech.

THANK YOU ADDRESS

President Dr. Tsuyoshi Miyazaki of PAWEES, distinguished delegates and members of PAWEES, honorable guests, colleagues, Ladies and Gentlemen：

I am really very excited and most delighted with this thoughtful Award.

Agriculture is the fundamental industry for national development. It is known that Farmland Irrigation & Engineering Enterprise is essential for sustainable management of Agriculture. There is one common pronunciation of “sheng” in Chinese as the prefix of many words, such as “sheng-chan” for production, “sheng-tai " for ecology, and “sheng-huo” for livelihood. The three Paddy Irrigation Functions stand for three “sheng” functions of production, ecology and livelihood.

I emphasize these irrigation multi-functionalities all the time and oriented my policy objectives to the Three Paddy Irrigation Functions. My philosophy of paddy irrigation management is rather pure and clear, it is simply about trying to catch people’s awareness of the importance of paddy, water and environment; calling for the unifications of the paddy growers’ countries in the Asian Monsoon region to exchange our experiences and wisdom to resolve our prevailing common problems for this generation and, the perspective issues for the next.

In Taiwan, the government gives subsidies to 17 irrigation associations, and my department have to propose projects for their training and education, and we made a great effort to strengthen farmland irrigation and drainage management, extend the freedom and precision of agriculture water utilization, carry out water-saving measures and monitoring of irrigation water quality, efficiently and dynamically operate agriculture water to overcome water shortage throughout drought period; therefore increase competitiveness of agriculture and sustainability of water environment.

In the past couple of years our best engineering achievements might be to promote green beatification on canals and ponds to create visual

enjoyment from superior rural landscape, and we would continue to perform this task in cooperation with improvement plan for public infrastructure.

Moreover, I would like to take this opportunity to express gratitude to the creative Father of PAWEES, Dr. Yohei Sato. In the end of year 2004 he gave a progress summary to every member, I translated it into Chinese and made duplicates for perusal. I also reported each achievement by PAWEES to the Executive Directors on TAES meeting. With his guidance and encouragement, every activity always received great attention and acknowledgement. Following and keeping good pace with PAWEES advancement, Taiwan has organized 2005 4th International Conference and 7th Annual Meeting in October 2008.

It is foreseeable that the future success of PAWEES is requiring our further enthusiasm and efforts. Having taken full accounts of the comprehensive characteristics of land and water system, accumulated those results of science and technology, and worked with modern approach, we could learn from our lifelong experiences, innovate and win leadership to maintain human living on the earth with limited natural resources. Following the pioneers' footsteps of irrigation ancestors, I have strong confidence that you could do much better than I have.

Finally, I would like to express my hearty thanks to the organizing committee in hosting the remarkable Conference and wish all participants a rewarding itinerary in Bogor, Indonesia.

Thank you very much.

附 件 四

2009 International Conference on Paddy and Water Environment Engineering
8th International Conference on Educational Accreditation System and APEC Engineers Project for Agricultural Engineering in Paddy Farming Regions
2009年水田與水環境國際研討會暨第8屆農業工程教育認證研討會

PAWEES 2009 BOGOR STATEMENT

October 8, 2009

國際水田與水環境學會2009年BOGOR宣言

PAWEES Conference 2009 and the 8th International Conference on Educational Accreditation System and APEC Engineers Project for Agricultural Engineering in Paddy Farming Regions were held October 7 and 8, 2009 in Bogor, Indonesia. Sixty-six research papers were presented and discussed in the conferences. The participants of the conferences have agreed to the following statements.

2009年水田與水環境國際研討會暨第8屆農業工程教育認證研討會於10月7~8日在印尼BOGOR舉行。此會議的討論內容共包括了66篇研究論文。會議後參會者們共同地做了以下的宣示:

1. PAWEES 2009 Conference has the main theme of "Promising Practice for the Development of Sustainable Paddy Fields" covering the following topics: enhancement of land, water, and labor productivities in paddy field cultivations, application of organic rice farming and uses of local varieties and their impacts to the restoration of natural resources, and function of rural values and amenities on supporting sustainable paddy field development. They can be categorized as the aspects related to the ensuring of the food security, social justice, economic development, paddy and natural disaster mitigation, climate change, and sustainable water environment.

2009年PAWEES會議主題是『具有潛力的永續稻田耕作技術』。主題下的討論項目包括了:

- 提升在水稻田農作地區的土地、水以及勞動生產力
- 以耕作有機米及其它本土種類的方式來促成自然生態回復
- 鄉村價值和娛樂設施在支持永續水稻田發展上的功能

會議討論的項目也涵蓋應確保糧食供應量、社會公平正義原則、經濟發展、減輕自然災害對稻田耕作的影響、全球氣候變化以及永續的水環境等。

2. The goal and activities of PAWEES shall expand to the co-operations with other paddy cultivation regions or countries of the world especially those in Asia Monsoon region.

2. PAWEES 未來的主要目標和活動，將在於建立並擴展與其它稻田農作地區國家的合作關係，特別是與亞洲季風地區國家的合作。

3. In order to ensure Agricultural Engineering (AE)'s essential and appropriate development in APEC, it is agreed that PAWEES endeavors to establish a new registration category for AE in APEC in order to secure the identity of AE.

3. 為了保證亞太經合組織的目標與活動有利於農業工程所必須且適當的發展，PAWEES 將致力為農業工程在亞太經合組織的工程認證項目中爭取一席之地。

4. International Journal PWE (Paddy and Water Environment) has published 205 manuscripts since its first issue in 2003 and gained an international recognition. PWE has requested ISI to register and is expected to be listed in the SCI (E) in December, 2009.

4. 國際水稻田和水環境雜誌（PWE）從2003年創刊號起，已經出版了205刊，並已在國際上得到認可。 PWE已經對美國科學資訊研究所（Institute for Scientific Information, ISI）提出申請，並可望在2009年12月被收錄在該機構的科學引文索引（SCI）理工類（E）期刊名單中。

5. PAWEES members have agreed to publish an English book for paddy farming and environmental issues. We hope to publish it in the near future.

5. PAWEES 成員們已經同意在近期內出版一本有關水稻田農作與環境問題的英文版刊物。

6. PAWEES members have discussed about the renewal of agreement between Springer and PAWEES by 2011 and revision of PAWEES' regulations.

6. PAWEES 成員們對延長與Springer 出版社的合約至2011年以及 PAWEES 章程修正等議題進行了討論。

7. The next PAWEES conference will be held in Korea in 2010. The goal of this coming conference is to discuss the issues related to conservation of biodiversity and ensuring sustainability in paddy rice production. Through the conference, we hope to enhance the exchange of our knowledge and experiences.

7. 下一屆PAWEES會議將於2010年在韓國舉行。 下一屆會議將討論生物多樣性的保育以及確保稻米產量的維持。我們希望可藉由會議來提升知識和經驗上的交流。