出國報告(出國類別：進修)

農委會農業菁英培訓計畫-
蔬菜產業因應農業機械化耕作模式
之農業人力調適對策研究

服務機關：行政院農業委員會桃園區農業改良場

姓名職稱：李金玲　助理研究員

派赴國家/地區：美國/德州

出國期間：**108** 年 **8** 月 **1** 日至 **112** 年 **5** 月 **31** 日

報告日期：**112** 年 **8** 月 **11** 日

摘要

筆者赴美國德州農工大學進修博士學位，原擬「蔬菜產業因應農業機械化耕作模式之農業人力調適對策研究」為題，但受新冠疫情影響致受訪對象有所調整，由原訂針對蔬菜產業相關受訪對象擴大為各項作物相關受訪對象，並將農業機械化耕作模式修正為以精準農業耕作模式為主要研究標的。面對國內人口老化及農業勞動人力結構的改變，農業缺工議題是現今農業所面臨的挑戰，精準農業科技的採用對於農業缺工有所助益。由於，農業科技需獲得農業推廣系統人員的推廣及農民採用，才能發揮效用。然而農業推廣人員若缺乏幫助農民採用精準農業科技的知能，將會是農民採用精準農業科技的障礙之一，進而對於農業缺工的改善效果將有所限制或成效緩慢。本研究利用不同的學術理論架構設計問卷，並針對農業推廣人員進行問卷調查，以瞭解影響農業推廣人員向農民推廣精準農業的意願；研究結果顯示，若能提升推廣人員的表現預期(performance expectancy)、社會影響(social influence)及促進條件(facilitating conditions)，將有助於提供農業推廣人員推廣精準農業科技的意願，進而有助於促進農民採用農業科技的使用率，進而有助於縮減農業缺工的需求。

目次

目的

面對 2050 糧食安全的挑戰,如何讓近 90 億人口獲得溫飽是一項重要的課題。。農業是我國立國的根本，然而我國農業經營規模小，農業勞動力以自家工或僱用農村人力為主。近年來，農村面臨人力老化，加以農事工時不固定，為了配合產業生產，有時需在清晨、夜間、無週休的長時間工作，且需在烈日下、高溫或低溫等環境工作；因此，大多勞動人力不願從事農業工作，導致國內農業勞動力不足，造成國內農業產能下降，市場競爭力不足，恐影響國人糧食供應及國內農業就業結構。

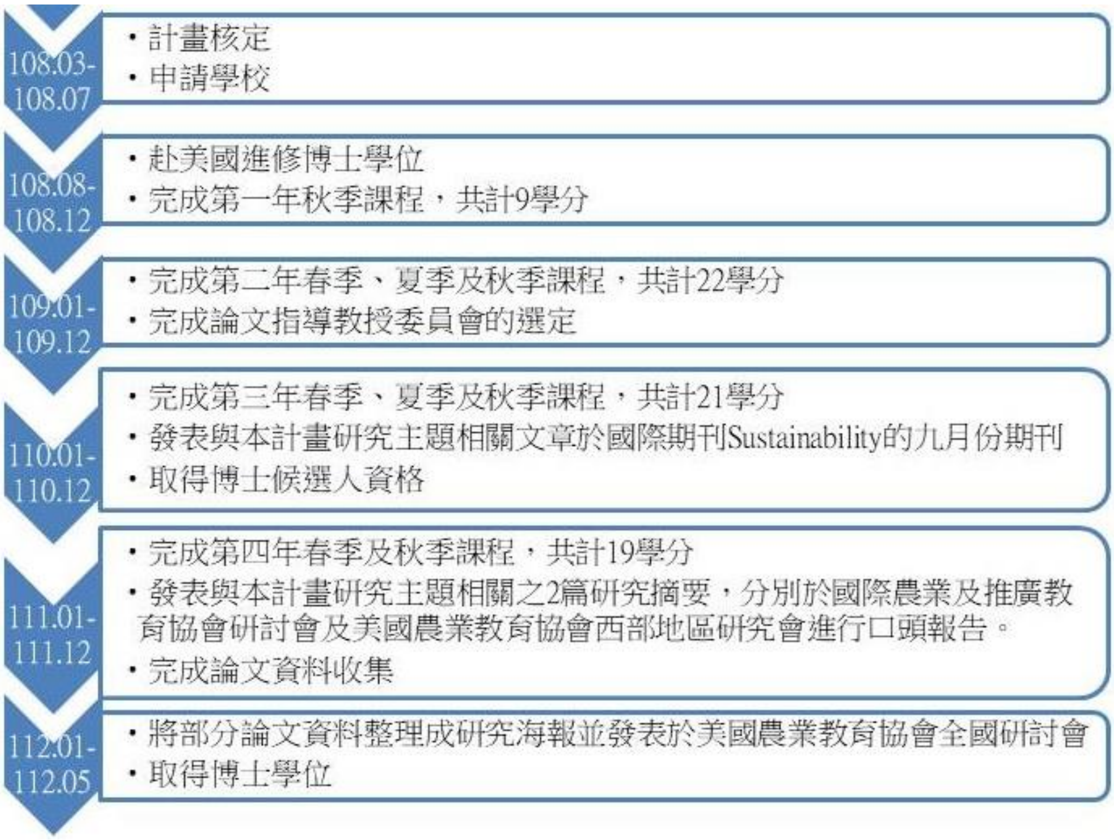
臺灣近年來積極度推廣農業機械及精準農業科技予農民運用,除能降低農民對於農工之需求，亦可協助農業生產管理，提高農民收益。精準農業科技的採用在全球已獲得重視,研究並認為採用精準農業將是提供充足糧食的解決方案之一(Benke & Tomkins, 2017; Erikson & Fausti, 2021; Fraser, 2018; Raliya et al., 2017)。研究亦同時顯示，精準農業的採用將有助於作物產業的勞工調度(Charania & Li, 2020; Charlton et al., 2019; Richards, 2018)。Schimmelpfennig(2016)的研究顯示，當生產玉米作物的小型農場採用精準農業科技時,相較於沒有使用精準農業科技的農場，在僱用勞工的成本上可降低 60% - 70%。

儘管採用精準農業對於農業生產有許多助益並可改善農業缺工現象,然而經過多年的推廣努力，許多精準農業的採用率仍然不高(Lowenberg-DeBoer & Erikson, 2018; Mitchell et al., 2020; Schimmelpfennig & Ebel, 2016; Tamirat et al., 2017)，因為，農民決定採用新科技(例如精準農業科技)的因素是很複雜的。研究發現農民們或許同意採用精準農業科技對農業生產管理是有很多好處,但同時，他們卻不夠肯定若自已採用精準農業科技,對自已的農業生產管理是否能帶來正面的獲益(kernecker et al., 2019; Lowenberg-DeBoer & Erikson, 2018)。由於不同的農民族群會對農業科技的資訊有不同的認知,進而影響到他們採用農業科技的決策過程(Ruokolainen & Widen, 2020)。因此，農業推廣系統在推廣精準農業知識

予農民就扮演著重要的角色(Rogers, 2003)。然而，Altalb 等(2015)表示，農業推廣人員缺乏幫助農民採用精準農業的知識是農民採用科技的障礙之一。Lee 等(2021)發現，農業推廣系統亦缺乏培訓農業推廣人員瞭解及推廣精準農業的專業技能。目前，政府在推動各項因應改善農業缺工措施時，推動自動化、機械化及智慧科技之省工栽培技術為其重點措施之一；且隨著政府農業設備及機械補助政策的推動，以及極端氣候因素的影響，農業產業作物耕作模式從過去使用簡易機械於露天栽培，逐漸地轉變至利用精準農業智慧生產及省工耕作模式，以提高總產值。然而，農業科技需獲得推廣及農民採用，才能發揮其效用。因此，瞭解在農業推廣系統工作的人員對採用精準農業的認識，藉以發展提升農業推廣人員在推廣精準農業能力之相關推廣項目，以幫助加快對精準農業採用的積極影響，以支持未來的糧食需求。美國德州農工大學的成立是基於學術研究、農業推廣及師生教學等三個構面做為協同發展，學校農學院體制內並有設置農業生活推廣服務系統(Texas A&M AgriLife Extension Service)。因此，本次透過農委會菁英培訓計畫，於 2019 年 8 月至 2023 年 5 月在該學校攻讀博士學位，以完成計畫進修之目的。

研究過程

本研究從計畫核定至取得博士學位歷時 3 年 10 個月。農委會菁英培訓計畫規定需於計畫核定起一年內取得國外學校的入學許可並啟程。由於計畫以取得博士學位為全程目標，因此，博士班前二年以修課為主，且因本計畫研究性質屬於科學研究，研究內容涉及研究人類行為，故需提交研究計畫送學校倫理委員會(IRB)審查通過後才能進行研究取樣。因此，在修課同時，亦同步連繫受訪族群的對接窗口以取得受訪族群的連絡資訊，並同時撰寫研究計畫書以提供倫理委員會審查。出國進修期間均妥善安排課程學習、研究時間及撰寫論文時間，以符合畢業要求。本研究計畫執行時間軸及內容如圖一。



圖一、農業菁英培訓計畫執行時間軸及內容

研究過程內容摘要

一、運用系統文獻回顧分析法，瞭解農業創新科技擴散予農民運用現況

精準農業是一種全面、可持續、創新的農業耕作及管理系統方法，可協助農民進行生產管理。採用精準農業可提高糧食安全及社區經濟可持續性並有助減緩農業勞力的需求。為了幫助推廣人員促進採用並更好地理解創新採用現象，有必要了解採用精準農業科技的創新屬性。本文章運用系統文獻回顧分析法(systematic review)，利用嚴謹的文章選擇基準，共篩選出 33 篇發表於具有影響指數(impact factor)的期刊文章做為研究材料進行分析，發現了四個主題。同時，針對研究目標，採用 Rogers(2003)的創新擴散理論(Diffusion of Innovation)架構對研究結果進行了解釋。研究結果顯示，相關優勢(relative advantage)和兼容性(compatibility)是加強採用精準農業科技所需的兩個創新屬性，而複雜性(complexity)屬性很少被用來促進採用精準農業科技。系統文獻回顧分析結果指出，由於變革推動者與農民之間對農業生產實踐屬性的溝通不足，農民對農業生產實踐的採用率因而沒有達到最高的潛在水準。農業推廣人員需要專業發展向農民宣導五種農業生產創新技術的特性，以提高農業創新科技的採用率，增加當地糧食安全的可持續性。因此，本研究建議未來從農業推廣專家的角度開展複雜性屬性的研究，以理解可示範農業科技予農民的方法，激勵農民採用農業生產創新科技的實踐。本文章發表於國際具影響指數期刊 Sustainability 的 2021 年 9 月期刊中，文章連結網址 https://doi.org/10.3390/su131810295 (附錄一)。

二、運用案例分析法，以瞭解農業推廣系統對於小農或邊緣農民獲得精準農業相關運用知識管道

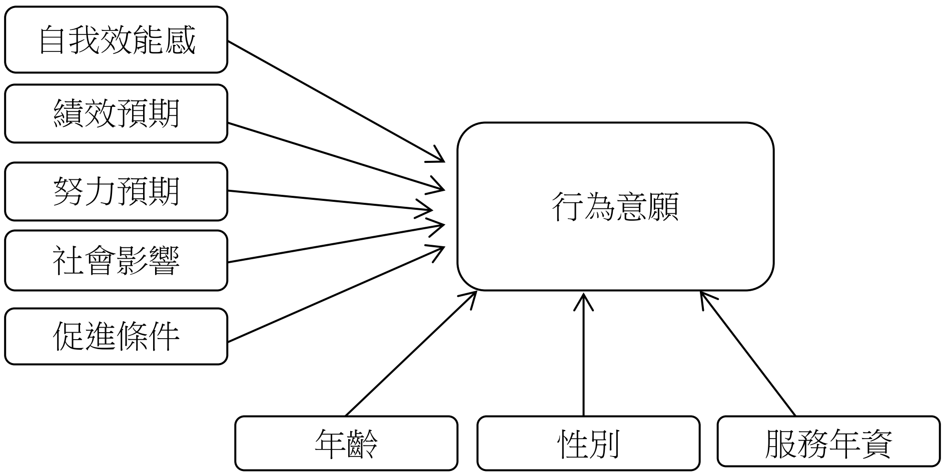
由於臺灣農民結構以小農居多，不同的農業創新科技有些很快被採用，有些被採用的速度較慢，採用率低。由於精準農業的採用在邊緣小農地區是

一個重要的降低全球貧窮的議題，且研究文獻顯示，只要能帶來幸福感，邊緣小農願意採用農業創新科技(Rahman et al., 2017)。然而獲得知識的管道不足或缺乏是採用精準農業的阻礙之一，因此，瞭解找出邊緣小農對於精準農業採用選擇的策略，將有助於農業推廣系統在未來提供更恰當的精準農業知識推廣管道。本研究運用案例分析法，並借助 google trend 分析過去 10 年內以精準農業相關關鍵字做網路搜索的 3 個地區，找到 3 個位於不同地區(中國、非洲及加拿大)小農對於精準農業採用的研究進行案例分析，分析結果歸納出 3 個小農主要採用精準農業的策略，分別為(1)資訊可及性(information accessibility)、(2)生產效率性(production efficiency)及(3)生產成本降低性(production cost reduction)。本研究結果顯示，推廣人員應清楚意識到有多種策略，可用予向不同背景下的邊緣小農提供採用精準農業的資訊。小農願意採用精準農業，但需要獲得足夠的資訊。本研究摘要發表於 2022 年國際農業及教育協會研討會(Conference of the Association for International Agricultural and Extension Education)，文章連結網址 https://doi.org/10.13140/RG.2.2.28599.39849 (附錄二)。

三、結合兩種理論架構，瞭解影響農業推廣人員推廣精準農業的意願

農業創新的研發需要獲得使用者的採用才有助於農業的可持續發展，因此，延續本計畫已運用系統文獻回顧法分析了近 20 年來國際在精準農業創新科技運用屬性及初步分析農民在獲得精準農業相關資訊的管道後，進一步對於推廣精準農業的農業推廣體系進行推廣意願之研究。過去文獻指出精準農業推廣專業人員的能力(Harder et al., 2013)。由於推廣專業人員缺乏對精準農業技術的交流，農民可能不會採用該技術(Lee et al., 2021)，因此，瞭解能夠提高推廣專業人員推廣精準農業可能性的預測因素，將同時提高糧食安全並對未來有效推廣精準農業及提高採用率有更全面地規劃的參考依據。

本研究使用 Venkatesh 等人(2003)的技術接受和使用統一理論模型 (Unified theory of the acceptance and use of technology, UTAUT)及 Bandura(1993)的自我效能理論(Self-efficacy theory)做為研究理論架構。本研究模型的各項評估構面分述如下:(1)自我效能感(Self-efficacy)是指個人對自己取得成就的能力的信念;(2)績效預期(Performance expectancy)是指使用技術能提高個人績效的程度;(3)努力預期(Effort expectancy)是指對技術易用性的看法;(4)社會影響(Social influence)是指有影響力的人認為個人應該使用技術的程度;(5)促進條件(Facilitating conditions)是指個人認為存在支持技術使用的基礎設施的程度;(6)行為意願(Behavioral intention)是指個人想為改變個人行為的意圖。圖二為本研究評估自我效能感、績效預期、努力預期、社會影響、促進條件、年齡、性別和服務年資對推廣專業人員推廣精準農業技術的行為意向的影響研究模型。



圖二、研究模型

本研究根據 Dillman 等人(2014)的問卷調查設計進行問卷調查及採樣,調查族群為美國三個州立大學農業推廣系統對推廣精準農業有經驗的推廣專業人員,可及性母體數為507位推廣專業人員,並發送線上問卷進行調查,

共計回收 255 份問卷，問卷回覆比例為 50.3%。本研究的問卷設計依據過去文獻的問卷設計及由大學專家組成的專業群進行效度(Validity)評估。各項評測因子的信度(Reliability)評估則是使用 Cronbach (1951)的 α 係數進行檢測，所有變數的 α 係數檢測結果如下，自我效能感的 α 係數為 0.95、績效預期的 α 係數為 0.89、努力預期的 α 係數為 0.89、社會影響的 α 係數為 0.87、促進條件的 α 係數為 0.78 及行為意願的 α 係數為 0.95，信度指數都在 0.75 以上。

One-way ANOVA 分析結果顯示績效預期($F(2,205) = 59.85, p < 0.1, \eta^2 = .38$)、社會影響($F(2,206) = 37.12, p < 0.1, \eta^2 = .27$)、自我效能感($F(2,206) = 27.57, p < 0.1, \eta^2 = .21$)、努力預期($F(2,205) = 16.47, p < 0.1, \eta^2 = .14$)及促進條件($F(2,206) = 9.99, p < 0.1, \eta^2 = .09$)等 5 項因子對於推廣專業人員推廣精準農業的行為意願具有統計上顯著地影響。

Pearson 相關性分析結果顯示，績效期望與行為意願有高度(strong)相關性($r = .72, p < .01$)。社會影響($r = .64, p < .01$)、自我效能感($r = .54, p < .01$)及努力期望($r = .50, p < .01$)則與行為意願有實質的(substantial)相關性。促進條件($r = .44, p < .01$)則與行為意願有中度(moderate)相關性(表一)。

表一、相關性分析結果

	n	1	2	3	4	5	6	7	8	9
1. 行為意願	207	-								
2. 績效預期	212	.72*	-							
3. 社會影響	207	.64*	.59*	-						
4. 自我效能	218	.54*	.61*	.44*	-					
5. 努力預期	210	.50*	.52*	.47*	.60*	-				
6. 促進條件	208	44*	.35*	.35*	.45*	.56*	-			
7. 年齡	186	-.03	-.04	-.00	.05	-.01	-.00	-		
8. 服務年資	187	-.06	-.05	.01	.09	.00	-.04	.74*	-	
9. 性別	193	-.11	-.16	-.12	-.17*	-.07	-.03	-.30*	-.21*	-

註：$^*p < .05$。

直線迴歸分析結果表示，績效預期、社會影響及促進條件為統計上具有顯著預測農業推廣專業人員推廣精準農業的行為意願，而其他 5 個預測因子則不具有統計上的顯著性，迴歸模型公式如下：

推廣專業人員推廣精準農業的行為意願 = .45 +.40 績效預期+ .32 社會影響 + .15 促進條件

本研究結果顯示，績效預期、社會影響及促進條件是預測推廣專業人員利益相關者推廣精準農業技術行為意願的因素。技術的積極屬性與推廣人員的專業利益的相伴共生，預示著推廣人員會向農民及其他相關人員推廣精準農業。當推廣專業人員認為推廣精準農業對自已或他人有益時，可能會導致更快的行為改變過程，而技術使用的組織或基礎設施可以預測推廣專業人員推廣精準農業技術的行為。

精準農業科技雖可以協助人人享有糧食安全的目標，並能協助改善高農業勞動力的需求，但前提是科技的採用率要提昇，因此加強推廣人員在推廣精準農業方面的培訓將是非常重要的一環。如果沒有適當且專業的推廣人員，將農業技術研究成果轉化為利益相關者(如農民)的知識，對於農業產業的糧食及勞動力需求的改善將會較為緩慢。而本研究運用 Venkatesh 等人的 UTAUT 模型進行之研究結果也發現技術接受和採用的考量面向與以往不同。本研究部份資料整理後將結果發表於國際具影響指數期刊 Foods 的 2023 年 5 月期刊中，文章連結網址 https://doi.org/10.3390/foods12112208 (附錄三)。

心得與建議

心得

美國進修博士學位對於個人工作職涯技能提升實有助益。由於在行政院農業委員會轄下農業改良場進行農業研究或推廣服務，工作技能實需與時精進，並具有國際前瞻之農業產業發展之敏銳性，以期能積極協助農委會各項政策及工作。因此，感謝服務機關推薦及農委會提供進修之機會，並期能提供以下進修經驗供未來欲赴美國進修博士學位同仁之參考。

一、選修有助於博士論文研究主題之課程

由於本計畫期程為三年，且以取得博士學位為計畫目標之前提下，因此，筆者在進行課程選修的方向都是基於對於博士論文之研究及撰寫有所助益而進行選課，且各項課程的相關作業及研究分析也以能輔助博士論文的完成進行，對於未來博士論文之撰寫具有事半功倍之效。

二、運用學校提供之學術資源

筆者求學的學校非常重視每個學生的就學權益及資源，每個學期都會不定期舉辦學術資源工作坊，例如圖書館檢索系統及文獻管理工作坊、校內及校外實習申請工作坊、論文撰寫系列講座等，而針對國際學生更有許多有別於當地學生的資源提供，如語言交流聯誼活動、學術用語寫作工作坊、學術倫理研討等，由於國際學生在美國修課除需瞭解學術專業語言外，更需運用生活語彙以融入當地環境文化，降低對不同環境的適應期，才能有助於求學的身心健康，故建議未來國外進修之人員應積極且善用學校的資源。

三、發揮個人研究強項與團隊合作

在美國的指導教授們大多不會主動要求學生進行何種研究主題，而是期望學生有自己想進行研究的主題，然後教授從旁協助其研究方法、分析過程及修正建議等，因此，學生應瞭解自身的興趣所在、個人特質及研究技能，並予以研習增強發揮，當學生自我認知能力有所不足或非專精領域時，應能

適時尋求適當人選，建立團隊，共同完成，對於個人領導能力的培養非常有幫助。

四、參與學術研討會，累積學術資源

校內為提升學生學術能力，會由學生團體或學校部門定期舉辦學生學術研討週，由校內不同學院的研究生發表研究主題，供校內相關研究主題的教授們進行研究建議，同時亦開放予全校師生到場聆聽，增進彼此公開學術演說的實戰經驗，培養學生未來參與校外的各項國際或全國研討會的演說能力及研究技能。另建議學生應積極發表研究於國際或全國研討會，除能獲得同研究領域專家學者的回饋意見外，亦可拓展個人學術人脈，累積未來與其他學者合作的研究機會。

建議

筆者所就讀的大學是依美國國會於 1862 年通過的 Morrill 法案(Act)，將國有土地撥放給德州政府，再由德州政府運用聯邦所贈予的土地或是出售土地所得之資金及當地人士的資金捐助，屬於美國贈地大學(Land Grant University)的州立農工贈地大學，因此，成立的目的以教育德州的公民，進行農業、機械等實務操作的學習工作，以強化農業和工業教育之推展。此外，為提高農業教育及促進農業實用科學的發展，依 1887 年的 Hatch 法案，國會通過提供農業試驗研究經費予各州立農工贈地大學，於農學院裏面設置農業試驗單位，讓農學院的教授得以應用當地豐富的資源以進行各項農業問題之試驗研究，並將試驗研究成果實際運用於教學及推廣服務之中，因此，贈地大學乃是以研究、教學及推廣為共同推動發展目標而成立的大學。因此，在大學的農業推廣系統下，於各州的各縣郡均有設置農業推廣人員，包括州立推廣專家、縣推廣專員及地方推廣人員，來協助學術研究試驗及落實田間應用，並實務推廣及知識分享予農民使用，因此，地方農民若有任何農務問題，都能找到適當的農業推廣人員進行諮詢或實務指導，而大

學的農業推廣系統也會定期或不定期的安排教育推廣訓練提昇各縣郡農業推廣人員的知能，讓學術與實務能實際橋接，擴散運用。綜觀國內的農業研究及推廣系統與美國的系統有所不同，是由各大學各自進行農業學術研究，研究成果提供學術界、產學界及政府參考，並無直接對口的推廣系統人員予以落實推廣予農民，少了知識分享的類似推廣人員的角色。由於國內的農業推廣系統設置於農業部下轄機關及機構，雖有相關的研究人員進行農業創新研究及成果推廣，但多為實務推廣，並非學術溝通，因此，仍期待未來產官學有更完整串聯，將創新農業新知有效傳達及應用予農業及農民。

參考文獻

Altalb, A. A. T., Filipek, T., & Skowron, P. (2015). The role of agricultural extension in the transfer and adoption of agricultural technologies. *Asian Journal of Agriculture and Food Sciences, 3*(5). 500–507. https://www.ajouronline.com/index.php/AJAFS/article/view/2962

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review*, *84*(2), 191–215. https://psycnet.apa.org/doi/10.1037/0033-295X.84.2.191

Benke, K., & Tomkins, B. (2017). Future food-production systems: Vertical farming and controlled environment agriculture. *Sustainability: Science, Practice and Policy*, *13*(1), 13–26. https://doi.org/10.1080/15487733.2017.1394054

Charania, I., & Li, X. (2020). Smart farming: Agriculture's shift from a labor intensive to technology native industry. *Internet of Things*, *9*, 1–15. https://doi.org/10.1016/j.iot.2019.100142

Charlton, D., Taylor, J. E., Vougioukas, S., & Rutledge, Z. (2019). Can wages rise quickly enough to keep workers in the fields? *Choices*, *34*(2), 1–7. http://dx.doi.org/10.22004/ag.econ.288634

Dillman, D. A., Smyth, J. D., & Christian, L. M. (2014). *Internet, phone, mail, and mixed-mode surveys : The tailored design method* (4th ed.). John Wiley & Sons Inc.

Erickson, B., & Fausti, S. W. (2021). The role of precision agriculture in food security. *Agronomy Journal*, *113*(6), 4455–4462. https://doi.org/10.1002/agj2.20919

Fraser, A. (2018). Land grab/data grab: Precision agriculture and its new horizons. *The Journal of Peasant Studies*, *46*(5), 893–912. https://doi.org/10.1080/03066150.2017.1415887

Harder, A., Ganpat, W., Moore, A., Strong, R., & Lindner, J. R. (2013). An assessment of extension officers' self-perceived programming competencies in selected Caribbean countries. *Journal of International Agricultural and Extension Education*, *20*(1), 33–46. https://doi.org/10.5191/jiaee.2013.20103

Kernecker, M., Knierim, A., Wurbs, A., Kraus, T., & Borges, F. (2019). Experience versus expectation: Farmers' perceptions of smart farming technologies for cropping systems across Europe. *Precision Agriculture*, *21*(1), 34–50. https://doi.org/10.1007/s11119-019-09651-z

Lee, C.-L., Strong, R., & Dooley, K. E. (2021). Analyzing precision agriculture adoption across the globe: A systematic review of scholarship from 1999–2020. *Sustainability*, *13*(18), 10295. https://doi.org/10.3390/su131810295
Lowenberg-DeBoer & Erikson, 2018

Raliya, R., Saharan, V., Dimkpa, C., & Biswas, P. (2017) Nanofertilizer for precision agriculture and sustainable agriculture: Current state and future perspectives. *Journal of Agricultural and Food Chemistry*, *66*, 6487–6503. https://doi.org/10.1021/acs.jafc.7b02178

Rahman et al., 2017

Richards, T. J. (2018). Immigration reform and farm labor markets. *American Journal of Agricultural* Economics, *100*(4), 1050–1071. https://doi.org/10.1093/ajae/aay027

Rogers, E. M. (2003). *Diffusion of innovations* (5th ed.). Free Press.

Ruokolainen, H., & Widén, G. (2020). Conceptualizing misinformation in the context of asylum seekers. *Information Processing & Management, 57*(3), 1–14. https://doi.org/10.1016/j.ipm.2019.102127

Schimmelpfennig, D., & Ebel, R. (2016). Sequential adoption and cost savings from precision agriculture. *Journal of Agricultural and Resource Economics, 41*(1), 97–115. https://www.jstor.org/stable/44131378

Tamirat, T. W., Pedersen, S. M., & Lind, K. M. (2017). Farm and operator characteristics affecting adoption of precision agriculture in Denmark and Germany. *Acta Agriculturae Scandinavica Section B - Soil & Plant Science*, *68*(4), 349–357. https://doi.org/10.1080/09064710.2017.1402949

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. *MIS Quarterly, 27*(3), 425–478. https://doi.org/10.2307/30036540

附錄

附錄一

sustainability

MDPI

Article

Analyzing Precision Agriculture Adoption across the Globe: A Systematic Review of Scholarship from 1999–2020

Chin-Ling Lee [1], Robert Strong [2,*] and Kim E. Dooley [2]

[1] Taoyuan District Agricultural Research and Extension Station, Council of Agriculture, Taoyuan 32745, Taiwan; chinling@tydais.gov.tw

[2] Department of Agricultural Leadership, Education, and Communications, Texas A&M University, College Station, TX 77843, USA; k-dooley@tamu.edu

* Correspondence: r-strong@tamu.edu

Abstract: Precision agriculture (PA) is a holistic, sustainable, innovative systems approach that assists farmers in production management. Adopting PA could improve sustainable food security and community economic sustainability. Developing an understanding of PA adoption attributes is needed in order to assist extension practitioners to promote adoption and better understand the innovation adoption phenomena. A systematic review of literature was conducted to investigate attributes that foster PA adoption. Thirty-three publications were examined, and four themes were found among the reviewed publications. The results were interpreted using Rogers' diffusion of innovations framework to address the research objectives. Relative advantage and compatibility were two dominant attributes needed to strengthen the adoption of PA, and the complexity attribute was rarely communicated to promote the adoption of PA. The systematic review indicated the rate of farmer's PA adoption does not occur at the highest potential levels due to inadequate communication of PA attributes from change agents to farmers. Extension field staff need professional development in communicating the five PA adoption attributes to farmers in order to improve PA adoption and enhance local sustainable food security. Thus, authors recommend future complexity studies from agricultural extension specialists' perspectives to comprehend demonstratable approaches to motivate farmers' adoption of PA.

Keywords: precision agriculture; agricultural extension; profitability; production quality; systematic review

Citation: Lee, C.-L.; Strong, R.; Dooley, K.E. Analyzing Precision Agriculture Adoption across the Globe: A Systematic Review of Scholarship from 1999–2020. *Sustainability* **2021**, *13*, 10295. https://doi.org/10.3390/su131810295

Academic Editors: Alexa Lamm and Marc A. Rosen

Received: 16 June 2021
Accepted: 9 September 2021
Published: 15 September 2021

1. Introduction

The UN adopted new Sustainable Development Goals aiming to end poverty, protect the planet, and ensure prosperity for all. In order to reach these goals, there is a need for long-term impact and large-scale influence [1]. Local partners know the problems they face and seek potential solutions. Adoption of a new approach (innovation) should have an observable advantage over previous techniques, allow for trialability, and fit into the local culture and resources availability. How can empirical research in journals be communicated effectively to stakeholders? There is a need for social and behavioral scientists to serve in translation science roles to help reach these goals.

Precision agriculture technology adoption is attracting more attention as a solution in food production to feed a growing population [2]. The history of agricultural development shows that the adoption of innovative technologies has been one of the essential factors in the growth of agricultural production systems [3–5]. Wolde et al. [6] recommended the 2050 Food Challenge necessitates global science-based innovations that concentrate on sustainable agricultural practices that support healthful dietary solutions.

From the perspective of information flow, the diffusion process of agricultural technology innovation involves government units, agricultural research and extension units, agricultural marketing units, media units, and consumers. Agricultural extension plays an important role in the development [7] and knowledge transfer [8] of innovations that sustain agricultural productivity. There are increased efforts from agricultural extension to promote precision agriculture (PA) in production contexts, such as viticulture to improve sustainability in Italy [9]. In Nigerian drylands, agricultural extension has been promoting precision approaches to teach fertilizer application [10]. Pluralized agricultural extension is perpetually faced with sustainability issues such as precision farming due to the cautious nature of farmers toward change [11].

PA technology is a management tool for monitoring the efficiency of resource inputs while reducing chemical use to avoid environmental damage and produce high quality products to satisfy growing demand on food [12,13]. Precision farming is a holistic, innovative systems approach that assists farmers in managing crop and soil variability to decrease costs, improve yield quality and quantity, and enhance farm income [14]. PA applies traditional farming practices with new technology, practices, and economic drivers to enhance sustainability in a dynamic balance [15]. Studies have reported positive outcomes from PA adoption, including economic savings in productivity factors [16], increasing yield and environmental sustainability [17], and improving food security and community economic vitality in developing regions [18]. The International Society for Precision Agriculture (ISPA) provides clarity and guidance on this important concept, to achieve the agricultural production quality, create production profits, and improve the efficiency of resource use and environmental sustainability [19]. Developing an understanding of PA adoption attributes is necessary in order to assist extension practitioners in the promotion and adoption of PA. Empirical evidence is needed for stakeholders to adopt this innovation [20].

The history of agricultural development suggests the adoption of innovative technologies has been a critical factor to improve sustainable livelihoods. However, several studies specified that the adoption rates of PA were low [21–23]. Decisions by farmers to adopt new technologies are multifaceted. PA adoption processes are complicated, and the intricacies exist in diverse elements and interactions [24]. Farmers are intrigued by PA innovations but are less convinced of its value even though they believe that PA technologies are useful to farming [25,26]. Barriers to PA adoption included technical issues with equipment, access to service software, the lack of compatibility of equipment to current farm operations [27], concerns regarding service providers misuse of agricultural data, challenges of managing the amount of PA data [28], user-friendly designs [10] and the cost [29,30].

Rogers' [31] diffusion of innovation was applied as the theoretical framework to determine whether research on PA included adoption features that impact the rate of adoption. Adoption refers to the decision to make full use of the innovation as the best available course of action, while rejection refers to the decision not to adopt an innovation. In adopting PA, knowledge and competences are required to acquire and manage data on farms [28]. Extension participants' knowledge increased when taught PA innovations through hands-on experiences with software, coupled with instructor guided and self-directed instruction [32].

Rogers' [31] five perceived attributes include relative advantage, compatibility, complexity, trialability, and observability. These attributes show research on farmers' adoption of PA factors can be impacted by extension specialists' workshops and training programs. Relative advantage, the first persuasion attribute, refers to the degree to which innovation is perceived as being better that to an existing idea or technology it replaced. The second attribute, compatibility, represents the degree to which innovation aligns with existing technology, past experience, and the needs of potential adopters. The third persuasion attribute, complexity, is the degree to an individual perceived as the relative difficulty of understanding and using an innovation. The fourth attribute is trialability, which is the degree to which an innovation may be tested. Observability, the last attribute, is the degree to which the results of an innovation can be seen by others.

A study on PA adoption by Lowerberg-DoBoer and Erickson [26] indicated that most research was aimed at understanding the factors of PA adoption at the farm level. Previous studies found that the use of PA was associated with higher production and profits [33,34]; however, whether the adoption factors related to yield and profit depended on the development of agricultural extension systems. There are few studies on the relationship between agricultural extension systems and PA technology adoption. Therefore, it is necessary to review the literature to examine the development of PA technology for evidenced-based decisions and translational science to promote adoption through extension systems to stakeholders.

This study implemented a systematic literature review over the last 20 years to determine PA adoption attributes for extension agents to improve sustainability among farmers. There were three research questions that guided this study: (a) What were the common adoption attributes promoting PA? (b) What were the main crop varieties in promoting PA adoption? and (c) What countries were represented? This systematic literature review describes current trends and future directions in promoting PA adoption.

2. Materials and Methods

A systematic review is a method using an exhaustive and comprehensive search based on explicit and strict protocols to review the existing literature with a synthesis of data focusing on a topic or on related key questions [35]. There were five steps utilized to collect, analyze, and interpret literature in this study. The first step was to identify the critical question of the research. Then, the researchers formulated the search parameters of the data selection procedure. The third step was to implement the systematic search procedure in the database. Data analysis was the fourth step, and the interpretation and summary of the materials were undertaken in the fifth step [36].

There were a variety of words employed to describe PA, including precision agriculture, precision farming, smart farming, smart agriculture, climate-smart farming, etc. Data collected from databases such as ScienceDirect with these terms were not specific enough. The intent was to investigate the trends of PA diffusion, not the characteristics or application of PA. Therefore, to obtain the targeted literature, the researchers chose Precision Agriculture, the premiere journal publishing PA scholarship, to conduct their electronic search. Precision Agriculture provides an effective forum for the dissemination of original research on topics in the rapidly evolving context of PA.

To understand the characteristics and role of the agricultural extension system in promoting PA, the researchers selected 12 journals focusing on the field of agricultural extension with the keyword, "precision agriculture." Six extension journals were identified by SCOPUS through a title search with extension as a keyword; Journal of Agricultural Education and Extension, Journal of Extension, Journal of Agricultural Extension, Agricultural Administration and Extension, International Journal of Agricultural Extension, and Journal of International Agricultural and Extension Education. However, none of these SCOPUS identified extension journals had literature respective to PA adoption in the last 20 years. The researchers expanded their systematic review to six additional extension focused journals that had published agricultural technology adoption studies all over the world; Journal of Extension and Human Sciences, Journal of Extension Systems, Journal of Extension Education, Journal of Agricultural Extension Management, Journal of Extension and Research, and Journal of Agricultural Extension and Rural Development. The additional six extension focused journals produced zero publications respective to PA adoption. Results were filtered by key terms and publication dates from 1999 to 2020 to ensure unbiased samples were collected. Precision Agriculture was the only journal in the systematic review's thirteen journal assessment of 20 years that produced PA adoption inquiries within this study's parameters and keywords.

The terms (T) and combinations (C) authors utilized for literature search were displayed in Table 1.

Literature was collected whose titles met the following themes on the publication title: (1) Production quality; (2) Improved profitability; (3) Improved the efficiency of resource use; and (4) Environmental sustainability. The themes were taken under the definition of PA by the ISPA (ISPA, 2019). These themes were selected based on the purpose of this study. Since our aim was to find the research that focused on PA adoption based on the attributes of PA. The research team established a set of code definitions and data collecting criteria (see Table 2).

Table 1. Terms and Combinations for Literature Search.

Terms	T1: Production T4: Crop T7: Efficiency T10: Effectiveness T13: Worker T16: Impact	T2: Quality T5: Profitability T8: Resource T11: Investments T14: Sustainability T17: Reduce	T3: Yield T6: Profit T9: Benefit T12: Labor T15: Environment T18: Precision agriculture
Combinations	C1: T1 and T2 C4: T3 and T6 C7: T15 and T16	C2: T2 and T3 C5: T7 and T8 C8: T16 and T17	C3: T3 and T4 C6: T9 and T10

Table 2. Descriptions of Coded Themes in the Systematic Review's Data Collection Process.

Coded Theme		Data Collection Process
Production quality	i	Production and quality were keyword searches in publication titles in the journal and there were no results.
	ii	Yield and quality were search keywords in journal titles and nine results were generated.
	iii	Crop and quality were the key terms used to search in the title of publications and there were two articles fitting the search term, but they were identical articles from the first search.
Improved profitability	i	Profitability was the key term search in the title and nine results were produced.
	ii	Profit was utilized as a key term to search for the articles and there were two results fitting the search term.
	iii	Profit and yield to search for articles and one article which was the same as the previous search in the theme one.
Improved the efficiency of resource use	i	Efficiency and resource generated zero results.
	ii	Efficiency produced six results, but there was one article which was the same as the previous search in theme two.
	iii	Benefit and effectiveness revealed three articles and one search result indicated effectiveness.
	iv	Based on the definition of PA, resource use includes human and material resources; hence, we further used key terms, investments, labor, and worker, to do the title search separately, and there were still zero results.
Environmental sustainability	i	Sustainability produced three results in titles.
	ii	Environment and impact had zero results.
	iii	Reduce and impact also had zero results.

2.1. Inclusion/Exclusion Criteria

Each article that met the coded themes was examined and were either included or excluded from further investigation based upon the following criteria: (a) publication type was peer-reviewed article that written in English; (b) search terms appearing in the title of articles; and (c) articles must be published between 1999 and 2020. Table 3 displays the implemented criteria for the systematic review.

Table 3. Eligibility Criteria for the review.

Inclusion Criteria	Exclusion Criteria
Publication type was a peer-reviewed article	Publication type was nonpeer-review
Articles were written in English	Articles were not written in English
Search terms appearing in the title of articles	Search terms other than in the title
Published in the period (1999–2020)	Published prior to 1999

2.2. Data Extraction

There were 38 articles from the combination of keyword searches needed for further eligibility screening. Six duplicate studies, and one book review article were excluded from the data analysis after the second review. As a result, 31 publications were investigated.

Five elements of the articles were documented, including the title, the crop varieties examined in the respective article, the region in which the study was conducted, the number of research keywords used, and the unveiled innovation attributes respective to PA. Data were extracted manually following a review of each full-text of publication and recorded into an Excel spreadsheet to analyze.

2.3. Data Analysis

After data collection, all the publications were analyzed with the crop varieties, regions, and keyword co-occurrence to provide descriptive statistics with narrative explanations. Three researchers provided interrater reliability in the analysis process. A VOSviewer tool was used to calculate the number of publications in which two keywords appeared together in the title, abstract, or keyword list. VOSviewer creates a cluster analysis. Clustering is a method that has the advantage of setting objects into a group by similarity or dissimilarity [37]. In general, keywords with high relevance tend to be grouped into the same cluster. Node size is related to the frequency of occurrence. The smaller the node, the lower the frequency of occurrence. The line describes the linkage between two keywords, which presented the connection between two keywords appearing in the same article. The thicker line means the stronger connection between the two keywords [38]. In this study, authors conducted a network analysis to display the trend and current status of researchers in promoting PA.

3. Results

Based on the systematic review, 31 publications were identified that met the coding criteria. The analysis was considered based on (a) publications productivity, (b) crop varieties, (c) regions, and (d) keyword frequency. Twelve selected agricultural extension journals matched the data extraction criteria. From Precision Agriculture volumes 1 through 22, there were 31 articles whose titles met the keywords in four coded themes on the publication title. Two of the 31 articles met the selection criteria in two different coded themes. Figure 1 shows the preferred data selection item for systematic reviews.

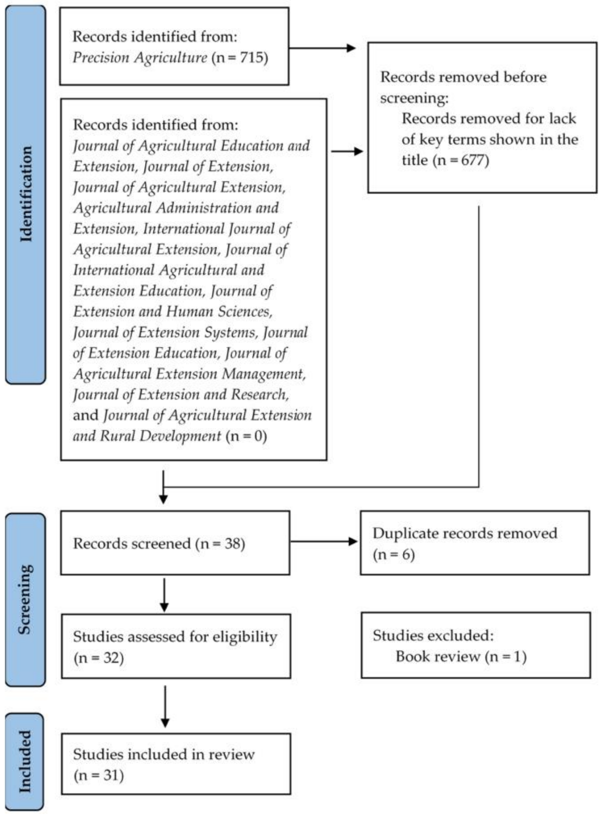


Figure 1. PRISMA flow diagram of data selection procedure.

3.1. Summary of Findings

Among the literature investigated (*n* = 33), improved profitability was the most published PA adoption theme. Twelve (*n* = 12, 36.4%) publications indicated improved profitably was the dominant characteristic to promote the adoption of precision agriculture as illustrated in Table 4. Improved proficiency use was the second theme (*n* = 10, 30%, production quality was the third ranking theme (*n* = 9, 27.3%), and the final PA adoption theme was environmental sustainability (*n* = 2, 6.1%). The overall mean and standard deviation for the four PA adoption themes were (*M* = 2.97, *SD* = 0.95) on the four-point anchored scale.

Table 4. Literature Analyzed Under the Coded Theme Improved Profitability.

Literature	Title	Crop	Country
Karatay and Meyer-Aurich [39]	Profitability and downside risk implications of site-specific nitrogen management with respect to wheat grain quality	wheat	Germany
Mills et al. [40]	The profitability of variable rate lime in wheat	wheat	USA
Stamatiadis et al. [41]	Variable-rate application of high spatial resolution can improve cotton N-use efficiency and profitability	cotton	Greece
Yost et al. [42]	A long-term precision agriculture system sustains grain profitability	corn; soybean	USA
Stefanini et al. [43] *	Effects of optical sensing based variable rate nitrogen management on yields, nitrogen use and profitability for cotton	cotton	USA
Tona et al. [44]	The profitability of precision spraying on specialty crops: a technical–economic analysis of protection equipment at increasing technological levels	grapevine; apple	Central-Southern Europe
Larson et al. [45]	Effect of field geometry on profitability of automatic section control for chemical application equipment	cotton	USA
Boyer et al. [46]	Profitability of variable rate nitrogen application in wheat production	wheat	USA
Maine et al. [47]	Impact of variable-rate application of nitrogen on yield and profit: a case study from South Africa	N/A	South Africa
O'Neal et al. [48]	Profitability of On-Farm Precipitation Data for Nitrogen Management Based on Crop Simulation	corn; soybean	USA
Young et al. [49]	Site-Specific Herbicide Decision Model to Maximize Profit in Winter Wheat	wheat; peas	USA
Reyns et al. [50]	Site-Specific Relationship Between Grain Quality and Yield	wheat	Belgium

* Duplicate record.

The theme of improving the efficiency of resource use was published the second most commonly, in 10 articles (*n* = 10, 30.3%) as presented in Table 5.

Table 5. Literature Analyzed Under the Coded Theme Improved the Efficiency of Resource Use.

Literature	Title	Crop	Country
Stamatiadis et al. [41] *	Variable-rate application of high spatial resolution can improve cotton N-use efficiency and profitability	cotton	Greece
Martinez et al. [51]	A cost-effective canopy temperature measurement system for precision agriculture: a case study on sugar beet	sugar beets	Spain
Pavuluri et al. [52]	Canopy spectral reflectance can predict grain nitrogen use efficiency in soft red winter wheat	wheat	USA
Ampatzidis et al. [53]	Portable weighing system for monitoring picker efficiency during manual harvest of sweet cherry	cherry tree	USA
Ortiz et al. [54]	Evaluation of agronomic and economic benefits of using RTK-GPS-based auto-steer guidance systems for peanut digging operations	peanut	USA
Go'mez-Cando'n et al. [55]	Sectioning remote imagery for characterization of Avena sterilis infestations. Part B: Efficiency and economics of control	wheat	Spain
Rascher and Pieruschka [56]	Spatio-temporal variations of photosynthesis: the potential of optical remote sensing to better understand and scale light use efficiency and stresses of plant ecosystems	soybean; avocado	USA
Torbett et al. [57]	Perceived importance of precision farming technologies in improving phosphorus and potassium efficiency in cotton production	cotton	USA
Biermacher et al. [58]	Maximum benefit of a precise nitrogen application system for wheat	wheat	USA
Krell and Pedigo [59]	Comparison of Estimated Costs and Benefits of Site-Specific Versus Uniform Management for the Bean Leaf Beetle in Soybean	soybean-corn rotation	USA

* Duplicate record.

Furthermore, nine (n = 9, 27.3%) articles have been published on production quality, which are exhibited in Table 6.

Table 6. Literature Analyzed Under the Production Quality Coded Theme.

Literature	Title	Crop	Country
Holland et al. [60]	Proximal fluorescence sensing of potassium responsive crops to develop improved predictions of biomass, yield and grain quality of wheat and barley	wheat; barley	Australia
Uribeetxebarria et al. [61]	Stratified sampling in fruit orchards using cluster-based ancillary information maps: a comparative analysis to improve yield and quality estimates	peach	Spain
Arno et al. [62]	Spatial variability in grape yield and quality influenced by soil and crop nutrition characteristics	grape	Spain
Aggelopulou et al. [63]	Spatial variation in yield and quality in a small apple orchard	apple	Greece
Link et al. [64]	Evaluation of current and model-based site-specific nitrogen applications on wheat (*Triticum aestivum* L.) yield and environmental quality	wheat	Germany
Jørgensen and Jørgensen [65]	Uniformity of wheat yield and quality using sensor assisted application of nitrogen	wheat	Denmark
Miao et al. [66]	Spatial variability of soil properties, corn quality and yield in two Illinois, USA fields: implications for precision corn management	corn	USA
Miao et al. [67]	Identifying important factors influencing corn yield and grain quality variability using artificial neural networks	corn	USA
Reyns et al. [50] *	Site-Specific Relationship Between Grain Quality and Yield	wheat	Belgium

* Duplicate record.

Environmental sustainability was the least published (n = 2, 6%) adoption construct from the systematic review analysis (see Table 7).

Table 7. Literature Analyzed Under the Coded Theme Environmental Sustainability.

Literature	Title	Crop	Country
Kountios et al. [68]	Educational needs and perceptions of the sustainability of precision agriculture: survey evidence from Greece	cotton; vegetable; cereal	Greece
Bongiovanni et al. [69]	Precision agriculture and sustainability	corn	Argentina

There were thirty-nine (n = 39) varieties of crops produced from the review. Wheat (n = 11, 28.2%) was the most PA produced crop, followed by corn (n = 6, 15.4%), cotton (n = 5, 13%), soybean (n = 4, 10.3%), grape and apple each earned n = 2, 5.1%, and sugar beets, cherry, vegetable, cereal, peach, peanut, avocado, barley, and peas n = 1, 2.6% were identical from the systematic review of the literature (see Figure 2).

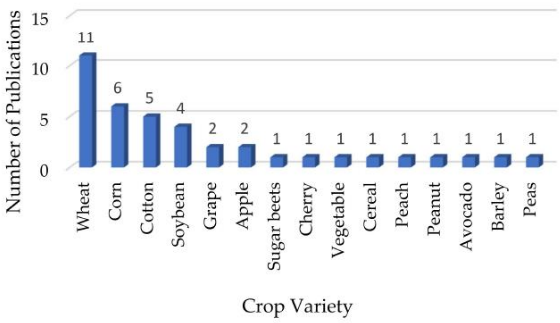


Figure 2. Distribution by crop variety.

The published inquiries occurred in developed regions. The majority of the thirty-one (n = 31) PA studies (n = 16, 51.6%) were conducted in the United States. The complete analysis of the number of published studies in respective regions were USA n = 16, 51.6%, Spain n = 4, 13%, Greece n = 3, 9.7%, Germany n = 2, 6.5%, Argentina n = 1, 3.2%, Australia n = 1, 3.2%, Belgium n = 1, 3.2%, Central-South Europe n = 1, 3.2%, Denmark n = 1, 3.2%, and South Africa n = 1, 3.2% (see Figure 3).

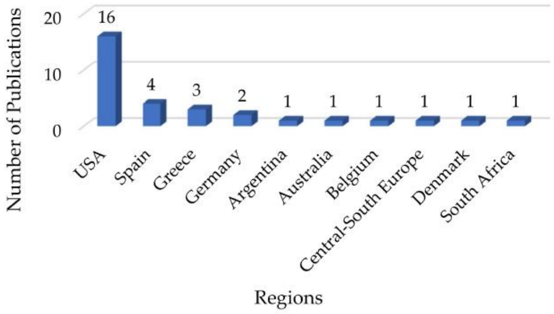


Figure 3. Distribution by Regions.

The VOSviewer tool was utilized to understand the variety of keywords used by researchers frequently in Precision Agriculture. The results indicated the number of publications in which 12 major keywords occurred together more than five times in the title, abstract, or keyword list, producing a total strength co-occurrence linkage of 110. The results indicated that the majority of publications had used these keywords, as depicted in Figure 4.

Figure 4. Number of publications keywords are presented.

VOSviewer revealed the connection of research keywords for PA. The size of nodes represented the frequency of keywords. The larger size of the node is the larger frequency count. As illustrated in Figure 5, the Agriculture node has the largest frequency of keywords and was double in size compared to the second ranked keywords. Profitability, crop, and agricultural economics also had higher frequencies. These three main clustered sections (green, red, and blue) are primarily the themes researchers found promoted PA adoption.

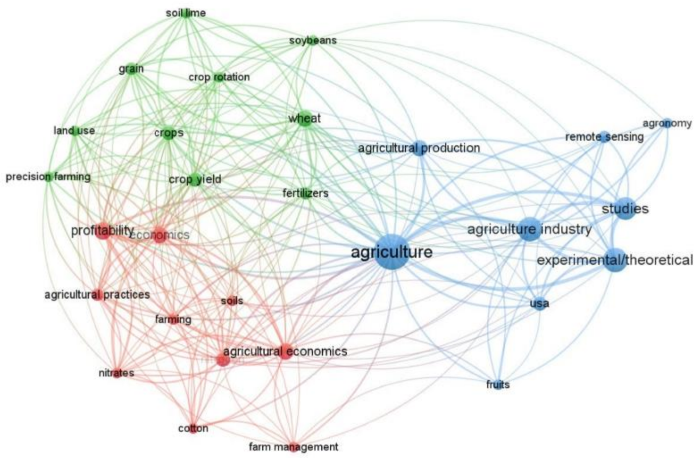


Figure 5. VOSviewer Analysis of Precision Agriculture (PA) Keyword Networks.

3.2. Findings of Innovation Attributes

Profitability and cost savings, yield and quality enhancement, and sustainability were three major benefits frequently discussed in the studies. Rogers' [31] five perceived attributes of innovation were employed to interpret the findings of technologies. Within each innovation attribute, several factors were the most prevalent in the investigated studies.

Relative advantage was illustrated, analyzed, inferred, and discussed in 29 of 31 publications. Out of 29 publications, 12 described the potential for PA adoption to reduce the amount of fertilizer usage and improve fertilizer efficiency. Stefanini et al. [43] utilized real-time on-the-go optical sensing measurements (OPM) to evaluate the profitability and nitrogen efficiency. Torbett et al.'s [57] model also indicated that precision farmers found that PA technologies were important for improving fertilizer efficiency. Out of 29 publications, 15 concluded that adoption of PA applications could maintain profitability while reducing resource usage in the conventional practice, thus improving yield and quality. Boyer et al. [46] implemented plant sensing to determine the amount of nitrogen to apply in the field and found that the technology had the potential to reduce nitrogen costs or increase grain yield and production profit. Additionally, Young et al. [49] applied a computerized site-specific herbicide decision model in the field and explained that a reduction on the herbicide dose could continue to increase profits.

Compatibility was frequently included in the examined publications. Fourteen of 31 studies indicated that researchers applied the technologies based upon what farmers used in the field. Studies by both Stefanini et al. [43] and Boyer et al. [46] designed research for variable-rate nitrogen management currently applied by farmers. Reyns et al. [50] employed previously developed sensors to obtain the grain yield data. Eight of 31 studies revealed that PA enhanced environmental protection by reducing fertilizer usage in which researchers applied the PA technologies based on what farmers had been using, and a match to the existing values that PA may lead to more sustainable cropping systems. Yost et al. [42] stated that even without profit gains, farmers should invest in PA to help environmental protection. Kountios et al. [68] concluded that farmers who had a better knowledge of PA would have a better acknowledgment of the environmental, economic, and social sustainability of PA.

There was one study explicitly addressing the complexity within 31 examined publications. Young et al. [49] stated that the computerized site-specific herbicide decision model was easy to use. In addition, Karatay and Meyer-Aurich [39] noted that their study needed to simplify complex production management to help with farmers' adoption of PA.

Trialability and observability were not explicitly addressed among studies, but 30 of 31 publications were conducted in on-farm trials or with computerized models. These results provided methods to replicate the PA application which would be considered as the attributes of trialability and observability. Figure 6 depicted the innovation attribute addressed among 31 examined studies.

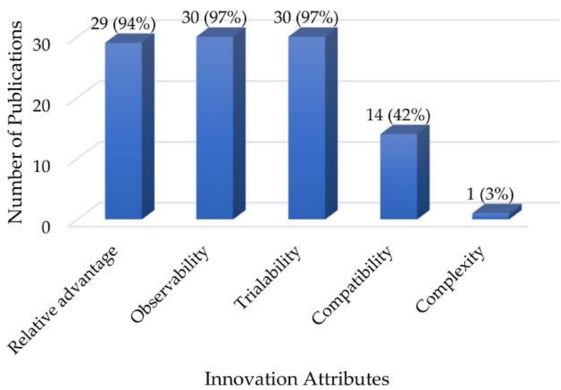


Figure 6. Descriptive Statistics of Innovation Attributes (n = 31).

4. Discussion

The data presented here inform international agricultural extension agents with evidence to promote the adoption of PA. Characteristics of PA as an innovation include profitability and efficiency of resource use, production quality, and environmental sustainability as attributes. Agricultural commodities produced from PA technology ranged from wheat to peas. The majority of PA inquiries were conducted in the United States over the last twenty years, which was consistent with the rate of adoption in the United States. PA application allows farmers to better select crop varieties and allocate needed resources to reduce costs and increase profit margins. This study indicated that PA was relatively adopted in grain crops, such as wheat and corn, and legume crops, such as soybean, those often grown to increase the food crop production to address food security.

Rogers' [31] five perceived attributes of innovation explained the factors most PA technologies commonly aligned to increase the adoption of PA. We concluded that relative advantage and compatibility were two major factors that researchers considered to promote their innovation. If something is perceived as better than the innovation proceeding and compatible with farmers current situation, the rate of adoption will increase.

In this study, there were more publications targeted on improving profitability to promote PA adoption. The results of the keyword frequency revealed that profitability and economics were highly cited by researchers in the publication. Profitability motivates producers to adopt PA because the innovation meets farmers economic needs also contributing a relative advantage.

Compatibility was another important reason that encouraged producers who adopt PA. The number of articles published with the "Improved the efficiency of resource use" theme was the second highest, which equates to Rogers' [31] compatibility that innovations align with the farmers' norm of belief and perspectives. Farmers' norms focus on producing crops in an efficient way, such as reducing the fertilizer usage amount, implementing more environmentally friendly production systems, or helping manual harvesting work, farmers are more likely to adopt for these reasons.

Co-occurrence analysis was implemented to obtain dominant keywords from PA adoption inquiries. Utilizing the VOSviewer tool, the researchers found clear themes on the diffusion trends. Our team identified three topic clusters of PA researchers, including profitability, crop, and agricultural economics, which demonstrate a research direction globally. The keyword frequency results denoted experimental and crop yield were highly cited in the publications that referred to Rogers' [31] trialability and observability attributes of the innovation. There were 30 of 31 articles analyzed in this study that described crop items in the experimental field which demonstrates the innovation to farmers. Improved profitability was the dominant theme that impacted sustainability of PA to improve farmers' income [70]. Producers could estimate and predict the yield and increase profit with PA applications.

The second dominant theme was improved efficiency of resource use related to farmers' concern about whether the PA technology was beneficial for producers to efficiently manage their manual labor and production materials [71,72]. Farmers who adopted PA were more efficient.

Theme three production quality indicated that farmers could use PA to improve the crop quality more precisely, such as by using the recommended amount of fertilizer based on the data, to have better market value on the production.

Technology's perceived complexity can be a factor slowing the rate of farmer adoption [31], and therefore, decreasing the odds of sustainability. None of the reviewed literature, except one inquiry, addressed the complexity of PA. This study revealed low PA complexity was the most poorly communicated adoption attribute, supporting Pathak et al.'s [24] finding that complexity is composed of multifarious exchanges. Through trialability and observability, it is imperative to demonstrate the ease of operation and cost of PA in comparison to increased efficiencies (cost–benefit analysis). However, if PA is perceived excessively complex or if complexity is unknown, farmers are likely to reject PA adoption [31]. So in essence, the attribute of complexity is about the adoption of technologies that are perceived as simple, or less complex. It is interesting that "ease of use" was not a prevalent theme.

5. Conclusions

With the continued increase in world population, limited capacity to expand the availability of natural resources (e.g., water and land), and a changing climate, there is a need to expand the adoption of precision agriculture approaches and tools. PA seeks to increase agricultural production without degrading natural resource quality and building resiliency of production systems to changing climate. Achieving these goals requires agricultural extensionists to promote innovative tools that quickly and reliably measure and monitor plant, soil, and atmospheric parameters in agricultural systems. As these tools and approaches are developed, it is important to train the current and future agricultural workforce, including educators, extension personnel, farmers, and ranchers with the advanced and necessary knowledge and skills in precision agriculture technologies. Using Rogers' attributes of an innovation as a theoretical lens to analyze research manuscripts, extension services can incorporate translation science to promote new practices.

This systematic literature review is exploratory and thus future research is needed to provide greater generalizability. As shown in Figure 2, our study found that wheat was the main crop variety of choice in promoting PA adoption, and PA adoption studies mainly were conducted in the United States. However, rice is one of the top production crops globally, yet none of the PA adoption literature focused on rice. China, India, and Indonesia are the three main rice-producing countries in the world and China is also one of the largest producers of wheat. However, PA adoption in China, India, and Indonesia were not present in the literature from the systematic review.

This study was conducted to understand PA adoption and the innovation's sustainability by farmers to support food production and increase food security. The agricultural extension system plays an important role in the diffusion process of agricultural innovation. The agricultural extension transfer process promotes education and training for farmers to assist in the adoption of PA innovations to advance agricultural development and provide sustainable solutions to agricultural issues [73]. However, zero literature matched the data extraction criteria from 12 agricultural extension journals, revealing that there was a chasm in the literature regarding agricultural extension agents, officers, or specialists' promotion of PA adoption. This finding is important due to the unknown of *who* is professionally developing agricultural extension field staff to promote PA adoption to target audiences. In addition to the who is the how. The data from this study's extension journal searches were void of *how* extension agents are trained to improve farmer PA adoption and assessing the adoption's impact. This speaks volumes if global agricultural extension field staff are expected to serve as change agents who promote and assess farmer PA adoption to improve local food security. Beyond the *who* and the *how*, is the first, and more appropriate question: are extension agents being professionally developed in the paradigm of farmer PA adoption? If not, sustainable PA adoption may never occur. The vast majority of PA adoption studies occurred in the U.S., but none of the studies indicated an extension agent knowledge transfer process. In addition to farmers, agricultural extension agents need education and training in PA adoption too.

The results of this study indicated previous inquiries did not fully examine the five attributes to predict PA adoption. It is likely these researchers are content experts and not familiar with change strategies, adoption and diffusion theory, or even translation science. In particular, our inquiry found researchers exercised relative advantage [24] and compatibility [27] as two dominant attributes to strengthen the adoption of PA. Improved profitability and efficiency were the driving factors of adoption uncovered in the systematic review juxtaposed to Pathak et al.'s findings [24]. This study provides a benchmark for partnerships with global extension services to promote adoption (when and if these systems are cultural appropriate). PA efficiencies can only impact stakeholders if the evidence from research is translated to the end users. International extension agents can act as translational scientists to increase communication channels for PA adoption primarily in trialability and observability. As a part of farmer field schools or extension workshops, the issue of "complexity" can be addressed by demonstrating and teaching farmers the ease of use of these technologies.

Author Contributions: Conceptualization, C.-L.L.; methodology, C.-L.L. and R.S.; literature review, C.-L.L.; discussions and conclusions development, C.-L.L.; formal analysis, C.-L.L.; data curation, C.-L.L.; writing—original draft preparation, C.-L.L.; writing—review and editing, R.S. and K.E.D. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: No new data were created or analyzed in this study. Data sharing is not applicable to this article.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Thompson, R.J.; Storberg-Walker, J. *Leadership and Power in International Development: Navigating the Intersections of Gender, Culture, Context, and Sustainability*; Emerald Publishing Limited: Bingley, UK, 2018; p. 368. ISBN 978-1-7874-3999-3.
2. Godfray, H.C.J.; Beddington, J.R.; Crute, I.R.; Haddad, L.; Lawrence, D.; Muir, J.F.; Pretty, J.; Robinson, S.; Thomas, S.M.; Toulmin, C. Food Security: The Challenge of Feeding 9 Billion People. *Science* **2010**, *327*, 812–818. [CrossRef] [PubMed]

3. Basso, B.; Dobrowolski, J.; McKay, C. From the Dust Bowl to Drones to Big Data: The Next Revolution in Agriculture. *Georget. J. Int. Aff.* **2017**, *18*, 158–165. [CrossRef]
4. Gallardo, R.K.; Sauer, J. Adoption of Labor-Saving Technologies in Agriculture. *Annu. Rev. Resour. Econ.* **2018**, *10*, 185–206. [CrossRef]
5. Zambon, I.; Cecchini, M.; Egidi, G.; Saporito, M.G.; Colantoni, A. Revolution 4.0: Industry vs. Agriculture in a Future Development for SMEs. *Processes* **2019**, *7*, 36. [CrossRef]
6. Wolde, Z.; Wei, W.; Kunpeng, W.; Ketema, H.; Wang, K. Local community perceptions toward livelihood and water–energy–food nexus: A perspective on food security. *Food Energy Secur.* **2020**, *9*, 1–15. [CrossRef]
7. Afzal, A.; Al-Subaiee, F.S.; Mirza, A.A. The Attitudes of Agricultural Extension Workers towards the Use of E-Extension for Ensuring Sustainability in the Kingdom of Saudi Arabia. *Sustainability* **2016**, *8*, 980. [CrossRef]
8. Arnés, E.; Díaz-Ambrona, C.G.H.; Marín-González, O.; Astier, M. Farmer Field Schools (FFSs): A tool for empowering sustainability and food security in peasant farming systems in the Nicaraguan Highlands. *Sustainability* **2018**, *10*, 3020. [CrossRef]
9. Materia, V.C.; Giarè, F.; Klerkx, L. Increasing Knowledge Flows between the Agricultural Research and Advisory System in Italy: Combining Virtual and Non-virtual Interaction in Communities of Practice. *J. Agric. Educ. Ext.* **2014**, *21*, 203–218. [CrossRef]
10. Jellason, N.P.; Conway, J.S.; Baines, R.N. Understanding impacts and barriers to adoption of climate-smart agriculture (CSA) practices in North-Western Nigerian drylands. *J. Agric. Educ. Ext.* **2021**, *27*, 55–72. [CrossRef]
11. Dunne, A.; Markey, A.; Kinsella, J. Examining the reach of public and private agricultural advisory services and farmers' perceptions of their quality: The case of county Laois in Ireland. *J. Agric. Educ. Ext.* **2019**, *25*, 401–414. [CrossRef]
12. Mourhir, A.; Papageorgiou, E.I.; Kokkinos, K.; Rachidi, T. Exploring Precision Farming Scenarios Using Fuzzy Cognitive Maps. *Sustainability* **2017**, *9*, 1241. [CrossRef]
13. Onyango, C.; Nyaga, J.; Wetterlind, J.; Söderström, M.; Piikki, K. Precision Agriculture for Resource Use Efficiency in Smallholder Farming Systems in Sub-Saharan Africa: A Systematic Review. *Sustainability* **2021**, *13*, 1158. [CrossRef]
14. Paustian, M.; Theuvsen, L. Adoption of precision agriculture technologies by German crop farmers. *Precis. Agric.* **2017**, *18*, 701–716. [CrossRef]
15. Balafoutis, A.; Beck, B.; Fountas, S.; Vangeyte, J.; Van Der Wal, T.; Soto, I.; Gómez-Barbero, M.; Barnes, A.; Eory, V. Precision Agriculture Technologies Positively Contributing to GHG Emissions Mitigation, Farm Productivity and Economics. *Sustainability* **2017**, *9*, 1339. [CrossRef]
16. Loures, L.; Chamizo, A.; Ferreira, P.; Loures, A.; Castanho, R.; Panagopoulos, T. Assessing the Effectiveness of Precision Agriculture Management Systems in Mediterranean Small Farms. *Sustainability* **2020**, *12*, 3765. [CrossRef]
17. Ullah, A.; Nawaz, A.; Farooq, M.; Siddique, K. Agricultural Innovation and Sustainable Development: A Case Study of Rice–Wheat Cropping Systems in South Asia. *Sustainability* **2021**, *13*, 1965. [CrossRef]
18. Yue, Y.; Zhou, Y.; Wang, J.; Ye, X. Assessing wheat frost risk with the support of GIS: An approach coupling and growing season meterological index and a hybrid fuzzy neutral network model. *Sustainability* **2016**, *8*, 1308. [CrossRef]
19. International Society of Precision Agriculture. *Precision ag Definition: International Society of Precision Agriculture*; International Society of Precision Agriculture: Monticello, IL, USA, 2019; Available online: https://www.ispag.org/about/definition (accessed on 13 July 2021).
20. Bosompem, M. Potential challenges to precision agriculture technologies development in Ghana: Scientists' and cocoa extension agents' perspectives. *Precis. Agric.* **2021**, *22*, 1578–1600. [CrossRef]
21. Bramley, R.G.V. Lessons from nearly 20 years of Precision Agriculture research, development, and adoption as a guide to its appropriate application. *Crop Pasture Sci.* **2009**, *60*, 197–217. [CrossRef]
22. Fountas, S.; Pedersen, S.M.; Blackmore, S. *ICT in Precision Agriculture—Diffusion of Technology an Overview of Precision Agriculture. ICT in Agriculture: Perspective of Technological Innovation*; Gelb, E., Offer, A., Eds.; ResearchGate: Berlin, Germany, 2004. [CrossRef]
23. Schimmelpfennig, D.; Ebel, R. Sequential Adoption and Cost Savings from Precision Agriculture. *J. Agric. Resour. Econ.* **2016**, *41*, 97–115. Available online: http://www.jstor.org/stable/44131378 (accessed on 22 April 2021).
24. Pathak, H.S.; Brown, P.; Best, T. A systematic literature review of the factors affecting the precision agriculture adoption process. *Precis. Agric.* **2019**, *20*, 1292–1316. [CrossRef]
25. Kernecker, M.; Knierim, A.; Wurbs, A.; Kraus, T.; Borges, F. Experience versus expectation: Farmers' perceptions of smart farming technologies for cropping systems across Europe. *Precis. Agric.* **2020**, *21*, 34–50. [CrossRef]
26. Lowenberg-DeBoer, J.; Erickson, B. Setting the Record Straight on Precision Agriculture Adoption. *Agron. J.* **2019**, *111*, 1552–1569. [CrossRef]
27. Robertson, M.J.; Llewellyn, R.; Mandel, R.; Lawes, R.; Bramley, R.; Swift, L.; Metz, N.; O'Callaghan, C. Adoption of variable rate fertiliser application in the Australian grains industry: Status, issues and prospects. *Precis. Agric.* **2012**, *13*, 181–199. [CrossRef]
28. Sarri, D.; Lombardo, S.; Pagliai, A.; Perna, C.; Lisci, R.; De Pascale, V.; Rimediotti, M.; Cencini, G.; Vieri, M. Smart Farming Introduction in Wine Farms: A Systematic Review and a New Proposal. *Sustainability* **2020**, *12*, 7191. [CrossRef]
29. Cosby, A.M.; Falzon, G.A.; Trotter, M.G.; Stanley, J.N.; Powell, K.S.; Lamb, D.W. Risk mapping of redheaded cockchafer (Adoryphorus couloni) (Burmeister) infestations using a combination of novel k-means clustering and on-the-go plant and soil sensing technologies. *Precis. Agric.* **2016**, *17*, 1–17. [CrossRef]
30. Rogovska, N.; Laird, D.A.; Chiou, C.-P.; Bond, L.J. Development of field mobile soil nitrate sensor technology to facilitate precision fertilizer management. *Precis. Agric.* **2019**, *20*, 40–55. [CrossRef]

31. Rogers, E.M. *Diffusion of Innovations*, 5th ed.; Free Press: New York, NY, USA, 2003; p. 551. ISBN 978-0-7432-2209-9.
32. Luck, J.; Fulton, J.; Rees, J. Hands-On Precision Agriculture Data Management Workshops for Producers and Industry Professionals: Development and Assessment. 2015, Volume 53. Available online: https://archives.joe.org/joe/2015august/tt10.php (accessed on 26 April 2021).
33. Asseng, S.; Asche, F. Future farms without farmers. *Sci. Robot.* **2019**, *4*, eaaw1875. [CrossRef]
34. Saiz-Rubio, V.; Rovira-Más, F. From Smart Farming towards Agriculture 5.0: A Review on Crop Data Management. *Agronomy* **2020**, *10*, 207. [CrossRef]
35. Vindrola-Padros, C.; Brage, E.; Johnson, G.A. Rapid, Responsive, and Relevant? A Systematic Review of Rapid Evaluations in Health Care. *Am. J. Eval.* **2021**, *42*, 13–27. [CrossRef]
36. Wright, R.W.; A Brand, R.; Dunn, W.; Spindler, K.P. How to Write a Systematic Review. *Clin. Orthop. Relat. Res.* **2007**, *455*, 23–29. [CrossRef]
37. Ravikumar, S.; Agrahari, A.; Singh, S.N. Mapping the intellectual structure of scientometrics: A co-word analysis of the journal Scientometrics (2005–2010). *Scientometrics* **2015**, *102*, 929–955. [CrossRef]
38. Chen, X.; Chen, J.; Wu, D.; Xie, Y.; Li, J. Mapping the Research Trends by Co-word Analysis Based on Keywords from Funded Project. *Procedia Comput. Sci.* **2016**, *91*, 547–555. [CrossRef]
39. Karatay, Y.N.; Meyer-Aurich, A. Profitability and downside risk implications of site-specific nitrogen management with respect to wheat grain quality. *Precis. Agric.* **2020**, *21*, 449–472. [CrossRef]
40. Mills, B.E.; Brorsen, W.; Arnall, D.B. The profitability of variable rate lime in wheat. *Precis. Agric.* **2020**, *21*, 369–386. [CrossRef]
41. Stamatiadis, S.; Schepers, J.S.; Evangelou, E.; Glampedakis, A.; Dercas, N.; Tsadilas, C.; Tserlikakis, N.; Tsadila, E. Variable-rate application of high spatial resolution can improve cotton N-use efficiency and profitability. *Precis. Agric.* **2020**, *21*, 695–712. [CrossRef]
42. Yost, M.A.; Kitchen, N.R.; Sudduth, K.A.; Massey, R.E.; Sadler, E.J.; Drummond, S.T.; Volkmann, M.R. A long-term precision agriculture system sustains grain profitability. *Precis. Agric.* **2019**, *20*, 1177–1198. [CrossRef]
43. Stefanini, M.; Larson, J.A.; Lambert, D.M.; Yin, X.; Boyer, C.N.; Scharf, P.; Tubaña, B.S.; Varco, J.J.; Dunn, D.; Savoy, H.J.; et al. Effects of optical sensing based variable rate nitrogen management on yields, nitrogen use and profitability for cotton. *Precis. Agric.* **2019**, *20*, 591–610. [CrossRef]
44. Tona, E.; Calcante, A.; Oberti, R. The profitability of precision spraying on specialty crops: A technical–economic analysis of protection equipment at increasing technological levels. *Precis. Agric.* **2018**, *19*, 606–629. [CrossRef]
45. Larson, J.A.; Velandia, M.M.; Buschermohle, M.J.; Westlund, S.M. Effect of field geometry on profitability of automatic section control for chemical application equipment. *Precis. Agric.* **2016**, *17*, 18–35. [CrossRef]
46. Boyer, C.N.; Brorsen, B.W.; Solie, J.B.; Raun, W. Profitability of variable rate nitrogen application in wheat production. *Precis. Agric.* **2011**, *12*, 473–487. [CrossRef]
47. Maine, N.; Lowenberg-DeBoer, J.; Nell, W.T.; Alemu, Z.G. Impact of variable-rate application of nitrogen on yield and profit: A case study from South Africa. *Precis. Agric.* **2010**, *11*, 448–463. [CrossRef]
48. O'Neal, M.; Frankenberger, J.R.; Ess, D.R.; Lowenberg-DeBoer, J. Profitability of On-Farm Precipitation Data for Nitrogen Management Based on Crop Simulation. *Precis. Agric.* **2004**, *5*, 153–178. [CrossRef]
49. Young, D.L.; Kwon, T.J.; Smith, E.G.; Young, F.L. Site-Specific Herbicide Decision Model to Maximize Profit in Winter Wheat. *Precis. Agric.* **2003**, *4*, 227–238. [CrossRef]
50. Reyns, P.; Spaepen, P.; De Baerdemaeker, J. Site-Specific Relationship Between Grain Quality and Yield. *Precis. Agric.* **2000**, *2*, 231–246. [CrossRef]
51. Martínez, J.; Egea, G.; Agüera, J.; Pérez-Ruiz, M. A cost-effective canopy temperature measurement system for precision agriculture: A case study on sugar beet. *Precis. Agric.* **2017**, *18*, 95–110. [CrossRef]
52. Pavuluri, K.; Chim, B.K.; Griffey, C.A.; Reiter, M.S.; Balota, M.; Thomason, W.E. Canopy spectral reflectance can predict grain nitrogen use efficiency in soft red winter wheat. *Precis. Agric.* **2015**, *16*, 405–424. [CrossRef]
53. Ampatzidis, Y.G.; Whiting, M.D.; Liu, B.; Scharf, P.A.; Pierce, F.J. Portable weighing system for monitoring picker efficiency during manual harvest of sweet cherry. *Precis. Agric.* **2013**, *14*, 162–171. [CrossRef]
54. Ortiz, B.V.; Balkcom, K.B.; Duzy, L.; Van Santen, E.; Hartzog, D.L. Evaluation of agronomic and economic benefits of using RTK-GPS-based auto-steer guidance systems for peanut digging operations. *Precis. Agric.* **2013**, *14*, 357–375. [CrossRef]
55. Gómez-candón, D.; López-granados, F.; Caballero-novella, J.J.; García-ferrer, A.; Peña-barragán, J.M.; Jurado-expósito, M.; García-torres, L. Sectioning remote imagery for characterization of Avena sterilis infestations. Part B: Efficiency and economics of control. *Precis. Agric.* **2012**, *13*, 337–350. [CrossRef]
56. Rascher, U.; Pieruschka, R. Spatio-temporal variations of photosynthesis: The potential of optical remote sensing to better understand and scale light use efficiency and stresses of plant ecosystems. *Precis. Agric.* **2008**, *9*, 355–366. [CrossRef]
57. Torbett, J.C.; Roberts, R.K.; Larson, J.A.; English, B.C. Perceived importance of precision farming technologies in improving phosphorus and potassium efficiency in cotton production. *Precis. Agric.* **2007**, *8*, 127–137. [CrossRef]
58. Biermacher, J.T.; Epplin, F.M.; Brorsen, B.W.; Solie, J.B.; Raun, W.R. Maximum benefit of a precise nitrogen application system for wheat. *Precis. Agric.* **2006**, *7*, 193–204. [CrossRef]
59. Krell, R.K.; Pedigo, L.P.; Babcock, B.A. Comparison of Estimated Costs and Benefits of Site-Specific Versus Uniform Management for the Bean Leaf Beetle in Soybean. *Precis. Agric.* **2003**, *4*, 401–411. [CrossRef]

60. Holland, J.E.; Cammarano, D.; Fitzgerald, G.J.; Perry, E.M.; Poile, G.; Conyers, M.K. Proximal fluorescence sensing of potassium responsive crops to develop improved predictions of biomass, yield and grain quality of wheat and barley. *Precis. Agric.* **2019**, *20*, 379–397. [CrossRef]
61. Uribeetxebarria, A.; Martínez-Casasnovas, J.A.; Escolà, A.; Rosell-Polo, J.R.; Arnó, J. Stratified sampling in fruit orchards using cluster-based ancillary information maps: A comparative analysis to improve yield and quality estimates. *Precis. Agric.* **2019**, *20*, 179–192. [CrossRef]
62. Arnó, J.; Rosell, J.R.; Blanco, R.; Ramos, M.C.; Martínez-Casasnovas, J.A. Spatial variability in grape yield and quality influenced by soil and crop nutrition characteristics. *Precis. Agric.* **2012**, *13*, 393–410. [CrossRef]
63. Aggelopoulou, K.D.; Wulfsohn, D.; Fountas, S.; Gemtos, T.A.; Nanos, G.D.; Blackmore, S. Spatial variation in yield and quality in a small apple orchard. *Precis. Agric.* **2010**, *11*, 538–556. [CrossRef]
64. Link, J.; Batchelor, W.D.; Graeff, S.; Claupein, W. Evaluation of current and model-based site-specific nitrogen applications on wheat (Triticum aestivum L.) yield and environmental quality. *Precis. Agric.* **2008**, *9*, 251–267. [CrossRef]
65. Jørgensen, J.R.; Jørgensen, R.N. Uniformity of wheat yield and quality using sensor assisted application of nitrogen. *Precis. Agric.* **2007**, *8*, 63–73. [CrossRef]
66. Miao, Y.; Mulla, D.J.; Robert, P.C. Spatial Variability of Soil Properties, Corn Quality and Yield in Two Illinois, USA Fields: Implications for Precision Corn Management. *Precis. Agric.* **2006**, *7*, 5–20. [CrossRef]
67. Miao, Y.; Mulla, D.J.; Robert, P.C. Identifying important factors influencing corn yield and grain quality variability using artificial neural networks. *Precis. Agric.* **2006**, *7*, 117–135. [CrossRef]
68. Kountios, G.; Ragkos, A.; Bournaris, T.; Papadavid, G.; Michailidis, A. Educational needs and perceptions of the sustainability of precision agriculture: Survey evidence from Greece. *Precis. Agric.* **2018**, *19*, 537–554. [CrossRef]
69. Bongiovanni, R.; Lowenberg-Deboer, J. Precision Agriculture and Sustainability. *Precis. Agric.* **2004**, *5*, 359–387. [CrossRef]
70. Lin, P.; Lee, W.S.; Chen, Y.M.; Peres, N.; Fraisse, C. A deep-level region-based visual representation architecture for detecting strawberry flowers in an outdoor field. *Precis. Agric.* **2020**, *21*, 387–402. [CrossRef]
71. Jensen, H.G.; Jacobsen, L.-B.; Pedersen, S.M.; Tavella, E. Socioeconomic impact of widespread adoption of precision farming and controlled traffic systems in Denmark. *Precis. Agric.* **2012**, *13*, 661–677. [CrossRef]
72. Silva, C.B.; De Moraes, M.A.F.D.; Molin, J.P. Adoption and use of precision agriculture technologies in the sugarcane industry of São Paulo state, Brazil. *Precis. Agric.* **2011**, *12*, 67–81. [CrossRef]
73. Altalb, A.A.T.; Filipek, T.; Skowron, P. The role of agricultural extension in the transfer and adoption of agricultural technologies. *Asian J. Agric. Food Sci.* **2015**, *3*, 500–507. Available online: https://ajouronline.com/index.php/AJAFS/article/view/2962 (accessed on 26 April 2021).

附錄二

The Neglect of Marginalized Farmers in the Innovation-Decision Process: Precision Agriculture Adoption Attributes for Smallholder Farmers

Presentation · April 2022
DOI: 10.13140/RG.2.2.28599.39849

2 authors:

Chin-Ling Lee
Texas A&M University

Robert Strong
Texas A&M University

The Neglect of Marginalized Farmers in the Innovation-Decision Process: Precision Agriculture Adoption Attributes for Smallholder Farmers

Chin-Ling Lee
Texas A&M University
600 John Kimbrough Blvd
College Station, TX 77843-2116
cllee1261@tamu.edu

Robert Strong Jr.
Texas A&M University

Keywords: Extension, information accessibility, production efficiency, production cost reduction

Introduction and Theoretical Framework

Precision agriculture (PA) adoption is a solution to food security (Mourhir et al., 2017). PA is a management strategy that enables farmers to use spatial and temporal data to improve production efficiency and quality, sustainability of agricultural practice, and cost minimization (Paustian & Theuvsen, 2017). However, some PA technologies were adopted fast, while others have lagged (Lowenberg-DeBoer & Erickson, 2019). PA adoption in marginalized smallholders is an important issue for global poverty reduction. The majority of the global small farms, if defined by land size, are in Asia and Africa (Lowder et al., 2014). They are the largest category of employment and small business group among the poor (Gatzweiler & Von Braun, 2016). However, poor people are willing to use and accept technologies that bring well-being (Rahman et al., 2017).

The lack of information is a barrier to adoption, and potential adopters can communicate with each other (Rogers, 2003, Strong, 2012; Wynn et al., 2013). The agricultural extension system plays an important role in providing PA information to producers. Kanter et al. (2019) reported adoption in smallholder farmer of PA technologies are due to the lack of extension services and information dissemination. Lee et al. (2021) found the absence of professional development for extension officers understanding of promoting PA adoption with farmers.

Purpose and Objectives

The purpose of this study was to understand PA adoption strategies to assist agricultural extension systems develop strategies to improve PA smallholder farmer adoption. Specifically, the objectives were:

1. Identify the strategies for PA adoption by smallholder farmers.
2. Provide future research directions for agricultural extension systems to better provide strategies for PA adoption by smallholder farmers.

Methodology

This study implemented a case study methodology to focus on a contemporary phenomenon in real life, in which boundaries between phenomenon and context are not clear (Yin 2009). This study analyzed the global search trends by using Google Trends with the search terms precision agriculture, smart agriculture, precision farming, smart farming, and climate-smart agriculture, and found that in the past 10 years, the search hotspots are in Asia and Africa, which are also the regions with the highest number of smallholder farmers in the world. Therefore, two studies, Xie et al. (2021), a seven-year study of smallholder farmers accessing and sharing the benefits of digital farming in China; and, Onyango et al. (2019), a study of PA practices to improve smallholder farmers' productivity using systematic reviews in Sub-Saharan Africa (SSA), are used as case studies in this study. To better depict the impact of PA on smallholder farmers globally, this study also incorporated Rotz et al.'s (2019) study on how to transform agricultural technologies in a way that supports the marginalized farmers in North America. Three studies found to be helpful in addressing question concerning the impact of PA on smallholders that requires more in-depth scholarly attention.

Result and Conclusions

A lack of literature exists respective to marginalized smallholder farmer adoption of PA. There were three main categories of PA strategies used by smallholder farmers in both developed and developing countries gathered from the case study.

PA information accessibility
In developing countries, smallholder farmers received PA information indirectly. Formal and informal educational channels should be recognized and communicated to smallholder farmers to improve PA adoption (Kendall et al., 2021). Onyango et al. (2019) found there had been limited information on the use of PA offered to smallholder farmers in SSA. Besides, the government's recommendation on technologies does not recognize that there are differences between farms or regions. Xie et al. (2021) identified that PA information was not directly perceived by smallholder farmers; instead, they realized the use of PA by the outsourcing service. On the opposite, in the developed country like Canada, Rotz et al. (2019) indicated that smallholders could get PA information through the internet or PA providers directly. However, the problems smallholder farmers face was the increasingly economically oppressed by agri-tech companies, agri-food, and retail giants in the food system. This oppression may be exacerbated with the rise of agricultural data sharing.

Production efficiency
Xie et al. (2021) indicated that smallholder farmers could be involved in an organization (e.g., cooperatives) to increase their land operation efficiency in China. Onyango et al. (2019) summarized that smallholder farmers increased productivity by exploring local means and resources available to them in SSA. Establishing a local farmer organization seems to be a more practical solution for smallholder farmers in developing countries (Xie et al., 2021). In developed countries, the situation is just the opposite. Rotz et al. (2019) reported that many farmers sought to build and design equipment and sensor systems themselves through technologies because smallholder farmers would be able to control the end-product to reach the quality they preferred.

Production cost reduction
PA applications were targeted to lower production costs mainly on resources input (e.g., fertilizers) without considering labor costs in the developing countries. In contrast, PA technologies targeted overall costs included labor costs mainly in the developed country. Rotz et al. (2019) reported rising land costs had forced smallholder farmers to adopt technologies to reduce labor costs, especially displacing migrant laborers. PA smallholder farmers use of fertilizer applications was examined with Nigerian farmers (Jellason et al., 2021).

Recommendations and Educational Importance

More global agricultural extension inquiries are needed to better understand smallholder farmer adoption of innovations to ensure they are not neglected in the innovation-decision process (Rogers, 2003). International agricultural extension practitioners should consider information accessibility, production efficiency, and production cost reduction adoption characteristics of smallholder farmers when developing PA technology promotion policies. Findings provide clarity that extension practitioners should be aware that there are various strategies can be used to deliver PA adoption to smallholder farmers, especially in the smallholder farmers of different context. Smallholder farmers are willing to adopt PA (Rahman et al., 2017), but need to acquire adequate information. To increase global food security under the multiplicity of changing climate and market variability requires the adoption of proven PA technologies to meet these extraordinary challenges (Olsovsky et al., 2021).

References

Rahman, S. A., Taghizadeh, S. K., Ramayah, T., & Alam, M. M. D. (2017). Technology acceptance among micro-entrepreneurs in marginalized social strata: The case of social innovation in Bangladesh. *Technological Forecasting and Social Change*, *118*, 236–245. https://doi.org/10.1016/j.techfore.2017.01.027

Rogers, E. M. (2003). *Diffusion of innovations* (5th ed.). Free Press.

Rotz, S., Gravely, E., Mosby, I., Duncan, E., Finnis, E., Horgan, M., LeBlanc, J., Martin, R., Neufeld, H. T., Nixon, A., Pant, L., Shalla, V., & Fraser, E. (2019). Automated pastures and the digital divide: How agricultural technologies are shaping labour and rural communities. *Journal of Rural Studies*, *68*, 112–122. https://doi.org/10.1016/j.jrurstud.2019.01.023

Strong, R. (2012). Improving loan distribution to farmers: Informational needs of Mexican banks. *Journal of International Agricultural and Extension Education, 19*(3), 1–13. https://doi.org/10.5191/jiaee.2012.19306

Wynn, J. T., Coppedge, R. H., & Strong, R. (2013). Future IPM trends in Trinidad and Tobago: A qualitative study of farmers' perspectives. *Journal of International Agricultural and Extension Education, 20*(2), 65–76. https://doi.org/10.5191/jiaee.2013.20205

Xie, L., Luo, B., & Zhong, W. (2021). How are smallholder farmers involved in digital agriculture in developing countries: A case study from China. *Land*, *10*(3), 1–16. https://doi.org/10.3390/land10030245

Yin, R. K. (2009). *Case study research: Design and methods* (4th ed.) Sage.

附錄三

foods

MDPI

Article

A Correlational Study of Two U.S. State Extension Professionals' Behavioral Intentions to Improve Sustainable Food Chains through Precision Farming Practices

Chin-Ling Lee [1], Robert Strong [2,*], Gary Briers [2], Theresa Murphrey [2], Nithya Rajan [3] and Shelli Rampold [4]

[1] Taoyuan District Agricultural Research and Extension Station, Council of Agriculture, Taoyuan 32745, Taiwan; chinling@tydais.gov.tw
[2] Department of Agricultural Leadership, Education, and Communications, Texas A&M University, College Station, TX 77843, USA; g-briers@tamu.edu (G.B.); t-murphrey@tamu.edu (T.M.)
[3] Department of Soil and Crop Sciences, Texas A&M University, College Station, TX 77843, USA; nrajan@tamu.edu
[4] Department of Agricultural Leadership, Education, and Communications, The University of Tennessee, Knoxville, TN 37996, USA; srampold@utk.edu
* Correspondence: r-strong@tamu.edu

Abstract: Precision farming provides one of the most important solutions for managing agricultural production to advance global food security. Extending professionals' competencies to promote precision farming practices can increase the adoption rate, ultimately impacting food security. Many studies have addressed barriers to the adoption of precision farming technologies from the farmers' perspective. However, few are available data on the perspectives of extension professionals. Agricultural extension professionals play an important role in innovative agricultural technology adoption. Thus, this study applied four constructs from the unified theory of acceptance and use of technology (UTAUT) model to investigate behavioral intentions to promote precision farming among extension professionals from two extension systems. In total, 102 (N = 102) agricultural extension professionals were surveyed. The results indicated that performance expectancy and social influence were individually significant predictors of extension professional behavioral intentions to promote precision farming technologies. There were no significant differences between the professionals of two extension systems. Gender, age, and years of service did not affect extension professionals' intention to promote precision agriculture technologies. The data suggested the need for training programs to develop advanced competencies to promote agricultural innovation. This study contributes to the future professional development programs for extension professionals on communicating innovations to address food security and sustainability issues.

Keywords: innovative agricultural practices; UTAUT model; performance expectancy; social influence; professional development programs; change agents

Citation: Lee, C.-L.; Strong, R.; Briers, G.; Murphrey, T.; Rajan, N.; Rampold, S. A Correlational Study of Two U.S. State Extension Professionals' Behavioral Intentions to Improve Sustainable Food Chains through Precision Farming Practices. *Foods* **2023**, *12*, 2208. https://doi.org/10.3390/foods12112208

Academic Editor: Maria Lisa Clodoveo

Received: 8 May 2023
Revised: 24 May 2023
Accepted: 29 May 2023
Published: 31 May 2023

1. Introduction

Food security is an important issue worldwide. According to [1], the FAO anticipated the depreciation of food security by 2030. As the global population grows toward 9.6 billion by 2050 [2], many solutions have been proposed to meet future food needs while maintaining the environment [3]. Many challenges, such as extreme climates, threaten food security [4] and require global scientific innovation focusing on sustainable agricultural practices that support healthy agricultural dietary solutions [5]. Food experts indicated that while there is no single solution to food security, technology can play an important role in global food security and in maintaining agricultural sustainability [6]. Currently, agriculture has further opportunities to apply more intelligent tools because of the widespread use of digital technologies in various fields [7]. The advances in information and communication technologies have enabled farmers to access a large amount of site-specific data for their farms, which provide farmers with the opportunity to apply precision-farming approaches to make more accurate decisions to reduce unnecessary inputs and achieve production quantity and quality [8,9]. Thus, precision-farming technologies have received increased attention in providing solutions for food production to feed a growing global population [10–13].

Precision agriculture is the application of information technology to manage agricultural production to better advance global food security [11]. In addition, adopting precision agriculture technologies is necessary to adjust to [14] extreme climates that can bring new pests and diseases [15]. However, studies have noted that precision farming technologies require a variety of knowledge and skills among farmers and that the application of these technologies on farms may change farmers' approach to farm management from an experience-driven to a data-driven practice [16,17].

Extension professionals serve as agricultural change agents that represent an organization in local communities by interfacing with community leaders and stakeholders [18]. The extent farmers observe members of their social system using precision-faming applications influences the cultural structure (change agents and opinion leaders of farmers [19]. Farmer are more willing to use an innovation that is promoted by an opinion leader in their social system versus one that is not. However, the difficulties in accessing the technology and extension service create barriers to adopting agricultural technology [20]. The adoption of precision farming technologies depends much on the extension's dissemination of each innovation's advantages [21]. Agricultural extension change agents are a factor that influences the decision-making process of farmers to adopt or reject innovations [22]. Lee et al. [23] found that extension professionals in the extension system lacked professional development in promoting the adoption of precision farming technologies by farmers. Lack of information dissemination and extension service will result in a low precision farming technologies adoption rate [24]. Emmanuel et al. [25] suggested that various institutions should train more extension professionals because they have significant impact on agricultural innovative technology adoption by farmers. Therefore, developing extension professionals' competency to enhance production practices with precision farming technologies is a necessary part of improving services that meet the needs of farmers [26]. Many studies have addressed barriers to adoption of precision-farming technologies, including accessibility, socioeconomic status (e.g., age, gender, education), digital divide, misinformation, and availability [27]. However, there are few data on extension professionals' behavioral intention to promote precision farming technologies to increase the adoption rate by farmers. In addition, due to the nature of the precision farming technology, adoption and diffusion vary by crop variety, region, and country [28]. Thus, this study's purpose was (1) to explore the perspectives of agricultural extension professionals from two extension systems in the United States and (2) to identify the factors that influence their intentions to promote precision farming technology practices. The contribution of this study sought to improve precision farming information dissemination, extension professional development needs, and approaches to improve farmer adoption of precision farming innovations that optimized food chain and land sustainability.

2. Theoretical Framework

The unified theory of acceptance and use of technology (UTAUT) model by Venkatesh et al. [29] was used to investigate the behavioral intentions of agricultural extension professionals, including county agents and state specialists, to promote precision farming technologies in their extension roles. The UTAUT model combines eight prior models or theories to explore technology adoption [29]. Many studies indicated that the UTAUT variables applied to determine users' technology adoption vary in different contexts [30]. Many studies applying the UTAUT model in an agricultural context have focused on technology adoption by end users (i.e., farmers) [31], not by promotors. The

UTAUT model has proved to be an appropriate contextualization tool to measure the adoption of agricultural technologies [32,33]. Four main constructs play important roles as variables influencing individuals' acceptance behavior: performance, effort expectancy, social influence, and facilitating conditions.

Performance expectancy refers to the degree to which an individual believes using technologies improves performance [34]. Viewing the relevant models integrated into the UTAUT model, performance expectancy echoes the perceived usefulness of technology acceptance model [35] and relative advantage of innovation of diffusion theory [22].

Effort expectancy is the perception of ease of use. If individuals feel they don't need to make a huge effort to use technology, their willingness to use it will increase [36].

Social influence is the extent to which individuals believe that people who are important to them think they should use technology. Prior studies have indicated that social influence can affect individuals' behavior [37].

Facilitating conditions refer to the extent to which an individual believes that infrastructure to support the use of the technology exists. Studies have demonstrated that the higher the facilitating conditions provided, the greater the chances of technology adoption by end users [38,39].

Venkatesh et al. [29] identified four moderators—age, gender, voluntariness, and experience—that may affect the relationship between four key determining constructs and intention of innovation usage. Existing UTAUT studies supported age, gender, and experience as moderators in innovation adoption [40–42]. However, expectations about an individual to engage in precision farming technology promotion and adoption may change through age and previous work experience [43]. Thus, in this study, we modified the UTAUT model to include age, gender, and experience as independent variables instead of moderating variables. We used participants' years of service in extension positions of the participants as a variable of experience. The modified UTAUT model is shown in Figure 1.

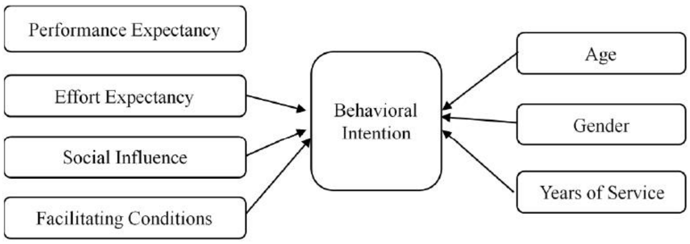


Figure 1. Modified Venkatesh et al.'s [29] UTAUT model used in this study.

This study used this conceptual model to examine whether selected factors of extension professionals affect their behavioral intentions to promote precision farming technologies. Specifically, the objectives of this study were to:

(1) Describe agricultural extension professionals' performance expectancy, effort expectancy, social influence, facilitating conditions, and behavioral intentions to promote precision farming technologies.
(2) Investigate the relationship between performance expectancy, effort expectancy, social influence, and facilitating conditions on agricultural extension professionals' behavioral intentions to promote precision farming technologies.
(3) Examine the mean difference of four variables—performance expectancy, effort expectancy, social influence, and facilitating condition—between two extension system groups.
(4) Predict behavioral intentions using independent variables (performance expectancy, effort expectancy, social influence, facilitating conditions, age, gender, and years of service).

3. Method

3.1. Population and Samples

The technology that can be applied to precision farming varies by crop and region [28]. Therefore, to have a more complete understanding the perspectives of agricultural Extension professionals in various fields toward the promotion of precision farming, this study selected two extension systems—the University of California's Cooperative Extension (UC Extension) and the University of Tennessee Extension (UT Extension)—in the United States and conducted a survey design with an instrument distributed to 468 agricultural extension professionals in the UC and UT extension systems. The research procedures and instrument were approved by Texas A&M University under IRB 2022-0175M for the implementation of the study with these two extension systems.

The population comprised individuals identified as extension agents or specialists who may actively or possibly work with precision farming technologies with crop producers in their role in either the UC or UT extension systems. We used a list of UT extension professionals obtained from the University of Tennessee Extension Department and a list of California Extension professionals identified by the first author as the sampling frame. Random sampling was used to select participants from the sampling frame [44]. The sample consisted of 102 agents and specialists—51 from UT Extension and 51 from UC Extension.

Food crops were the primary crop among extension professionals who responded to the survey—32 of 37 UC extension professionals (n = 32, N = 37; 86%) and 39 of 46 UT extension professionals (n = 39, N = 46; 85%) responded with crop varieties they worked with. The extension professionals in the two extension systems differed in the types of crops they specialized in within the food crop category. According to the crop variety answered by the participants, the food crop category included vegetables (i.e., leafy green, onion, lettuce, etc.), fruits (i.e., watermelon, berries, etc.), and grains (i.e., rice, wheat, etc.). In total, 29 of 46 UT Extension professionals (n = 26, N = 46; 52%) reported that grains were the dominant food crops they specialized in and that fruits (n = 10, N = 46; 22%) were the least-reported crop for their work. UC extension professionals' responses in terms of crops were the opposite of UT's responses, with fruit reported as the primary crops in which extension professionals worked—with 25 of 37 UC Extension professionals responding (n = 25, N = 37; 68%)—while grains (n = 5, N = 37; 14%) were the least-reported crop varieties in which they specialized. Figure 2 depicted the types of crops in which the surveyed extension professionals from two extension systems were specialized.

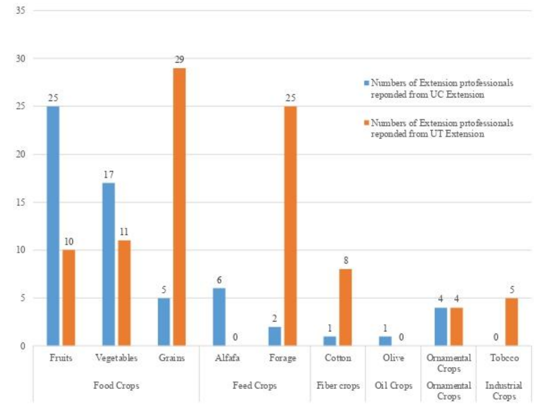


Figure 2. Crop variety worked on by surveyed extension professionals in two extension systems.

3.2. Data Collection

A questionnaire was developed to operationalize and measure five constructs important in this study (performance expectancy, effort expectancy, facilitating conditions, social influence, and behavioral intention to promote precision agriculture technologies). Each construct was measured using a multi-item scale. To measure participants' level of agreement with the provided statements for performance expectancy, effort expectancy, facilitating conditions, social influence, and behavioral intention constructs, we used a 5-point response scale of 1 = *strongly disagree*, 2 = *disagree*, 3 = *neither agree nor disagree*, 4 = *agree*, and 5 = *strongly agree*. The statements used to measure each construct were based on the literature [45] and were adjusted slightly to be appropriate for research objectives. We developed the questionnaire in the Qualtrics survey platform, and we administered the questionnaire via email. We followed Dillman et al.'s [46] five-step survey design method to contact participants and collect data.

A total of 102 participants accessed the instrument with a response rate of 22% (n = 102, N = 468). In total, 71 out of 102 participants responded with their gender, and more than half of the participants who answered the gender question were male (n = 51, f = 68.92%). We used a cross-sectional design in which we tested age differences based on U.S. Census age groups between young (<34 years), middle-aged (35 to 54 years), and older (>55 years) participants. In addition, we tested the experience variable using groups of lesser (<10 years), moderate (10 to 20 years), and high (>20 years) experience. In total, 72 out of 102 participants responded with their age and years of service. The age range of participants was 25 to 75 years, with a mean age of 49 years old (n = 72, SD = 14.95). The participants' years of service as an extension agent or specialist ranged from less than 1 year to 49 years, with a mean of 17.59 years of service (n = 72, SD = 14.21). Table 1 summarizes some of the demographic characteristics of the sample.

Table 1. Participants' demographic characteristics.

Characteristics	*f*			%
	UT Extension	**UC Extension**	**Total**	
Gender				
Male	34	17	51	68.92
Female	8	12	20	27.03
Prefer not to answer	0	3	3	4.05
				100.00
Age				
Under 34 years	7	5	12	16.67
35 to 54 years	15	15	30	41.67
55 years and older	13	17	30	41.67
				100.01
Years of Service as an Extension Agent/Specialist				
Less than ten years	12	20	32	44.44
10–20 years	7	2	9	12.50
More than 20 years	18	13	31	43.06
				100.00

3.3. Data Analysis

We used SPSS 28.0 to analyze the data collected through the Qualtrics survey platform. Descriptive and inferential statistics were used to analyze data [47]. Cronbach's [48] alpha coefficients were calculated to measure the internal consistency of five constructs of this study, yielding coefficients of 0.93 for performance expectancy, 0.90 for effort expectancy, 0.72 for facilitating condition, 0.84 for social influence, and 0.96 for behavioral intention. In addition, Cronbach [48] indicated that reliability coefficients of 0.70 or higher are acceptable and that those of 0.80 or higher are good.

Davis' [49] conventions were used to describe the magnitude of the correlation between pairs of variables: $0.01 \geq r \geq 0.09$ = *Negligible*, $0.10 \geq r \geq 0.29$ = *Low*, $0.30 \geq r \geq 0.49$ = *Moderate*, $0.50 \geq r \geq 0.69$ = *Substantial*, $r \geq 0.70$ = *Very Strong*. ANOVA analysis and *t*-test were used to test the group mean differences of the significant independent variables. A Pearson correlation analysis was used to examine the relationship between constructs used in the UTAUT model. The multiple linear regression analysis was used to test whether four constructs (performance expectancy, effort expectancy, social influence, and facilitating conditions) have statistically significant power to predict the dependent variable, behavioral intention to promote precision-farming technologies. The regression model used in this study is shown below.

$$Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + e$$

Y = Dependent variable
β_0 = Population Y intercept
β_i = Population Slope Coefficient
Xi = Independent Variable
e = Random error

4. Results

4.1. Descriptive Results

The first objective of this study was to describe agricultural extension professionals' performance expectancy, effort expectancy, social influence, facilitating conditions, and behavioral intentions to promote precision farming technologies. Data collected from the Tennessee extension system showed that the highest-scoring construct was "Behavioral Intention" (*M* = 3.36, *SD* = 0.72); the lowest-scoring construct was "Facilitating Conditions" (*M* = 3.00, *SD* = 0.77). Only the grand mean of facilitating conditions construct was 2.78 (*SD* = 0.64), which was lower than 3.00; the other four grand means of constructs were all slightly higher than 3.0, indicating that the Tennessee respondents slightly agreed with the statements provided by the survey (Table 2).

Table 2. Descriptive statistics for UTAUT constructs of UT extension participants.

Constructs	*n*	*M*	*SD*
Behavioral Intention	44	3.36	0.72
Performance Expectancy	45	3.33	0.75
Social Influence	44	3.19	0.56
Effort Expectancy	45	3.00	0.77
Facilitating Conditions	44	2.78	0.64

Note. Grand mean = 3.13, *SD* = 0.69, scale: 1 = *strongly disagree*, 2 = *disagree*, 3 = *neither*, 4 = *agree*, and 5 = *strongly agree*.

Data collected from the UC extension system showed that, similarly to data collected from Tennessee participants, the highest-scoring construct was "Behavioral Intention" (*M* = 3.53, *SD* = 0.68); the lowest-scoring construct was "Facilitating Conditions" (*M* = 2.72, *SD* = 0.78). The grand means for all four constructs were slightly higher than 3.0, except for the construct of facilitating conditions, which had a grand mean below 3.0 (*M* = 2.72; *SD* = 0.78), indicating slight agreement among UC Extension respondents with the construct statements provided in this study (Table 3).

Table 3. Descriptive statistics for UTAUT constructs of UC extension participants.

Constructs	*n*	*M*	*SD*
Behavioral Intention	37	3.53	0.68
Performance Expectancy	38	3.34	0.87
Social Influence	37	3.20	0.70
Effort Expectancy	37	3.00	0.78
Facilitating Conditions	37	2.72	0.78

Note. Grand mean = 3.16, *SD* = 0.76, scale: 1 = *strongly disagree*, 2 = *disagree*, 3 = *neither*, 4 = *agree*, and 5 = *strongly agree*.

4.2. Inferential Results

4.2.1. The Relationships between UTAUT Constructs

A Pearson correlation coefficient was computed to determine the linear relationship between behavioral intention and performance expectancy, between behavioral intention and effort expectancy, between behavioral intention and facilitating conditions, and between behavioral intention and social influence. The results analyzed from data collected from Tennessee participants indicated significant positive relationships between behavioral intention and other four constructs, performance expectancy ($r = 0.80$, $p < 0.01$), effort expectancy ($r = 0.53$, $p < 0.01$), facilitating conditions ($r = 0.50$, $p < 0.01$), and social influence ($r = 0.67$, $p < 0.01$; see Table 4).

Table 4. Correlation between UTAUT constructs of UT extension participants.

	Performance Expectancy	Behavioral Intention	Social Influence	Effort Expectancy	Facilitating Conditions
Performance Expectancy	-				
Behavioral Intention	0.80 *	-			
Social Influence	0.64 *	0.67 *	-		
Effort Expectancy	0.59 *	0.53 *	0.33 *	-	
Facilitating Conditions	0.43 *	0.50 *	0.35 *	0.62 *	-

Note. * $p < 0.05$. Magnitude: $0.01 \geq r \geq 0.09$ = *Negligible*, $0.10 \geq r \geq 0.29$ = *Low*, $0.30 \geq r \geq 0.49$ = *Moderate*, $0.50 \geq r \geq 0.69$ = *Substantial*, $r \geq 0.70$ = *Very Strong* (Davis, 1971).

The Pearson correlation coefficient results analyzed from data collected from the UC extension participants indicated significant positive relationships between behavioral intention and the other four constructs, performance expectancy ($r = 0.68$, $p < 0.01$), effort expectancy ($r = 0.49$, $p < 0.01$), facilitating conditions ($r = 0.55$, $p < 0.01$), and social influence ($r = 0.72$, $p < 0.01$; see Table 5).

Table 5. Correlations between UTAUT constructs of UC extension participants.

	Performance Expectancy	Behavioral Intention	Social Influence	Effort Expectancy	Facilitating Conditions
Performance Expectancy	-				
Behavioral Intention	0.68 *	-			
Social Influence	0.58 *	0.72 *	-		
Effort Expectancy	0.48 *	0.49 *	0.51 *	-	
Facilitating Conditions	0.38 *	0.55 *	0.53 *	0.67 *	-

Note. * $p < 0.05$. Magnitude: $0.01 \geq r \geq 0.09$ = *Negligible*, $0.10 \geq r \geq 0.29$ = *Low*, $0.30 \geq r \geq 0.49$ = *Moderate*, $0.50 \geq r \geq 0.69$ = *Substantial*, $r \geq 0.70$ = *Very Strong* (Davis, 1971).

4.2.2. Determine the Mean Differences of Variables among Participants from Two Extension Systems

We conducted a series of independent sample *t*-tests to examine the mean difference of UTAUT variables (performance expectancy, effort expectancy, social influence, facilitating conditions, and behavioral intention) among participants from two different areas. The results of the *t*-tests showed no significant mean differences between the two groups for all variables (see Table 6).

Table 6. *t*-test results for comparing UT extension participants and UC extension participants.

Group	*n*	*M*	*SD*	*t*	*df*	*p*
Performance Expectancy						
UC Extension	38	3.34	0.75	−0.04	81	0.97
UT Extension	45	3.33	0.87			
Effort Expectancy						
UT Extension	45	3.00	0.77	0.07	80	0.95
UC Extension	37	2.99	0.78			
Social Influence						
UC Extension	37	3.20	0.56	−0.06	79	0.95
UT Extension	44	3.19	0.70			
Facilitating Conditions						
UT Extension	44	2.78	0.64	0.35	79	0.73
UC Extension	37	2.72	0.78			

Note. Scale: 1 = strongly disagree, 2 = disagree, 3 = neither, 4 = agree, and 5 = strongly agree.

The results in Table 1 show that the two groups of respondents who were middle-aged (35 to 54 years) and older (>55 years) with longer service made up the majority of respondents, and the number of respondents was the same. Therefore, we also conducted an independent sample *t*-test to investigate the mean difference in participants' behavioral intentions from two different age groups with 30 participants in each group. The result of the *t*-test indicated no significant mean differences between the two groups (see Table 7).

Table 7. *t*-test results for comparing participants' age Groups.

Group	*n*	*M*	*SD*	*t*	*df*	*p*
Behavioral Intention						
55 years and older	30	3.46	0.75	−1.12	58	0.27
35 to 54 years	30	3.26	0.67			

Note. Scale: 1 = strongly disagree, 2 = disagree, 3 = neither, 4 = agree, and 5 = strongly agree.

The results in Table 1 show that the two groups of respondents with fewer than 10 years of service and those with more than 20 years of service made up the majority of respondents, and the number of respondents was similar. Therefore, we conducted an independent sample *t*-test to investigate the mean difference in participants' behavioral intentions from two different years of service groups. The result of the *t*-test indicated no significant mean differences between the two groups (Table 8).

Table 8. *t*-test results for comparing participants' years of service groups.

Group	*n*	*M*	*SD*	*t*	*df*	*p*
Behavioral Intention						
Fewer than 10 years of service	32	3.72	0.57	1.64	61	0.11
More than 20 years of service	31	3.47	0.65			

Note. Scale: 1 = strongly disagree, 2 = disagree, 3 = neither, 4 = agree, and 5 = strongly agree.

The results in Table 1 showed that more than 69% of respondents were male. Therefore, we conducted chi-squared analysis, and the results indicated that each independent variable—including performance expectancy ($X^2(4, N = 51) = 37.12, p < 0.01$), effort expectancy ($X^2(4, N = 51) = 17.71, p < 0.01$), social influence ($X^2(4, N = 51) = 19.83, p < 0.01$), and promotion condition ($X^2(4, N = 51) = 14.19, p = 0.01$)—had a significant relationship with the dependent variable, the behavioral intention of extension professionals to promote precision agriculture (see Table 9).

Table 9. A comparison of the chi-squared for four UTAUT constructs and behavioral intention construct in male participants.

	Negative Intention		Moderate Intention		Positive Intention			
	n	%	*n*	%	*n*	%	X^2	*p*
Performance Expectancy								
Negative Opinion	6	11.8	3	5.9	0	0	37.12	<0.01 *
Moderate Opinion	5	9.8	17	33.3	4	7.8		
Positive Opinion	0	0	2	3.9	14	27.5		
Effort Expectancy								
Negative Opinion	7	13.7	11	21.6	1	2.0	17.71	<0.01 *
Moderate Opinion	3	5.9	11	21.6	11	21.6		
Positive Opinion	1	2.0	0	0	6	11.8		
Facilitating Conditions								
Negative Opinion	9	14	14	27.5	4	7.8	14.19	0.01 *
Moderate Opinion	2	8	8	15.7	11	21.6		
Positive Opinion	0	0	0	0	3	5.9		
Social Influence								
Negative Opinion	5	4	4	7.8	0	0	19.83	<0.01 *
Moderate Opinion	6	18	18	35.3	12	23.5		
Positive Opinion	0	0	0	0	6	11.8		

Note. * $p < 0.05$. Three groups were used for each independent variable, coded as Negative Opinion = scale 1–2, Moderate Opinion = scale 3, and Positive Intention = 4–5. Three groups were used for Behavioral Intention, coded as Negative intention = scale 1–2, Moderate intention = scale 3, and Positive intention = scale 4–5. Scale: 1 = strongly disagree, 2 = disagree, 3 = neither, 4 = agree, and 5 = strongly agree.

4.2.3. Determine the Predictor of Behavioral Intention to Promote Precision-Farming Technologies

For the final objective of this study, we sought to determine whether the seven independent variables (performance expectancy, effort expectancy, social influence, facilitating conditions, age, gender, and years of service) used in this study could be predictors of extension professionals' behavioral intention to promote precision-farming technologies. To assess the multiple linear regression analysis, we coded four UTAUT predictors, performance expectancy, effort expectancy, social influence, and facilitating conditions as 1 = *strongly disagree*, 2 = *disagree*, 3 = *neither*, 4 = *agree*, to 5 = *strongly agree*. In addition, the moderator gender was coded as 1 = *male*, 2 = *female*, 3 = *other*, and 4 = *rather not answer*. The independent variable, age, was analyzed using the actual age of the participants as a quantitative variable rather than a categorical variable in this study to include more information.

We regressed the dependent variable, behavioral intention to promote precision agriculture technologies, on the independent variables. The table below illustrates the multiple linear regression model ($R^2 = 0.65$, $F = 15.67$, $p = < 0.01$). The model explained 65% of the variance in behavioral intention scores. The results indicated that two constructs, performance expectancy ($p < 0.01$) and social influence ($p < 0.01$), significantly predicted behavioral intention. In addition, the other two constructs, effort expectancy ($p = 0.58$) and facilitating conditions ($p = 0.07$), were not significant predictors of behavioral intention. The regression analysis results also revealed no statistically significant interaction between the effects of moderators of age, gender, and years of service on individuals' behavioral intention to promote precision farming technologies. Participants predicted behavioral intention to promote precision farming technologies was equal to 0.33 (intercept) + 0.36 performance expectancy + 0.36 social influence. The regression model explained that 65% of the variance of extension professionals' intention to promote the technologies was due to their beliefs of performance expectancy and the social influence of precision farming technologies for agriculturalists (Table 10).

Table 10. Regression coefficients of all independent variables on behavioral intention.

Independent Variable	Beta	*SE*	*β*	*t*	*p*
Performance Expectancy	0.36	0.10	0.42	3.75	<0.01 *
Social Influence	0.36	0.11	0.32	3.21	<0.01 *
Facilitating Conditions	0.18	0.10	0.20	1.84	0.07
Effort Expectancy	0.05	0.09	0.06	0.55	0.58
Gender	0.01	0.08	0.01	0.07	0.94
Age	0.01	0.01	0.15	0.90	0.37
Years of Service	−0.01	0.01	−0.23	−1.39	0.17

Note. * $p < 0.05$.

5. Discussions

The descriptive results revealed that the grand means for behavioral intention, performance expectancy, effort expectancy, and social influence indicated that extension professionals in both states slightly agreed with the statements provided by the instrument used in this study. However, the grand means of facilitating conditions in both states indicated that extension professionals slightly disagreed with the statements provided by the instrument, indicating that extension professionals believed that the lack of suitable technical and organizational environmental support would reduce their intention to promote precision agriculture.

According to the findings of this study, there were no significant differences between UT and UC extension participants. Age and years of service were not variables that affected extension professionals' intentions to promote precision-farming technologies. In addition, older or younger extension professionals and those of different amounts of service experience did not significantly affect the extension professionals' behavioral intention to promote precision farming technologies. The professionals surveyed are willing to promote farming technologies as long as they have opportunities to enhance their performance expectancy, effort expectancy, social influence, and facilitating conditions.

The regression results are consistent with the previous studies [50,51] applying the UTAUT model to the field of technology use, indicating that performance expectancy and social influence are significant predictors of technology acceptance. The finding indicates that an extension professional's or others' perceived expectation that an extension professional will benefit from improved performance may be a motivator for promoting the technology adoption.

6. Conclusions and Implications

The data revealed gaps in information dissemination, professional development needs for current and future professionals' training opportunities, and strategies for improving farmer adoption. The adoption of precision farming technologies is one strategy for improving sustainable food chains and systems. Agricultural extension, change agents, and professionals serve essential roles in disseminating innovation attributes across local communities in the battle to sustain food chains and improve land sustainability. Given the low response rate and focus on two states, we recognize that the data can be generalized to only the two state extension systems investigated. However, findings can be used by others to guide future studies.

The very strong and substantial significant positive correlation coefficients of all UTAUT independent variables on behavioral intention indicated that extension professionals need to be supported with professional development training to enhance their competencies in promoting precision agriculture technologies. Extension professionals in both state extension systems had similar intentions to promote precision agriculture technologies to stakeholders [29]. The data informs extension administrators, program leaders, professional development staff, and specialists of variables necessary in professional development to improve extension professionals' promotion of precision farming technologies.

The results indicated that there were no significant differences in the agreements of all constructs (performance expectancy, effort expectancy, social influence, facilitating conditions, and behavioral intention) used in this study between extension professionals from two state extension systems. In addition, gender, age, and years of service were not variables that affected extension professionals' intention to promote precision farming technologies. Thus, we concluded that there is no need to target a specific age, gender, or years of service experience range and that we should instead use a generalized approach. Data indicated that extension professionals believed their behavior to promote precision farming technologies was related to performance expectancy, effort expectancy, social influence, and facilitating conditions. The regression model explained that 65% of the variance of extension professionals' intention to promote the technologies was due to their beliefs of performance expectancy and the social influence of precision agriculture technologies for agriculturalists.

Many studies have examined the implementation of the UTAUT model with the technology's acceptance [52]. Still, few research appear to have explored the acceptance of the promotion of precision agriculture from the agricultural extension professionals' perspectives. Therefore, this study has expanded the UTAUT application in an agriculture context with new technology (precision farming).

The current study provides a primary understanding of factors influencing agricultural extension professionals' behavioral intention to promote precision farming technology adoption. We further suggest training programs addressing the development of advanced competencies needed to promote agricultural innovation as supported by [26]. Agricultural program development specialists must be aware that age, gender, or years of service are not barriers to extension agents and specialists promoting precision farming technologies. The results of performance expectancy, effort expectancy, social influence, facilitating conditions, and behavioral intention [29] among extension agents and specialists from different states highlight the importance of how training programs can comprehensively apply to different areas to help effectively facilitate the diffusion of precision agriculture technologies and bridge the gap in precision agriculture information dissemination channels. Social network systems, such as mentorship, can be leveraged to encourage extension professionals to engage in precision agriculture dissemination. This study contributes to the future professional development programs for agricultural extension professionals on communicating agricultural innovations with educators, extension agents and specialists, producers, and stakeholders to address food security, climate change adaptation, and sustainability issues [21].

Author Contributions: Conceptualization, C.-L.L.; methodology, C.-L.L., R.S., G.B., T.M., N.R. and S.R.; formal analysis, C.-L.L.; discussions and conclusions development, C.-L.L.; data curation, C.-L.L.; writing—original draft preparation, C.-L.L.; writing—review and editing, R.S., G.B., T.M., N.R. and S.R. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by USDA Hatch Project TEX09890: The Adoption Impact of Food and Agricultural Sciences Curricula on Public Health.

Data Availability Statement: Data is contained within the article.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Simola, A.; Boysen, O.; Ferrari, E.; Nechifor, V.; Boulanger, P. Economic integration and food security—The case of the AfCFTA. *Glob. Food Secur.* **2022**, *35*, 100651. [CrossRef]
2. Food and Agriculture Organization of the United Nations. *The Future of Food and Agriculture: Trends and Challenges*; Food and Agriculture Organization of the United Nations: Rome, Italy, 2017.
3. Crist, E.; Mora, C.; Engelman, R. The Interaction of Human Population, Food Production, and Biodiversity Protection. *Science* **2017**, *356*, 260–264. [CrossRef]
4. Ganpat, W.G.; Ramjattan, J.; Strong, R. Factors Influencing Self-Efficacy and Adoption of ICT Dissemination Tools by New Extension Officers. *J. Int. Agric. Ext. Educ.* **2016**, *23*, 72–85. [CrossRef]

5. Wolde, Z.; Wei, W.; Kunpeng, W.; Ketema, H. Local Community Perceptions Toward Livelihood and Water–Energy–Food Nexus: A Perspective on Food Security. *Food Energy Secur.* **2020**, *9*, e207. [CrossRef]
6. Carthy, U.M.; Uysal, I.; Badia-Melis, R.; Mercier, S.; O'Donnell, C.; Ktenioudaki, A. Global Food Security—Issues, Challenges and Technological Solutions. *Trends Food Sci. Technol.* **2018**, *77*, 11–20. [CrossRef]
7. Xin, J.; Zazueta, F. Technology Trends in ICT–Towards Data-Driven, Farmer-Centered and Knowledge-Based Hybrid Cloud Architectures for Smart Farming. *Agric. Eng. Int. CIGR J.* **2016**, *18*, 275–279.
8. Asif, A.S.; Uddin, M.N.; Dev, D.S.; Miah, M.A.M. Factors Affecting Mobile Phone Usage by the Farmers in Receiving Information on Vegetable Cultivation in Bangladesh. *J. Agric. Inf.* **2017**, *8*, 33–43. [CrossRef]
9. Azumah, S.B.; Donkoh, S.A.; Awuni, J.A. The Perceived Effectiveness of Agricultural Technology Transfer Methods: Evidence from Rice Farmers in Northern Ghana. *Cogent Food Agric.* **2018**, *4*, 1503798. [CrossRef]
10. Benke, K.; Tomkins, B. Future Food-Production Systems: Vertical Farming and Controlled Environment Agriculture. *Sustain. Sci. Pract. Policy* **2017**, *13*, 13–26. [CrossRef]
11. Erickson, B.; Fausti, S.W. The Role of Precision Agriculture in Food Security. *J. Agron.* **2021**, *113*, 4455–4462. [CrossRef]
12. Gupta, M.; Abdelsalam, M.; Khorsandroo, S.; Mittal, S. Security and Privacy in Smart Farming: Challenges and Opportunities. *IEEE Access* **2020**, *8*, 34564–34584. [CrossRef]
13. Raliya, R.; Saharan, V.; Dimkpa, C.; Biswas, P. Nanofertilizer for Precision Agriculture and Sustainable Agriculture: Current State and Future Perspectives. *J. Agric. Food Chem.* **2017**, *66*, 6487–6503. [CrossRef]
14. Balafoutis, A.; Beck, B.; Fountas, S.; Vangeyte, J.; Van Der Wal, T.; Soto, I.; Gómez-Barbero, M.; Barnes, A.; Eory, V. Precision Agriculture Technologies Positively Contributing to GHG Emissions Mitigation, Farm Productivity and Economics. *Sustainability* **2017**, *9*, 1339. [CrossRef]
15. Sundström, J.F.; Albihn, A.; Boqvist, S.; Ljungvall, K.; Marstorp, H.; Martiin, C.; Nyberg, K.; Vågsholm, I.; Yuen, J.; Magnusson, U. Future Threats to Agricultural Food Production Posed by Environmental Degradation, Climate Change, and Animal and Plant Diseases—A Risk Analysis in Three Economic and Climate Settings. *Food Secur.* **2014**, *6*, 201–215. [CrossRef]
16. Bulter, D.; Holloway, L. Technology and Restructuring the Social Field of Dairy Farming: Hybrid Capitals, 'Stockmanship' and Automatic Milking Systems. *Sociol. Rural.* **2016**, *56*, 513–530. [CrossRef]
17. Eastwood, C.R.; Chapman, D.F.; Paine, M.S. Networks of Practice for Co-construction of Agricultural Decision Support Systems: Case Studies of Precision Dairy Farms in Australia. *Agric. Syst.* **2012**, *108*, 10–18. [CrossRef]
18. Strong, R.; Wynn, J.T., II; Lindner, J.R.; Palmer, K. Evaluating Brazilian agriculturalists' IoT smart agriculture adoption barriers: Understanding stakeholder salience prior to launching an innovation. *Sensors* **2022**, *22*, 6833. [CrossRef]
19. Carolan, M. Publicising Food: Big Data, Precision Agriculture, and Co-Experimental Techniques of Addition. *Sociol. Rural.* **2015**, *57*, 135–154. [CrossRef]
20. Tambo, J.A.; Abdoulaye, T. Climate Change and Agricultural Technology Adoption: The Case of Drought Tolerant Maize in Rural Nigeria. *Mitig. Adapt. Strateg. Glob. Chang.* **2012**, *17*, 277–292. [CrossRef]
21. Mikwamba, K.; Dessein, J.; Kambewa, D.; Messely, L.; Strong, R. Collaborative Governance Dynamics in Innovation Platforms: Case of Malawi's District Stakeholder Panel. *J. Agric. Educ. Ext.* **2021**, *27*, 255–275. [CrossRef]
22. Rogers, E.M. *Diffusion of Innovations*, 5th ed.; Free Press: New York, NY, USA, 2003.
23. Lee, C.-L.; Strong, R.; Dooley, K. Analyzing Precision Agriculture Adoption Across the Globe: A Systematic Review of Scholarship from 1999–2020. *Sustainability* **2021**, *13*, 10295. [CrossRef]
24. Kanter, D.R.; Bell, A.R.; McDermid, S.S. Precision Agriculture for Smallholder Nitrogen Management. *One Earth* **2019**, *1*, 281–284. [CrossRef]
25. Emmanuel, D.; Owusu-Sekyere, E.; Owusu, V.; Jordaan, H. Impact of Agricultural Extension Service on Adoption of Chemical Fertilizer: Implications for Rice Productivity and Development in Ghana. *NJAS—Wagening. J. Life Sci.* **2016**, *79*, 41–49. [CrossRef]
26. Seitz, P.; Strong, R.; Hague, S.; Murphrey, T.P. Evaluating Agricultural Extension Agent's Sustainable Cotton Land Production Competencies: Subject Matter Discrepancies Restricting Farmers' Information Adoption. *Land* **2022**, *11*, 2075. [CrossRef]
27. Pathak, H.S.; Brown, P.; Best, T. A Systematic Literature Review of The Factors Affecting the Precision Agriculture Adoption Process. *Precis. Agric.* **2019**, *20*, 1292–1316. [CrossRef]
28. Roberts, P.C. Precision agriculture: A Challenge for Crop Nutrition Management. *Plant Soil* **2002**, *247*, 143–149. [CrossRef]
29. Venkatesh, V.; Morris, M.G.; Davis, G.B.; Davis, F.D. User Acceptance of Information Technology: Toward A Unified View. *MIS Q.* **2003**, *27*, 425–478. [CrossRef]
30. Attuquayefio, S.; Addo, H. Review of Studies with UTAUT as Conceptual Framework. *Eur. Sci. J.* **2014**, *10*, 249–258. [CrossRef]
31. Ronaghi, M.H.; Forouharfar, A. A Contextualized Study of the Usage of the Internet of Things (IoTs) in Smart Farming in A Typical Middle Eastern Country within the Context of Unified Theory of Acceptance and Use of Technology Model (UTAUT). *Technol. Soc.* **2020**, *63*, 101415. [CrossRef]
32. Faridi, A.A.; Kavoosi-Kalashami, H.; Bilali, H.E. Attitude Components Affecting Adoption of Soil and Water Conservation Measures by Paddy Farmers in Rasht County, Northern Iran. *Land Use Policy* **2020**, *99*, 104885. [CrossRef]
33. Li, W.; Clark, B.; Taylor, J.A.; Kendall, H.; Jones, G.; Li, Z.; Jin, S.; Zhao, C.; Yang, G.; Shuai, C.; et al. A Hybrid Modelling Approach to Understanding Adoption of Precision Agriculture Technologies in Chinese Cropping Systems. *Comput. Electron. Agric.* **2020**, *172*, 105305. [CrossRef]

34. Davis, F.D.; Bagozzi, R.P.; Warshaw, P.R. Extrinsic and Intrinsic Motivation to Use Computers in the workplace. *J. Appl. Soc. Psychol.* **1992**, *22*, 1111–1132. [CrossRef]
35. Davis, F.D. Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. *MIS Q.* **1989**, *13*, 319–340. [CrossRef]
36. Moya, M.B.; Engotoit, B.; Mayoka, G.K. Mediating Effect of Price Value on Effort Expectancy and Behavioural Intentions to Use Mobile Communication Technologies by Commercial Farmers in Uganda. *ICTACT J. Manag. Stud.* **2018**, *4*, 754–763. [CrossRef]
37. Giua, G.; Materia, V.C.; Camanzi, L. Smart Farming Technologies Adoption: Which Factors Play a Role in The Digital Transition? *Technol. Soc.* **2022**, *68*, 101869. [CrossRef]
38. Shi, Y.; Siddik, A.B.; Masukujjaman, M.; Zheng, G.; Hamayun, M.; Ibrahim, A.M. The Antecedents of Willingness to Adopt and Pay for the IoT in the Agricultural Industry: An Application of the UTAUT 2 Theory. *Sustainability* **2022**, *14*, 6640. [CrossRef]
39. Wang, H.; Tao, D.; Yu, N.; Qu, X. Understanding Consumer Acceptance of Healthcare Wearable Devices: An Integrated Model of UTAUT and TTF. *Int. J. Med. Inform.* **2020**, *139*, 104156. [CrossRef]
40. Lian, J.W.; Yen, D.C. Online Shopping Drivers and Barriers for Older Adults: Age and Gender Differences. *Comput. Hum. Behav.* **2014**, *37*, 133–143. [CrossRef]
41. Ruggeri, K.; Kacha, O.; Menezes, I.G.; Kos, M.; Franklin, M.; Parma, L.; Landon, P.; Mattews, B.; Miles, J. In with the New? Generational Differences Shape Population Technology Adoption Patterns in the Age of Self-Driving Vehicles. *J. Eng. Technol. Manag.* **2018**, *50*, 39–44. [CrossRef]
42. Zaremohzzabieh, Z.; Samah, B.A.; Omar, S.Z.; Bolong, J.; Mohamed Shaffril, H.A. Fisherman's Acceptance of Information Effect of Age and Experience. *J. Appl. Sci.* **2014**, *14*, 873–882. [CrossRef]
43. Pierpaoli, E.; Carli, G.; Pignatti, E.; Canavari, M. Drivers of Precision Agriculture Technologies Adoption: A Literature Review. *Procedia Technol.* **2013**, *8*, 61–69. [CrossRef]
44. Creswell, J.W.; Guetterman, T.C. *Educational Research: Planning, Conducting, and Evaluating Quantitative and Qualitative Research*, 6th ed.; Pearson: New York, NY, USA, 2019.
45. Irby, T.L.; Strong, R. Agricultural Education Students' Acceptance and Self-Efficacy of Mobile Technology in Classrooms. *NACTA* **2013**, *57*, 82–87. Available online: https://www.jstor.org/stable/10.2307/nactajournal.57.1.82 (accessed on 9 March 2023).
46. Dillman, D.A.; Smyth, J.D.; Christian, L.M. *Internet, Phone, Mail, and Mixed-Mode Surveys: The Tailored Design Method*, 4th ed.; John Wiley & Sons: Hoboken, NJ, USA, 2014.
47. Fraenkel, J.R.; Hyun, H.H.; Wallen, N.E. *How to Design and Evaluate Research in Education*, 10th ed.; McGraw Hill Education: New York, NY, USA, 2019.
48. Cronbach, L.J. Coefficient Alpha and the Internal Structure of Tests. *Psychometrika* **1951**, *16*, 297–334. [CrossRef]
49. Davis, J.A. *Elementary Survey Analysis*; Prentice Hall: Hoboken, NJ, USA, 1971.
50. El-Masri, M.; Tarhini, A. Factors Affecting the Adoption of E-Learning Systems in Qatar and USA: Extending the Unified Theory of Acceptance and Use of Technology 2 (UTAUT2). *Educ. Technol. Res. Dev.* **2017**, *65*, 743–763. [CrossRef]
51. Hu, S.; Laxman, K.; Lee, K. Exploring Factors Affecting Academics' Adoption of Emerging Mobile Technologies-An Extended UTAUT Perspective. *Educ. Inf. Technol.* **2020**, *25*, 4615–4635. [CrossRef]
52. Williams, M.D.; Rana, N.P.; Dwivedi, Y.K. The Unified Theory of Acceptance and Use of Technology (UTAUT): A literature Review. *J. Enterp. Inf. Manag.* **2015**, *28*, 443–488. [CrossRef]