行政院及所屬機關出國報告

（出國類別：開會）

受邀出席參加亞洲太平洋地區糧食肥料技術中心(FFTC)與馬來西亞農業發展研究所(MARDI MARDI)以及菲律賓農業、漁業與資源研究發展委員會(DOST-PCAARRD)合辦之「永續食物生產之農業廢棄物經營(Agriculture Waste Management for Sustainable Food Production)」國際研討會專題演講及與交流事宜報告書

服務機關：行政院農業委員會

姓名職稱：傅子煜執行秘書、林昭吟視察

派赴國家：馬來西亞

出國期間：2023 年 7 月日至 7 月 13 日

報告日期：2023 年 9 月 8 日

摘要

由亞洲太平洋地區糧食肥料技術中心(Food and Fertilizer Technology Center for The Asian and Pacific Region, FFTC)邀請行政院農業委員會企劃處氣候變遷調適及淨零排放專案辦公室執行秘書傅子煜參與其與馬來西亞農業發展研究所(Malaysian Agricultural Research and Development Institute, MARDI)及菲律賓農業、漁業與資源研究發展委員會(Department of Science and Technology-Philippine council for Agriculture, Aquatic and Natural Resources and Development, DOST-PCAARRD) 於 2023 年 7 月 10 日至 12 日於馬來西亞合辦「永續食物生產之農業廢棄物經營(Agriculture Waste Management for Sustainable Food Production」國際研討會，並進行專題討論 15 分鐘演講並發表「邁向淨零排放：臺灣的碳中和與循環農業路徑」 (Towards Net-Zero: Taiwan's Pathway to A Carbon Neutral and Circular Agriculture)。本案出國期間自 2023 年 7 月 9 日起至 2023 年 7 月 13 日止，此次研討會計有馬來西亞、臺灣、韓國、日本、菲律賓、泰國、印尼、越南等 8 國計一百多名研究人員參與，並進行 12 篇論文發表，本次除透過該研討會揭示我國於淨零循環農業之政策及推動場域外，並藉由參與本國際研討會擴展研究視野與各國研究人員進行學術交流，了解亞太各國在農業剩餘資源政策發展、技術現況及相關技術發展，以增加臺灣未來推動淨零農業循環實力。本次研討會議後，亦由 FFTC 安排參訪業界參訪，包含金馬崙高原(Cameron Highlands)的 PJ Eco Recycling Plaza 參訪其零廢棄物技術應用商店，MARDI 有機農場的試驗成果及 Chitose Oriental Lilyh 園區了解其如何將蔬果等菜餘盡其使用，達農業剩餘資源循環零廢棄之作法進行經驗分享及技術交流。未來我國除應加大資源投入農業淨零排放科研與誘因機制設計外，也應積極參與國際鏈結事務，如人才培育、參與或辦理國際研討會、雙邊/多邊交流或啟動國際合作專案等，以期未來我國農業部門可成為永續技術服務提供者，並成為其他國家農業淨零排放楷模。

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壹、 目的

近年來聯合國政府間氣候變遷專門委員會(IPCC)於公布之各項氣候變遷相關報告指出，人類對地球暖化的影響無庸置疑，地球大氣、海洋、冰雪圈與生物圈已在發生廣泛且快速的變遷，其程度與各地區的極端天災是過去數千年來前所未見。我國屬海島國家，不僅海平面上升速度是全球平均的 2 倍，1991-2020 年間，我國全年平均溫度已上升 1.6℃，且有增溫加速趨勢，降雨型態也發生改變，最大日暴雨強度及年最大連續不降雨日數增加趨勢明顯，皆對我國農業造成極大挑戰。爰此，近年國際上有關氣候變遷與淨零排放等議題之討論程度熱烈，我國也於 2022 年 3 月 30 日由行政院國家發展委員會正式對外宣布臺灣 2050 淨零排放路徑與 12 項關鍵戰略，包含風電/光電、氫能、前瞻能源、電力系統與儲能、節能、碳捕捉、利用及封存、運具電動化及無碳化、資源循環零廢棄、自然碳匯、淨零綠生活、綠色金融、公正轉型。面對國家整體淨零排放目標，各部門無不積極響應，而我國行政院農業委員會(下稱農委會，2023 年 8 月 1 日改制為農業部)於 2022 年 2 月 9 日對外宣布農業部門推動淨零排放之具體作為，包含四大主軸、19 項策略與 59 項措施，並提出將提前於 2040 年達到農業淨零排放之積極目標，顯示我國農業部門對於氣候變遷與淨零排放議題之高度重視。

本次由亞洲太平洋地區糧食肥料技術中心(Food and Fertilizer Technology Center for The Asian and Pacific Region, FFTC)邀請農委會企劃處氣候變遷調適及淨零排放專案辦公室執行秘書傅子煜參與其與馬來西亞農業發展研究所(Malaysian Agricultural Research and Development Institute, MARDI)及菲律賓農業、漁業與資源研究發展委員會(Department of Science and Technology-Philippine council for Agriculture, Aquatic and Natural Resources and Development, DOST-PCAARRD) 於2023年7月10日至12日於馬來西亞合辦之「永續食物生產之農業廢棄物經營(Agriculture Waste Management for

Sustainable Food Production」國際研討會，並於第四主題-增加永續及收入之廢棄物經營-挑戰及解決辦法(Session 4：Panel discussion：Waste Management for Increasing Sustainability and Income - Challenges and Solutions)進行專題討論 15 分鐘演講並發表「邁向淨零排放：臺灣的碳中和與循環農業路徑」 (Towards Net-Zero: Taiwan's Pathway to A Carbon Neutral and Circular Agriculture) 論文。

貳、過程

一、2023 年 7 月 10 日研討會議程：

議程主要分為四大主題，分別為以廢棄物作為未使用資源之永續食物生產系統 (Session 1：Utilization of Wastes as an Untapped Resource for Sustainable Food Systems)、農業廢棄物經營技術之育成 (Session 2：Technological Innovations in Agricultural Waste Management)、農業廢棄物經營的經濟及政策觀點(Session 3：Economic and Policy Aspects of Agricultural Waste Management)、增加永續及收入之廢棄物經營-挑戰及解決辦法(Session 4：Panel discussion：Waste Management for Increasing Sustainability and Income - Challenges and Solutions)，議程如下：

2023 MARDI-PCAARRD-FFTC Workshop
Agricultural Waste Management for Sustainable Food Production

Workshop 08：30 – 17：30 (GMT+8), July 10th, 2023
Hybrid mode： Putrajaya Marriott Hotel (onsite) and Webex (online)
Field trip 08：00 – 19：30 (GMT+8), July 11th – 12th, 2023

July 10th, 2023 (Monday), **08：00 – 17：30** (GMT+8) **Workshop**

Time (GMT+8)	Topics and speakers	Note
08：00 – 08：30	Onsite registration and Online login	
	Opening	30 min
08：30 – 08：50	**Welcome and Remarks** MARDI： Dato' Dr. Mohamad Zabawi Bin Abdul Ghani DOST-PCAARRD： Dr. Reynaldo V. Ebora FFTC： Dr. Su-San Chang	*20 min*
08：50 – 09：00	Photo session	*10 min*
09：00 – 09：40	**Keynote lecture** Dr. Loh Soh Kheng (MPOB, Malaysia) **Sustaining Agricultural Production via Waste to Wealth Circular Approach** Moderator： Dr. Tzu-yu Fu (Council of Agriculture, Taiwan)	*40 min (30 min talk +10 min Q&A)*

	Session 1 **Utilization of Wastes as an Untapped Resource for Sustainable Food Systems** Moderator： Dr. Rosliza Jajuli (MARDI, Malaysia)	
09：40– 10：10	Topic 1-1： **Strategies to Recycling Agricultural Byproducts for Increasing Crop Production; Natural Recycling Agriculture and Biochar** Dr. Jin-Hyeob Kwak (Jeonbuk National University, Korea)	*30 min (20 min talk + 10 min Q&A)*
10：10 – 10：40	Topic 1-2： **Application of By-products from Agriculture as Feed Resources for Livestock in Taiwan** Dr. Jeng-Bin Lin (Livestock Research Institute, Taiwan)	*30 min*
10：40 – 11：00	**Tea Break**	*20 min*
11：00 – 11：30	Topic 1-3： **Technological Innovations in Agricultural Waste Management in Malaysia** Dr. Sashikala A/P Maruthai Pillai (MARDI, Malaysia)	*30 min*
11：30 – 12：00	Topic 1-4： **Creation of Food Waste Composting and Recycling Loop in Malaysia** Mr. Shinsuke Takeuchi (KITA, Japan)	*30 min*
	Session 2： **Technological Innovations in Agricultural Waste Management** Moderator： Dr. Teoh Chin Chuang (MARDI, Malaysia)	
12：00 – 12：30	Topic 2-1： **Production Forecasting Systems for Stable Supply and Waste Reduction of Field Vegetables** Dr. Koji Sugahara (NARO, Japan)	*30 min*
12：30 – 13：00	Topic 2-2： **Technological Innovations in Agricultural Waste Management in the Philippines** Ms. Ofelia F. Domingo (DOST-PCAARRD, Philippines)	*30 min*
13：00 – 14：00	**Lunch Break**	*1 hr*
	Session 3： **Economic and Policy Aspects of Agricultural Waste Management** Moderator： Ms. Ofelia F. Domingo (DOST-PCAARRD, Philippines)	
14：00 – 14：30	Topic 3-1： **Community Practice - Sustainable Cassava Value Chain through Knowledge and Technology**	*30 min*

	Transfer in Thailand, Cambodia, Lao PDR, Vietnam, and Myanmar Dr. Warinthorn Songkasiri (BIOTEC, Thailand) (online)	
14：30 – 15：00	Topic 3-2： **Economic Aspect of Sustainable Agricultural Waste Management Strategies in Indonesia： A Case Study of Oil Palm and Sugarcane** Dr. Yusman Syaukat (IPB University, Indonesia)	*30 min*
15：00 – 15：30	Topic 3-3： **Barriers and Policy Gaps for Utilization of Agricultural By-products and Waste for Sustainable Food Production in Vietnam** Dr. Tran Van The (Institute of Agricultural Environment, VAAS, Vietnam)	*30 min*
15：30 – 15：50	**Tea Break**	*20 min*
15：50 – 17：00	**Session 4** **Panel discussion： Waste Management for Increasing Sustainability and Income – Challenges and Solutions** Moderator： Mr. Mohd Rashid Rabu (MARDI, Malaysia) Topic 1： **Integrated Organic Farming (IOF)： Close Loop System/Circular Economy** Prof Anthony Wong (Natural Farming Association Malaysia) Topic 2： **Towards Net-Zero： Taiwan's Pathway to a Carbon Neutral and Circular Agriculture** Dr. Tzu-yu Fu (Counsil of Agriculture, Taiwan)	*1 hr* *10 min*
17：00-17：10	**Summary by FFTC**	*10 min*
17：10 – 17：30	**Closing Remarks** MARDI： Dato' Dr. Mohamad Zabawi Bin Abdul Ghani DOST-PCAARRD： Dr. Reynaldo V. Ebora FFTC： Dr. Su-San Chang	*20 min*

二、2023 年 7 月 11 至 12 日業界參訪行程：

於金馬崙高原(Cameron Highlands)參訪 PJ 生態循環農業廣場(PJ Eco Recycling Plaza)及 MARDI 有機農場、沼氣系統(MARDI Organic Farm & Biogas System) 及參訪 Chitose Oriental Lilyh 循環農業園區。

July 11th, 2023 (Tuesday), **Field Trip Program**

Time (GMT+8)	Topics	Note
08：00 – 08：30	Hotel pickup	
08.30 – 09.30	Travel to PJ Eco Recycling Plaza	
09：30 – 11：00	Visit PJ Eco Recycling Plaza	
11：00 – 13：00	Travel to Cameron Highlands	
13：00 – 14：00	Lunch	
14：00 – 17：00	Travel to Cameron Highlands	
17：00 – 20：00	Check-in hotel and free & easy	
20：00 – 21：00	Dinner	

July 12th, 2023 (Wednesday), **Field Trip Program**

Time (GMT+8)	Topics	Note
08：00 – 08：30	Briefing for the waste program at the Hotel	
08：30 – 09：00	Travel to MARDI Cameron Highlands	
09：00 – 09：30	Briefing on MARDI Cameron Highlands Agropark	
09：30 – 10：30	Visit MARDI Organic Farm & Biogas System	
10：30 – 11：00	Coffee break	
11：00 – 11：30	Explore MARDI Agropark	
11：30 – 12：30	Lunch	
12：30 – 13：00	Travel to Chitose Oriental Lily (Vegetables & Fruits shop using zero waste management practices)	
13：00 – 14：00	Visit Chitose Oriental Lily	
14：00 – 14：20	Travel to Compost Centre, Blue Valley	
14：20 – 14：45	Visit Compost Centre (Briefing by Greenviro Sdn. Bhd.)	
14：45 – 15：00	Tea break	
15：00 – 19：00	Travelling back	
19：00 – 19.30	Arrive at MARDI HQ / Hotel	

參、心得與感想

此次參加「Agriculture Waste Management for Sustainable Food Production」國際研討會係由亞洲太平洋地區糧食肥料技術中心(FFTC)與馬來西亞農業發展研究所(Malaysian Agricultural Research and Development Institute, MARDI)以及菲律賓農業、漁業與資源研究發展委員會(Department of Science and Technology-Philippine council for Agriculture, Aquatic and Natural Resources and Development, DOST-PCAARRD)合辦之國際研討會，此次研討會由 FFTC 張淑賢主任主持，計有馬來西亞、臺灣、韓國、日本、菲律賓、泰國、印尼、越南等 8 國合計共 100 多位學者及專家參與交流，研討會議程分為專題演講及四大主題分別進行共 12 篇研究有關農業剩餘資源再利用及循環農業等相關論文發表，研討會內容摘述如下：

一、專題演講：第一篇由馬來西亞棕梠油委員會(Malaysia Palm Oil Board)的 Loh Soh Kheng 博士進行專題演講，發表「Sustaining Agricultural Production via Waste to Wealth Circular Approach」論文，講述馬來西亞藉由棕梠產業農業剩餘資源的利用，達到氣候循環的永續農業生產的作為。

二、第一節主題：以廢棄物作為未使用資源之永續食物生產系統(Session 1：Utilization of Wastes as an Untapped Resource for Sustainable Food Systems)。第一篇由韓國 Jeonbok National University 的 Jin-Hyeob Kuak 教授發表「Strategies to Recycling Agricultural Byproducts for Increasing Crop Production; Natural Recycling Agriculture and Biochar」論文：內容為講述生物炭在農業剩餘資源與循環農業扮演的角色。第二篇由本國行政院農業委員會畜產試驗所的林正斌研究員兼組長發表「Application of By-products from Agriculture as Feed Resources for Livestock in Taiwan」論文，內容為講述臺灣農業剩餘資源當畜牧飼料資源化的應用方向及研究

成果。第三篇由馬來西亞農業發展研究所 Sashikala Maruthai Pillai 教授發表「Technological Innovations in Agricultural Waste Management in Malaysia」論文，內容為講述馬來西亞在農業剩餘資源如蔬果及稻稈等循環應用的技術開發。第四篇由日本 Kitakyushu International Techno-cooperative Association 的 Shinsuke Takeuchi 教授發表「Creation of Food Waste Composting and Recycling Loop in Malaysia 」論文，內容講述日本在馬來西亞推展蔬果廢棄物在循環農業鏈的成果。

三、第二節主題：農業剩餘資源經營技術之育成 (Session 2：Technological Innovations in Agricultural Waste Management)。第一篇由日本 National Agriculture and Research Organization 的 Sugahark Koji 教授發表「Production Forecasting Systems for Stable Supply and Waste Reduction of Field Vegetables」論文，內容講述生產預測系統在蔬菜田降低廢棄物及穩定蔬菜供應的應用。第二篇由菲律賓 Department of Science and Technology-Philippine council for Agriculture, Aquatic and Natural Resources and Development 的 Ofelia F. Domingo 教授發表「Technological Innovations in Agricultural Waste Management in the Philippines」論文，內容講述菲律賓在農業剩餘資源的研究發展成果，並要求達到農業經濟利益、社會接受的技術及策略直到農業及環境問題解決。

四、第三節主題：農業剩餘資源經營的經濟及政策觀點(Session 3：Economic and Policy Aspects of Agricultural Waste Management)。第一篇由泰國 National Science and Technology Development 的 Warinthorn Songkasiri 教授發表「Community Practice - Sustainable Cassava Value Chain through Knowledge and Technology Transfer in Thailand, Cambodia, Lao PDR,

Vietnam, and Myanmar」論文，內容講述永續的樹薯生產鏈的技術輸出在泰國、柬埔寨、菲律賓、越南及緬甸的應用及支援協助樹薯的全球綠色食物資源在全球市場。第二篇由印尼 Department of Resource and Environment Economics 的 Yusman Syaukat 教授發表「Economic Aspect of Sustainable Agricultural Waste Management Strategies in Indonesia： A Case Study of Oil Palm and Sugarcane」論文，內容講述印尼在油棕及甘蔗農業剩餘資源經濟面向方面的永續策略。第三篇由越南 Institute for Agricultural Environment 的 Tran Van The 教授發表「Barriers and Policy Gaps for Utilization of Agricultural By-products and Waste for Sustainable Food P： roduction in Vietnam」論文，內容講述越南農業副產物及廢棄物在永續食物生產利用的政策。

五、第四節主題：主題討論–增加農業剩餘資源永續收入及經營之挑戰與解決辦法(Session 4：Panel discussion： Waste Management for Increasing Sustainability and Income – Challenges and Solutions。由馬來西亞 Market Intelligence & Agribusiness Research Centre 的 Mohd Rashid Rabu 主任擔任主持人，邀請業者 Integrate Organic Farming 集團的執行長 Anthony Wong 發表「Integrated Organic Farming (IOF)： Close Loop System/Circular Economy」及行政院農業委員會氣候變遷調適及淨零排放專案辦公室傅子郁執行秘書發表「Towards Net-Zero： Taiwan's Pathway to a Carbon Neutral and Circular Agriculture」並參與討論農業剩餘資源永續經營利用之挑戰與解決辦法。

此次奉派參加FFTC與MARDI及DOST-PCAARRD於馬來西亞合辦之「Agricultural Waste Management for Sustainable Food Production」國際研討會，透過此機會瞭解各國循環農業、農業剩餘資源的研究議題及方向，同時也比對各國相關領域之研究設備，積極認識各國研究

人員及研究團隊，藉此讓農委會相關團隊及研究人員與各國技術交流，同時並拓展及推動未來更多國際合作之機會，並藉由此次研討會的技術交流及精進科技研發，達成與國際循環農業及淨零政策接軌。淨零排放屬新興議題，我國農業部門之淨零排放策略規劃快速且完善，透過於本次國際研討會與亞洲各國專家互相分享交流，有效提高國際能見度之效，未來除應加大資源投入農業淨零排放科技研發與政策誘因機制設計外，也應持續積極參與國際鏈結相關事務，包含能力建構與人才培育、參與或辦理國際研討會、雙邊/多邊交流或啟動國際合作專案等項目，以期未來我國農業部門可成為永續技術服務的提供者，並作為其他國家農業淨零排放政策規劃之楷模。

肆、 照片附錄

此次參加「Agriculture Waste Management for Sustainable Food Production」國際研討會由 FFTC 張淑賢主任主持(圖 1)，計有馬來西亞、臺灣、韓國、日本、菲律賓、泰國、印尼、越南等 8 國（圖 2-8）合計一百多位學者及專家參與交流；本次會議後進行業界參訪行程，包含金馬崙高原 (Cameron Highlands)的 PJ Eco Recycling Plaza 參訪其農業資源循環零廢棄物技術應用之商店（圖 9-12），MARDI 有機農場的試驗內容及沼氣的試驗成果（圖 13-16）及 Chitose Oriental Lilyh 園區了解其如何將蔬果廚餘盡其使用（圖 17-20），達農業資源循環零廢棄物之作法進行經驗分享及技術交流。

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<tr><td>圖 3. 菲律賓 DOST-PCAARRD ReynaldoV. Ebora 博士致詞</td><td>圖 4. 研討會講者及來賓合影</td></tr>
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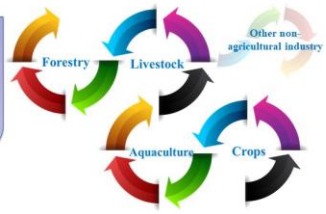
伍、 口頭報告簡報


Towards Net-Zero:
Taiwan's Pathway to A Carbon Neutral Circular Agriculture
Climate Change Program Office
Council of Agriculture, Executive Yuan
Outline
1. Net-Zero Strategies in Agriculture Sector
2. Encourage Circular Agriculture
3. Conclusion
2
Net-Zero Emissions in Taiwan's Agriculture Sector by 2040
1. Reduce Carbon Emission
2. Enhance Carbon Sink
3. Circular Agriculture
4. Green Trend
4
GHGs Emissions in Agriculture
In 2020, the agricultural sector emitted 6.4 million tonnes CO_2e of GHGs, accounting for 2.22% of the total.
By Emission Sources
By GHG Gases
3
Net-Zero Emissions in Taiwan's Agriculture Sector by 2040
Goal of 4 pillars
50% Reduction of agriculture GHG emissions from 2005(bas year) by 2040
Zero-waste agriculture & more than 1,000 cross-industry circular agricultural plants/factories by 2040
Reduce Carbon Emissions
Enhance Carbon Sinks
Encourage Circular Agricultur
Promote Green Trend
Additional 10 Mt CO_2-e carbon sink annually by 2040
100% self-sufficient green electricity in rural villages by 2040
5
Circular Agriculture
1. Turning agricultural residual resources into value-added materials and energy
2. Promoting cross-regional agricultural recycling demonstration sites
3. To promote technology research and development of the circular agriculture
6

Establish Cross-industry Business Viable Models

Technology of Changing Agricultural Wastes into Resources

- Manure reuse
- Bio-energy from agricultural wastes
- Biochar production & application
- …



Build cross-disciplinary circular agriculture demonstration sites

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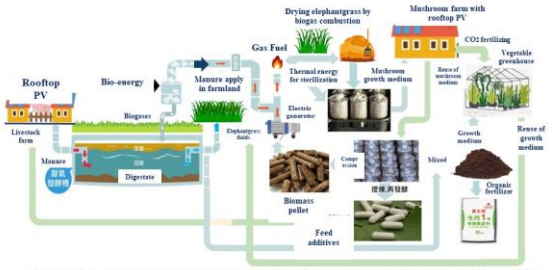
Circular Agriculture Models



Encourage circular agriculture cooperation among countries, enterprises, and sectors

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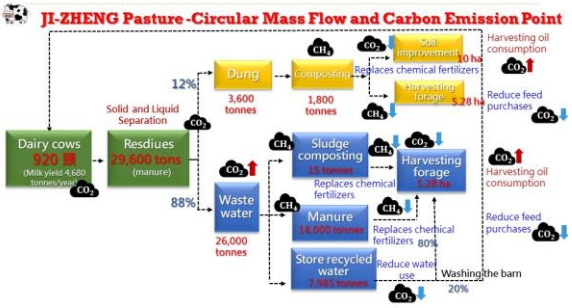
Circular Agriculture Case -Livestock

JI-ZHENG Pasture -Circular Mass Flow and Carbon Emission Point



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Circular Agriculture Case -Forestry

Wood — Cui-Feng Mountain House

Bamboo — Luo-Shan Bamboo Forest

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Circular Agriculture Case-Biochar Applications

Soil Carbon Sinks

- Biochar applied in crop field.

- Development of soil microorganism & additives.

Build cross-disciplinary circular agriculture demonstration sites

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Biogas Reuse in Livestock Farms

12

Conclusion

The circular agriculture must take into account the interactions between agricultural production, life, and ecology.

1. Various recycling efforts may involve the adjustment of national laws and regulations.
2. Cross-regional cooperation is the core of the circular agriculture.
3. Every link in the supply chain of the whole industry should be integrated with circular thinking.
4. To improve the reuse rate of agricultural residues and maximize the benefits of the circular economy is the most important issue.

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Thank You

COUNCIL OF AGRICULTURE
EXECUTIVE YUAN

陸、發表報告內容

Towards Net-Zero: Taiwan's Pathway to A Carbon Neutral and Circular Agriculture

Jhao-Yin, LIN and Tzu-Yu,FU*

Climate Change Program Office, Council of Agriculture, Executive Yuan, Taiwan

*Corresponding e-mail: tzuyufu@mail.coa.gov.tw

ABSTRACT

The "Taiwan's Pathway to Net-Zero Emissions [of Greenhouse Gases] in 2050" was announced on March 30, 2022. This pathway is built upon four major transformations: energy, industry, life, and society, supported by two essential governance foundations: technology research and development, and climate legislation. These are further supplemented by "12 Key Strategies". In February of last year (2022), Taiwan's agricultural sector proposed an ambitious goal to achieve net-zero emissions by 2040, ten years ahead of the national target. The roadmap to reach net-zero emissions in the agricultural sector comprises four pillars: reducing carbon emissions, enhancing carbon sinks, promoting circular agriculture, and fostering green trends. Given that Taiwan faces the challenge of lacking natural resources while generating significant amounts of agricultural waste simultaneously, it is crucial to improve the reuse rate of agricultural residues and maximize the benefits of the circular economy associated with those residues. This can be achieved through research and development of agricultural recycling technologies, as well as the refinement of relevant processes. By turning agricultural residues into materials and energy for other valuable usage, we can effectively recycle and reuse more available agricultural residual resources. To facilitate the recycling of agricultural residual resources, it is essential to establish recycling demonstration sites, as well as economically viable distribution channels and business models. Future efforts will involve fostering cross-country and cross-enterprise cooperation.

Keywords: Net-Zero Emissions, Greenhouse Gas and circular agriculture

FOUR PILLARS SUPPORTS AGRICULTURE SECTOR TOWARDS NET-ZERO EMISSIONS

Climate change and its impacts has long been a hot issue in seminars, forums,

workshops, symposiums and COPs. Nevertheless, only a few countries really did fast and specific reactions to fight or slowdown the impacts caused by climate change. According to Working Group III Contribution to The IPCC Sixth Assessment Report (AR6), global net GHG emissions were 59±6.6 Gt CO_2-e in 2019, about 12% higher than in 2010 and 54% higher than in 1990. The annual average during the decade 2010–2019 was 56±6.0 Gt CO_2-e, which is 9.1 Gt CO_2-e higher per year than in that of 2000-2009. This is the highest increase in average decadal emissions on record. Currently, there are more than 130 countries have declared their determination to reach net-zero emissions by 2050. Taiwan is of course one of them. In March 2022, Taiwan officially published Taiwan's Pathway to Net-Zero Emissions in 2050, which provides the action pathway to achieve "2050 Net-Zero Emissions". The blueprint aims to promote technology R&Ds and innovations in key areas, green transition of industry, and drive a new wave of economic growth. At the same time, it looks forward to promoting green financing and increasing investment at various key milestones.

In order to specialize in adaptation and mitigation issues of climate change in agriculture sector, the Council of Agriculture set up Climate Change Program Office (CCPO) on September 1, 2021, Last year (2022), in February, Taiwan's agriculture sector proposed an ambitious goal that agriculture sector will reach net-zero emissions by 2040, which is 10 years earlier than the national goal. The roadmap to Net-Zero Emissions in agriculture sector includes four pillars: reduce carbon emissions, enhance carbon sinks, encourage circular agriculture, and promote green trend. There are 19 strategies with 59 measures covered under the 4 pillars. Among the four pillars of policy, circular agriculture appears to be most promising in terms of its potential to reduce Greenhouse Gas(GHG) emissions and enhance carbon sinks simultaneously.

ENCOURAGE CIRCULAR AGRICULTURE

Bio-energy and bio-based solutions could be important opportunities for mitigating impacts of climate change. The solid wastes generated from agriculture sector amounted to 4.92 million ton (Mt) with well-treatment rate of 99.7 % in 2020. The quantity reduced by 3 % and treatment rate increased by 4.7 % compared with 10 years ago, 5.02 Mt and 95 % in 2001, according to the data announced in Taiwan's Environmental-Economic Account. The wastes will be no longer wastes if they can be reused and recycled appropriately, they will become renewable resources. Most of the wastes from agricultural sector are bio-derived resources. They could be recycled as ingredients, raw material of other products, or transformed into bio-energy.

Bio-energy and bio-based products provide additional mitigation by the substitution of fossil fuels and fossil-based products. Under this pillar, 3 strategies with 12 measures have been identified for a zero-waste agriculture in Taiwan by 2040. Three strategies include " **turning agricultural residual resources into value-added materials and energy** ", "**promoting cross-regional agricultural recycling demonstration sites**" and "**to promote technology research and development of the circular agriculture**".

Turning agricultural residual resources into value-added materials and energy

In the past, most of agricultural residues were treated on site, with methods such as tilling and burying straw or residual materials on the ground, burning or making compost and bedding, etc. Nowadays, the residual resources are moving towards the reuse of fiber materials (for example, banana and pineapple fiber extraction technology) and the reuse of planting sludge in the same or different industries after wastewater treatment. Appropriate reuse of agricultural wastes possesses high mitigation potentials. The COA encourage livestock famers reuse the pig droppings for power generation and helping them to enhance the conversion efficiency. The biogas residues were recycled as organic fertilizer. Crop and forestry residues are also ideal ingredients of organic fertilizers or the feedstocks of biochar. Biochar is produced by heating organic matter in oxygen-limited environments with byproducts such as wood gas, pyroligneous acid and tar. It is estimated to persist from decades to thousands of years when biochar is applied into soil. Soil application plus bioenergy gives greater mitigation contribution than bioenergy alone. Taiwan is now conducting a guideline for biochar quality control and its application.

Agricultural by-products and residual materials include agricultural film, waste mushroom bags, bamboo forest extracts, and shellfish waste. New products are developed using the waste, such as shellfish waste made into oyster shell powder, tea processing products used in animal production, pet bedding, or cultural and creative goods, etc. The diversified use of agricultural by-products can expand the development of the circular agriculture industry.

The treated wastewater produced by the anaerobic fermentation of manure from the animal production can be used to irrigate farming, and reduce the use of chemical fertilizers; the digestate can be made into organic compost to revitalize farmland.

The reuse of biogas generated from livestock manure and urine and the generation of

electricity can increase agricultural green electricity and supply it to farms for self-sufficiency, enhance the efficiency of biogas utilization, expand the field of implementation and increase the efficiency of utilization, which can effectively achieve the effect of creating green energy and reducing carbon at the same time.

The development of decomposable agricultural materials, including seedling paper trays and tea seedling pots, will promote decomposable agricultural materials to reduce the waste of materials and save resources to achieve the function of environmental protection and resource reuse.

Promote cross-regional agricultural cycle demonstration areas

Taiwan is promoting the demonstration site of cross-area recycling in agriculture and the operation model of residual resources collection, with the aim of turning residual materials into gold through cross-area recycling. To promote livestock manure to provide biogas for power generation and other applications, as well as to expand the cross-regional recycling circle, and to expect more industries to join in the agricultural recycling economy to face the important work of climate change and net-zero emissions.

Circular agriculture should be a co-benefit and economically viable before its scaled application. This strategy tries to build cross-industrial business model for reusing the agricultural residues efficiently and economically. A total of more than one thousand plants/factories are expected by 2040.

The Council of Agriculture has set up a total of 10 or more demonstration sites for cross-regional circular agriculture in 2022. The purpose of cross-regional circular agriculture is to re-generate new economic values from agricultural by-products and surplus materials, not only for internal circular farming, but also for cross-regional, cross-business and cross-ministerial cooperation, so that agricultural resources can be reused and live on.

The agricultural residual resources operation model is to establish a cross-field operation model with livestock manure on the ground to recycle pasture, fruits and vegetables, rice fields, orchards, and aquaculture models. The Council of Agriculture expects to establish a circular low-carbon demonstration field and agricultural residual resources operation model by 2035, with a closed biological recycling rate of 90% in the park.

Agricultural residual resources require cross-country, cross-enterprise and cross-ministry cooperation to jointly meet the balance between the demand and supply sides. Cross-national agricultural recycling can conduct technical visits and exchanges, and cross-enterprise technical cooperation can be combined with industrial sectors such as energy, manufacturing, transportation or construction industries to integrate cross-regional reuse of surplus materials, spanning the supply chain and application of agricultural recycling.

To promote technology research and development of the circular agriculture

Detailed calculation of the mitigation contributions and benefits of circular agriculture is very important for its application and promotion, especially when the carbon credits are considered. This strategy focused on the calculation of carbon flux during the process of residues were reusing and/or recycling. Of course, the development of science-based and technology-based approaches are also concerned. For example, climate change brings extreme weather disasters like drought, thus water treatment and management models for livestock and aquaculture fishery are critical. These approaches not only have mitigation potential but also can improve the efficiency of water use, and improve resilience in facing climate change. Therefore, agricultural recycling technology is an important stepping stone for the future circular economy, and supporting the research and development of agricultural recycling technology can expand the scale of the industry. The strategy includes three measures, including "calculating the output and net-zero benefits of cross-regional agricultural recycling economy to promote the development of low-carbon recycling industry," "refining biogas reuse technology to improve the heat efficiency of biogas power generation," and "developing sustainable low-carbon agricultural, fishery, and livestock facilities and water treatment models to reduce environmental pollution.

Most of the livestock facilities in Taiwan's pig industry were built before 1971, and the concept of sustainability has not yet been incorporated into livestock facilities. In recent years, there has been an international trend of developing sustainable and low-carbon agricultural, fishery and livestock facilities. The European Union began to attach importance to animal welfare and biosecurity issues in early years, so the concept of sustainable net zero has been incorporated into the design and construction of barns in the last decade or so. For example, Denmark incorporated the Lego blocks concept into the design of the barn facilities and the 3R's principles of Recycle, Reuse and Reduce, as well as the traceability concept and the idea of traceability from farm to table.

CONCLUSION

The circular agriculture must take into account the interactions between agricultural production, life, ecology and life. Taiwan's Council of Agriculture is considering that various recycling efforts may involve the adjustment of national laws and regulations. In addition, "cross-regional cooperation" is the core of the circular agriculture. In addition, the supply chain is also the key to the success of recycling agriculture. Every link in the supply chain of the whole industry should be integrated with circular thinking.

Forty to fifty years ago, there was no such thing as residual resources in Taiwan's rural areas, as all possible agricultural residues had already been turned into by-product or determined for subsequent use. Given that Taiwan is facing the challenge of lacking natural resources while generating significant amounts of agricultural waste simultaneously, it is crucial to improve the reuse rate of agricultural residues and maximize the benefits of the circular economy associated with those residues. Meanwhile, among the four pillars of policy to reach net-zero emission, circular agriculture appears to be most promising in terms of its potential to reduce Greenhouse Gas(GHG) emissions and enhance carbon sinks simultaneously.

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