

「臺灣氣候變遷推估資訊與調適知識平台」計畫(111-114)

從熱緊迫辨識到智慧調適- 建構臺灣乳牛氣候風險評估與精準調適體系

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畜牧領域四年工作與成果



年度	工作重點	主要成果
第一年	四個代表縣市試算基期、升溫2°C及4°C情境	THI與乳量損失初步圖資彙整9個調適案例
第二年	擴展至全臺危害與衝擊分析推估各縣市乳量損失	全臺THI及乳量損失圖資彙整8個國外調適案例
第三年	生理量測建立本土乳牛群THI門檻值擴充採食量與繁殖衝擊評估	以THI約70為評估基礎乳量、採食量與空胎天數推估
第四年	串接DHI、牧場問卷與設備盤點量化脆弱度與調適能力	逐時THI工具與牧場調適分析氣候風險與調適差距架構

THI：溫濕度指數/THI門檻值：乳牛將明顯感受熱緊迫的數值

DHI：乳牛群性能改良計畫

空胎天數：分娩後到再次受胎之間的時間

四年成果形成乳牛氣候風險評估基礎



4個縣市

區域試算擴展至全臺THI與乳損圖資

THI約70

本土生理量測建立熱緊迫評估依據

3項衝擊

推估乳量、乾物質採食量與空胎天數

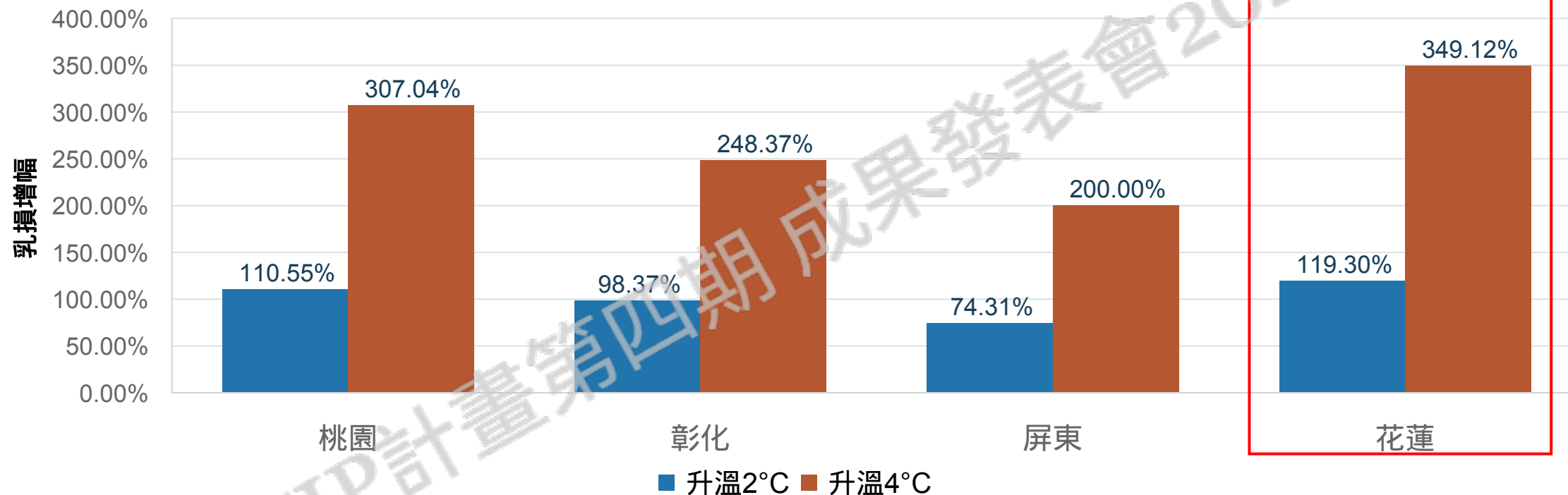
4個構面

建構牧場脆弱度與調適能力指標

第一年：四縣市乳量損失隨暖化增加



模型推估：乳量損失相對基期增加幅度



花蓮增幅最高；另完成9個國內外調適案例彙整

第二年：畜牧領域危害衝擊分析計算



氣候變遷推估資料
HiRAM

- 時間解析度：
 - 日資料
- 資料指標：
 - 溫度

溫溼度指數
THI

- $THI > 72$, 造成乳牛熱緊迫

危害圖 Hazards

- 乳牛持續受到熱緊迫，造成乳量減少

衝擊圖
Impact

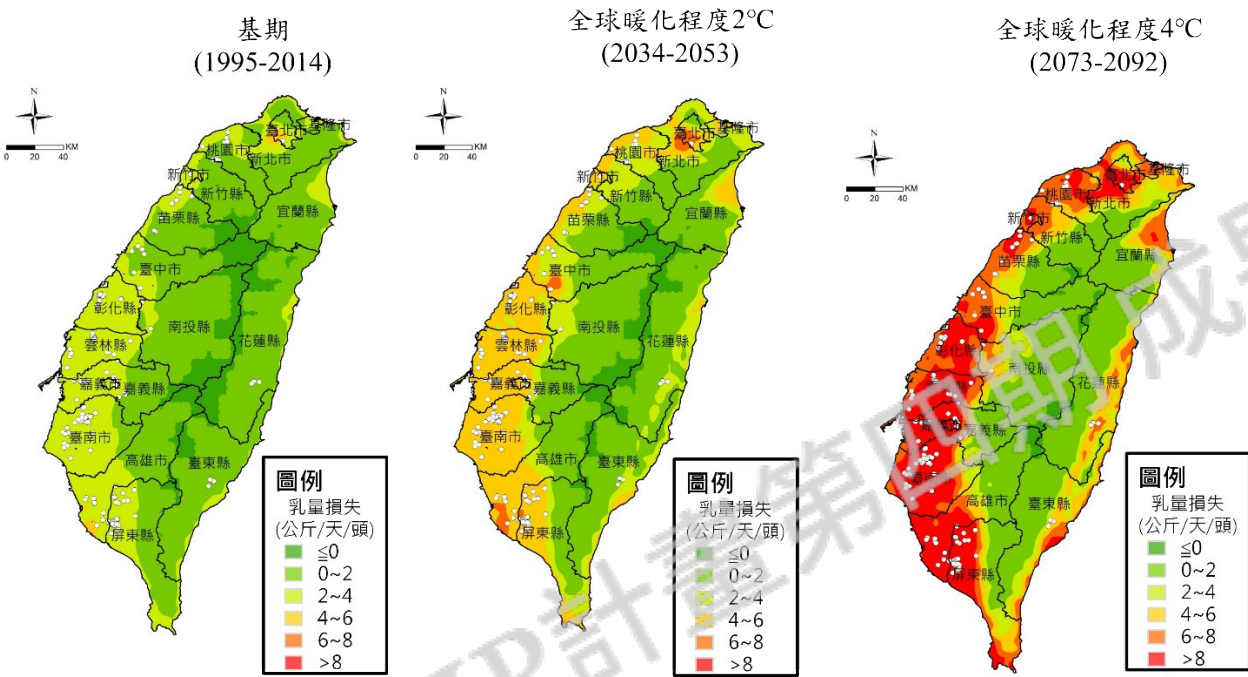
- 繪製未來乳產量損失圖

Longitude 經度	Latitude 緯度	Temperature 溫度(°C)	Relative Humidity 相對溼度(%)	THI
119.2	21.5	22.36	81.59	72.63
119.2	21.55	22.26	81.67	72.46
119.2	21.6	22.18	81.68	72.32
⋮				
119.2	22.95	19.40	76.98	66.59
119.2	23	19.35	77.29	67.27



2050年台南市酪農戶溫溼度指數

第二年：完成全臺乳量損失情境圖資



代表縣市乳損 (公斤 / 頭 / 日)

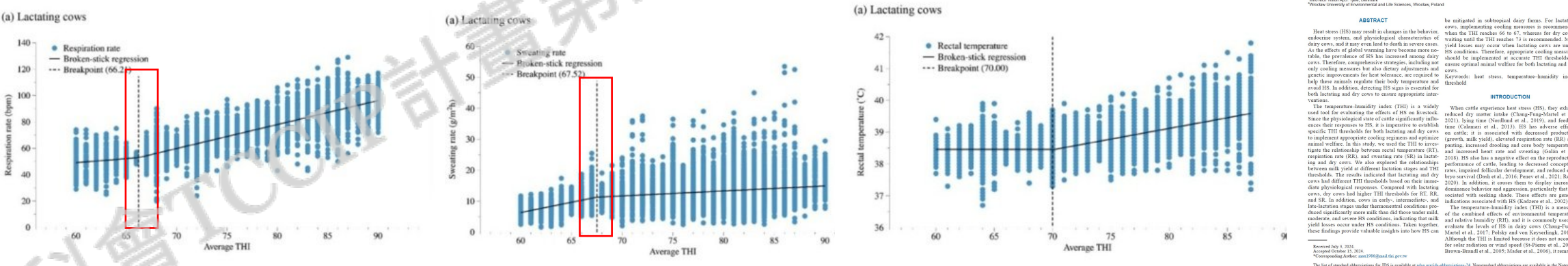
縣市	基期	2°C	4°C
彰化	2.5	4.4	8.0
雲林	2.4	4.0	7.4
臺南	2.5	4.3	7.8

8個國外調適案例
正壓風管改善等待區送風

第三年：生理量測支持本土THI約70閾值



泌乳牛生理反應	THI門檻值	成果意義
呼吸速率	66.21	較早出現熱反應
出汗速率	67.52	反映散熱反應
直腸溫度	70.00	支持本土THI約70評估閾值



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Stage-Specific Milk Yield Losses and Associated Sweating, Respiration, and Rectal Temperature Responses Under Varying THI Thresholds in Lactating and Dry Cows

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ABSTRACT

Heat stress (HS) may result in changes in the behavior, endocrine system, and physiological characteristics of dairy cows, and it may even lead to death in severe cases. As the effects of global warming have become more notable, the prevalence of HS has increased among dairy cows. Therefore, comprehensive strategies, including not only cooling measures but also dietary adjustments and genetic improvements for heat tolerance, are required to help these animals regulate their body temperature and avoid HS. In addition, detecting HS signs is essential for both lactating and dry cows to ensure appropriate interventions.

The temperature-humidity index (THI) is a widely used tool for evaluating the effects of HS on livestock. Since the physiological state of cattle significantly influences their responses to HS, it is imperative to establish specific THI thresholds for both lactating and dry cows to implement appropriate cooling regimens and optimize animal welfare. In this study, we used the THI to investigate the relationship between rectal temperature (RT), respiration rate (RR), and sweating rate (SR) in lactating and dry cows. We also explored the relationships between milk yield at different lactation stages and THI thresholds. The results indicated that lactating and dry cows had different THI thresholds based on their immediate physiological responses. Compared with lactating cows, dry cows had higher THI thresholds for RT, RR, and SR. In addition, cows in early, intermediate, and late-lactation stages under thermoneutral conditions produced significantly more milk than did those under mild, moderate, and severe HS conditions, indicating that milk yield losses occur under HS conditions. Taken together, these findings provide valuable insights into how HS can be mitigated in subtropical dairy farms. For lactating cows, implementing cooling measures is recommended when the THI reaches 66 to 67, whereas for dry cows, waiting until the THI reaches 73 is recommended. Milk yield losses may occur when lactating cows are under HS conditions. Therefore, appropriate cooling measures should be implemented at accurate THI thresholds to ensure optimal animal welfare for both lactating and dry cows.

Keywords: heat stress, temperature-humidity index, lactation, dry cows

INTRODUCTION

When cattle experience heat stress (HS), they exhibit reduced dry matter intake (Chang-Ping-Mand et al., 2021), lying time (Owen et al., 2019), and feeding time (Colburn et al., 2013). HS has adverse effects on cattle: it is associated with decreased production (growth, milk yield), elevated respiration rate (RR) and heart rate, increased rectal temperature (RT), and increased heart rate and sweating (Galati et al., 2018). HS also has a negative effect on the reproductive performance of cattle, leading to decreased conception rates, impaired follicular development, and reduced embryo survival (Dink et al., 2016; Pires et al., 2021; Roth, 2020). In addition, it causes them to display increased dominance behavior and aggression, particularly that associated with feeding shade. These effects are general indications associated with HS (Kadare et al., 2022).

The temperature-humidity index (THI) is a measure of the combined effects of environmental temperature and relative humidity (RH), and it is commonly used to evaluate the levels of HS in dairy cows (Chang-Ping-Mand et al., 2017; Polak and von Keyserlingk, 2017). Although the THI is limited because it does not account for solar radiation or wind speed (St-Pierre et al., 2003; Brown-Brandl et al., 2005; Mader et al., 2006), it remains

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The list of animal observations for THI is available at data.sciencemag.org/doi/10.1126/sciencemag.1234567. Nomenclature abbreviations are available in the Notes.

第三年：量化七個產乳縣市的乳量損失



未調適情境推估（公斤 / 頭 / 日）

產乳縣市	基期	升溫2°C	升溫4°C
桃園	4.50	6.42	9.05
彰化	6.92	9.75	12.91
雲林	6.36	8.94	12.05
嘉義	4.48	6.43	8.94
臺南	7.88	10.81	14.55
高雄	4.21	5.90	8.28
屏東	5.09	7.11	10.01

193-354元

升溫2°C每日乳值損失

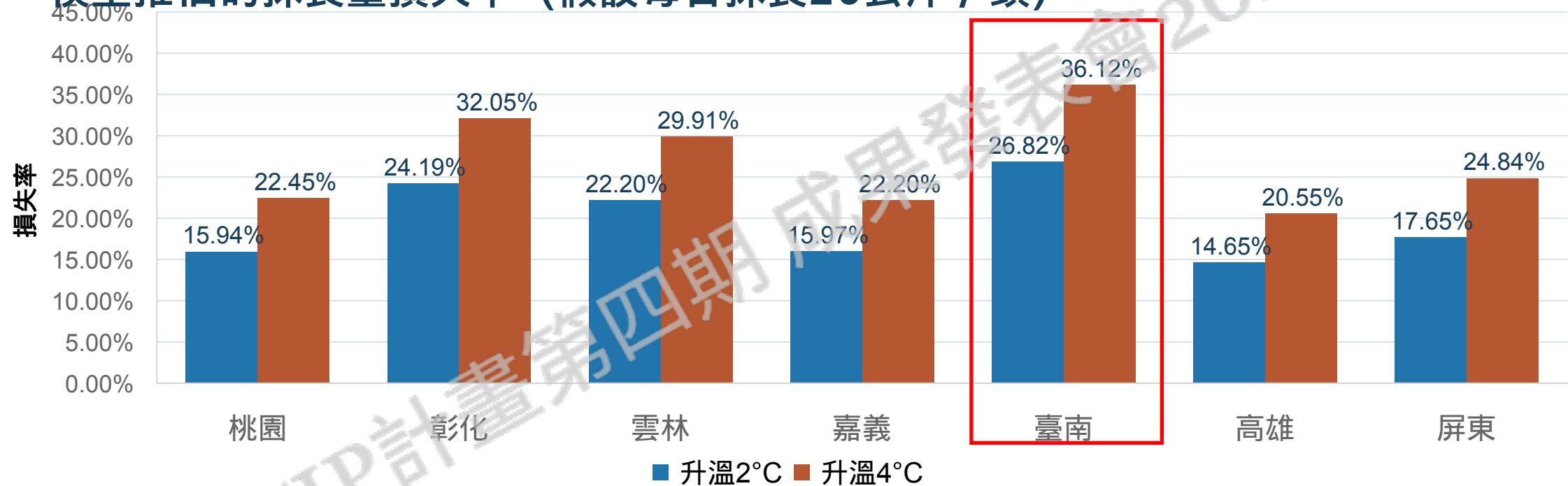
271-477元

升溫4°C每日乳值損失

第三年：暖化加重乾物質採食量損失



模型推估的採食量損失率（假設每日採食20公斤 / 頭）

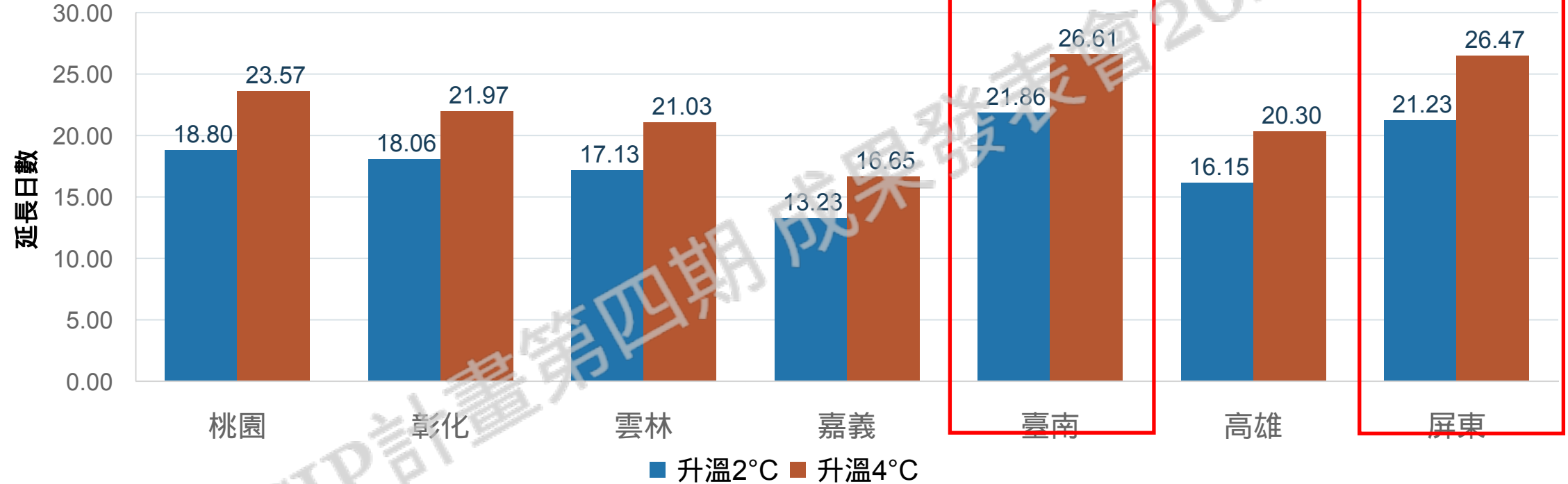


臺南升溫4°C損失7.22公斤 / 頭 / 日，模型損失率36.12%

第三年：繁殖衝擊以空胎天數延長量化



未調適情境推估：空胎天數延長（日）



升溫4°C推估延長16.65-26.61日，臺南與屏東較高

第四年：逐時THI工具與DHI資料串接



氣象測站基本資料-有人氣象測站基本資料

JSON XML API

氣象測站基本資料-無人氣象測站基本資料

JSON XML API

<https://opendata.cwa.gov.tw/dataset/climate/C-B0074-001>

最近測站代號	觀測日期	當日平均THI	當日最大THI	Dvalue	採樣日期
467050	2024/1/11	56.99	60.86	0	2024/1/14
467050	2024/2/15	64.04	71.56	4	2024/2/18
467050	2024/3/12	61.67	66.7	0	2024/3/15
467050	2024/4/12	73.31	75.66	24	2024/4/15
467050	2024/5/12	76.2	80.7	24	2024/5/15
467050	2024/6/11	81.09	83.55	24	2024/6/14
467050	2024/7/12	82.79	85.41	24	2024/7/15
467050	2024/8/11	81.92	84.9	24	2024/8/14
467050	2024/9/9	80.74	84.45	24	2024/9/12

配對牧場與最近測站

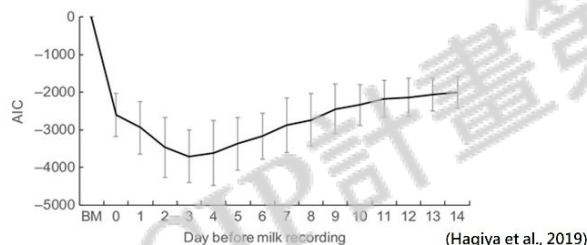
下載測站歷史資料
(DHI採樣日期前三天)

逐時計算當日平均THI
及最高THI

結合DHI資料統計分析

延遲效應

採樣日前3天發生的熱緊迫對乳牛
產乳量的影響最大。



逐時熱暴露

區域與時段查詢

SHP圖資輸出與平台訓練

採樣前3日 $THI \geq 70$

配對最近氣象測站

串接DHI與場內冬季乳量基準

第四年：牧場脆弱度指標涵蓋四個構面



脆弱度構面	已納入的牧場特徵
生物敏感性	品種、胎次、泌乳階段與疾病負擔
物理環境	畜舍、飼養密度與飼料穩定性
調適能力	降溫設備、環境監控與智慧管理
社會連結性	DHI、訓練、輔導及合作社參與

調適能力量表 α 接近0.7

標準化指數串接乳損分析；風險感知量表仍需修訂

第四年：設備盤點示監控與調適差異



36.36%

調查樣本未設環境監控

41.82%

調查樣本配置溫濕度感測器

報告觀察：感應式或AI控制牧場，夏季乳損較低

設備盤點已串接生產分析，支援調適需求辨識

畜產試驗所勇奪亞太暨台灣永續行動獎金級榮耀



- 畜產試驗所研究團隊針對氣候變遷對畜牧產業的影響，運用天氣預測模型與大數據分析，實踐聯合國永續發展目標（SDGs）。
- 評估未來氣候情境下的溫濕度指數（THI）變化，預測全國乳牛熱緊迫的泌乳量損失。
- 透過地理資訊系統（GIS）將數據視覺化，提供政策制定依據。
- 進行多項技術移轉與輔導產業，提升乳牛的生產效率並降低國產鮮乳的成本。





文字框 2 | 精準畜禽飼養管理：數位農業於乳牛場之應用

數位農業於乳牛場之應用：

面對氣溫逐年升高的氣候變遷，乳牛因熱緊迫造成乳量下降之威脅越趨嚴重，除畜舍等降溫設備改善外，面對乳牛夏季採食量降低及飼糧易酸臭等現場問題，少量多餐的餵飼方式是目前國內酪農戶積極努力的方向。面對牧場勞力短缺，如何達到少量多餐的餵飼方式，是目前亟待解決的問題。

引進國外自動餵飼系統，可精準投料分群飼養所需的營養配方，由送餐車依送餐排程送料，提供乳牛少量多餐的餵飼模式。臺灣經濟研究的經濟效益評估，投入1300萬之自動化餵飼設備，於餵飼630頭泌乳牛之情況下，節省柴油35,000公升/年，節省飼料成本540,000元/年，增加產乳量223,200公斤/年。



圖BOX4.4.2.1 自動餵飼系統及電動餐車送料
(資料來源：農業部畜產試驗所)

四年成果整合為氣候風險與調適評估架構



風險構面	四年研究已建立的成果
危害 H	本土乳牛群THI熱緊迫門檻值、逐時THI工具與暖化情境圖資
暴露 E	產乳縣市分析與牧場、DHI資料串接
脆弱度 V	四構面指標、設備盤點與調適能力分析

應用基礎：辨識高熱負荷區域與牧場調適需求

下一步：調適作為量化及評估調適效益

謝謝聆聽 敬請指教

TCCIP 臺灣氣候變遷推估資訊與調適知識平台
Taiwan Climate Change Projection Information and Adaptation Knowledge Platform

NSTC 國家科學及技術委員會
National Science and Technology Council

NCDR 國家災害防救科技中心
National Science and Technology Center
for Disaster Reduction



農業部畜產試驗所