中文摘要

農地過度施用化肥，使表土和地下水的氮素濃度大增，嚴重污染農業環境。本研究以重視環境整體相互運用的生態工程角度，設計高調控酪農場氮素流動的經營策略，探討包括馬可夫觀測器參數估測、數位適應控制系統設計和季節或暴雨時的氮流濃度變化。因此，文中以南投草屯一家酪農場中由乳牛舍、乳牛及飼料等組成的「乳牛庫」，由肥料、蘭尾草等組成的「牧草庫」，及由水塘、微生物等組成的「池塘庫」，此三庫中氮流濃度變化為我們分析該酪農場的三個狀態變數。池塘庫可視為廢水處理的功能，以去除氮酸鹽、BOD(生物需氧量)及減少氮流濃度。成熟的牧草當成乳牛主食，乳牛糞尿經池塘發酵後提供牧草田當有機肥，「氮素」是三庫共同營養質並相互作用流通。

一年半草屯酪農場現場調查為基本輸入資料。三庫交互關係乃以離散狀態空間描述法推導一動態數學模式，並以此系統模式可做為分析及預測氮流動態行為。因考慮氮流在取樣上具有隨機性與傳輸的延遲性，數位控制系統的設計可易於數值計算，且戶外環境多變存在不確定性，本研究乃以馬可夫鏈建立其序率動態數學模式，以模擬氮素的動態性。在模式假設中牛糞放流口，均在酪農戶農地內且氮素只以總氮表示，牧草全部當成乳牛主食等以作簡化。乃針對酪農場牛糞廢棄物及牧草田所產生的生物質量的綜合運用，基於永續發展並合理地使用可更新資源的觀點。

本文主要以農業生態學的觀點，使用狀態變數參考模式的適應控制(state variable reference model adaptive control)理論，使酪農場系統在不確定因素干擾或不穩定時，具足夠追蹤能力而達成穩定，其中使用遞迴最小平方法(Recursive Least Squares, RLS)以實施線上(on line)的馬可夫觀測器最佳估測參數，使生物系

統能“加強”高度調控能力，以朝向高度生物調控(biological cybernetics)之酪農場。此生物系統是考慮連繫生物與適應控制系統設計二者來達成，此控制律是建立在當時間無窮大時，可極小化線性二次成本函數。其控制目的乃針對酪農場中，當實施乳牛糞有機肥灌溉時可極小化殘氮污染到鄰田，所推求的適應控制系統。

模擬結果顯示，本文所提出的適應控制中三庫的氮流，因不同庫別間的生物系統反應，而呈現互為消長的動態關係。在系統出現蟲害、地下水污染等干擾時，馬可夫適應估測器結合PI控制器後，具有即時估測及濾波等特性。經估測及控制的反覆進行中實施濾波過程，而追蹤至參考模式。當適切地調變所設計的增益矩陣權重改變，對酪農場中殘氮濃度，能達令人滿意的調控效果。本模式為依賴生態系統、營養源信息和適應控制，對複雜農業生產系統進行朝高調控的新嘗試，以草屯酪農場模擬顯示出農業生態控制發揮出優越而強韌的效果。

關鍵詞：酪農場；庫；控制學；不確定性；適應控制；狀態變數；馬可夫觀測器；遞迴最小平方演算法；農業生態控制

Abstract

The excessive use of fertilizers in farms leads to nitrogen flow concentration severely accelerating in surface and ground water; a more complicating and uncertain aspect obviously exists in crops -environment systems. A highly cybernetic strategy for nitrogen flow concentration in livestock industries was derived from the viewpoint of ecosystem engineering. The research involves the Markov observer parameter estimation, digital adaptive control system design and the change of nitrogen flow concentration resulted from seasonal variations.

A dairy farm located at Tsao-Twen (referred to as TT dairy farm) in south Taiwan was employed as the study farm that is consists of a“dairy pool”representing dairy house, dairy and feed; a“pond pool”representing pond, microbiology activity; and a“pasture pool”representing fertilizers and Lan-Wei grass. The nitrogen flow as a nutrient in dairy, pasture and pond pools are chosen as system state variables. The pond pool presents the wastewater treatment to remove nitrate, biological oxygen demand, and generally reduced nitrogen flow concentration. The pasture was fed on organic fertilizer from the dairy’s excrement after entering the pond to ferment and the dairy takes mature pasture as the main food source. To illustrate the procedure, Markov chain is applied to describe the dynamic change of nitrogen flow by using stochastic model. The assumptions inhered in the analysis including dairy sewage effluent is disposed inside the farm, nitrogen is represented by the total nitrogen, and the dairy’s main food source is pasture.

It is an integrating and sustainable development idea in using the dairy’s manure and pasture’s biomass. The dynamic mathematical model is used in describing the three pools, and in employing the discrete state-space representation that through up to one year field investigation in TT dairy farm. The major advantage of modeling a

system allows us to predict the behavior of nitrogen flow in the three pools before it is not built completely. In addition, a digital control system as digital storage and delay is employed. We concerned with the numerical manipulation of data in sampled from nitrogen flow associated with random phenomena and transport with delay. This research use reference model adaptive control to make easier in attaining the stability when disturbances arises. Recursive least squares in Markov observer parameter estimation could be used on line and it also make an agroecological system towards the highly biological cybernetic ability by connecting biology and the design of adaptive control system. The control law is based on minimization of an infinite time linear quadratic cost function with state variable reference model. The purpose of control is to reduce the disturbances in the residual nitrogen, eventually avoids the pollution impact on the neighbor farmlands.

Results demonstrate the nitrogen flow of three pools presenting the dynamic behavior under the adaptive control system and Markove adaptive observer associated with PI controller has the ability of estimation in real time and of filtering as the pest occurs or underground water is been polluted. Tracking reference model was attained closely, as practices estimation and control repeatedly. When suitable tuned, give satisfactory control of residual nitrogen concentrations in dairy farm. Based on the ecosystem and information system in terms of the nutrition and adaptive control theory, the highly cybernetic model is a novel idea for the complicated agricultural production and reveals that agricultural ecosystems control give excellent and robust effect in the TT dairy farm.

Keywords: Dairy farm; Pool; Cybernetics; Uncertainty; Adaptive control; State variable; Markov observer; RLS algorithm; Agricultural ecosystems control.