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A Neural Network Approach to a Spatial Production System case for milk production

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Grass Black Box.

A Neural Network Approach to a Dairy Farm Production System

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1. Introduction

The usual conceptualisation of a dairy farmer production system involves three interrelated production systems: a feed production function which inputs are fertiliser, land, weather, machinery and labour; a cattle production function based cows, feed - bought or produced - machinery and labour; and a conversion production system that generates milk and beef.

The aim of this paper is to conceptualise the dairy farm production system in only one system using a neural network's mechanism with the whole set of inputs (fertiliser, land, weather, feed, cows, machinery and labour) and with only one output, milk.

In point 2 we review the concept of agricultural production systems. Along point 3 we systematise some models of agricultural systems. Point 4 explains the fundamental ideas related to neural networks. Point 5 calibrates a neural network model to the milk production in Terceira Island.

2. Agricultural Systems

System analysis reflects and holistic view of the reality through which the complexity of the system stems from the interaction between the various components. According to Caldwell (1994), an agricultural system represents a reasonably stable standard behaviour of farm and non - farm activities. It is managed taking into account available resources and pre defined aims, through a set of well defined cultural practices and restricted either by the internal behaviour of the system or by the biophysical, socio cultural, economic and institutional surrounding environment. Being so the agricultural activity involves different knowledge fields, and its whole behaviour is not properly understood whenever each subsystem is analysed detached from the others (Braga et al., 1997).

A cattle system can be represented by three interrelated sub systems (Hodgson, 1990): Vegetal growth (which result from resources such as soil, weather, and crops); animal consumption; and conversion into animal products (beef, milk, wood). Useful indicators are the productivity, stability and sustainability of the system (Pearson e Ison, 1987).

3. Agricultural Simulation Models

A model is a useful personal interpretation of a perception about the reality (Wilson, 1984, cited by Pearson e Ison,1987). Simulation models are simplifications of the real interactions between the various components of a system which, nevertheless, can give useful views and practical information (Braga et al., 1997) for farmers, extension services and researchers (Pearson e Ison, 1987). They can be systematised according to their uses: management or

research models (Jørgensen, 1994); and taking into account the scale of the approach (crop, farm, region, global) Braga et al. (1997).

4. Neural Networks Models

Neural networks are like different arrangements of simple artificial neurones, which try to reproduce - at least to some extent - the structure and the adaptative learning of human beings (Herbert Simon, 1945).

The usual model neuron (i) (Santin Alves e Pasquareli, 1997) computes, at time t, a logistic function $[g(h_i)]$ - with a parameter (β) - of a weight (${}^t w_{ij}$) sum of its inputs (${}^t V_j$) from other units $[h_i = \sum_j {}^t w_{ij} {}^t V_j]$, and outputs the resulting signal of that function (${}^{t+1} V_j$), for time (t+1).

$$(1) \quad {}^{t+1} V_j = g(h_i) \quad \text{where,}$$

$$(2) \quad g(h_i) = 1 / [1 + \exp(-2 \beta h_i)] \quad \text{and,}$$

$$(3) \quad h_i = \sum_j {}^t w_{ij} {}^t V_j$$

The learning process is done by updating the weights (${}^t w_{ij}$)¹ according to some rule that could induce final outputs to converge with predefined targets (O_j)

The use of these neural networks has spread through many fields (signal prediction, optimisation, image recognition, fitting functions and curves).

The statistical question (Jørgensen, 1994) we are interested to solve is to disguise a suitable mechanism to reproduce the quantity of milk as a function of different variables (fertiliser, feed, cows, land,...).

In a experience conducted in Kentucky (USA) Shearer et al. (2000) concluded that neural networks are a promising tool to predict the spatial variability of agricultural productions.

5. Model Calibration

Data used on this model came from (21 farms x 3 years) observations obtained from accountancy farm records from Terceira Island. The data used in the calibrations are synthesised in Table 1. The results are presented in Figures 1, 2 and 3.

Table 1: Synthesis of the Data Used in the Model Calibration

	Year	Area	Cattle	Fertil.	Feed	Vets	Fuel	Milk	Farm
		Hectare	Number	1000 PTE	1000 PTE	1000 PTE	1000 PTE	1000 PTE	

¹In the case of multi-layer feed-forward networks - used in this subsection - the algorithm that can be applied to update the weights is called back propagation procedure. It is described in (Hertz, Krogh & Palmer, 1991, pp.120) and it includes the following steps:

a) Compute a measure of distance (δ^0_j) between the predefined target (O_j) and the actual final output (${}^t V_j^f$):

$$(1) \quad \delta^0_j = g'(h_i)[O_j - {}^t V_j^f]$$

where $[g'(h_i)]$ is the derivative of function $g(h)$ which, in this case, is equal to $[2\beta g(1-g)]$;

b) Compute the measures of distance (δ^{m-1}_j) for all layers (m-1) and for every unit, using the formula:

$$(2) \quad \delta^{m-1}_j = g'(h^{m-1}_j) \sum_j {}^t w_{ij}^m \delta^m$$

c) Update the weights (${}^t w_{ij}^m$) using the expression:

$$(3) \quad {}^{t+1} w_{ij}^m = {}^t w_{ij}^m + \eta \delta^m_j {}^t v_j^{m-1}$$

Average		28	60	833	3319	472	586	9757	
STD		12	27	602	2935	555	312	6202	
MIN	1996	12	24	91	77	38	194	2463	1
MAX	1999	51	123	3721	16143	2914	1724	32063	21

Figure 1

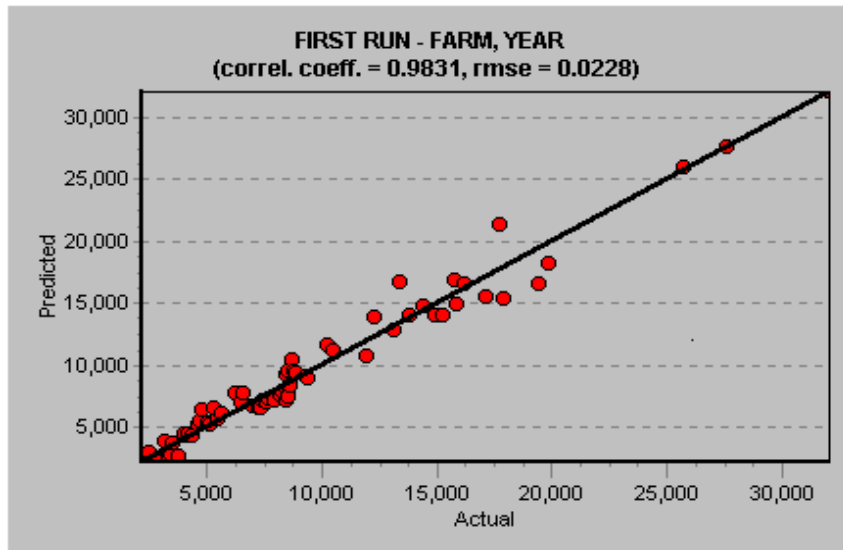


Figure 2

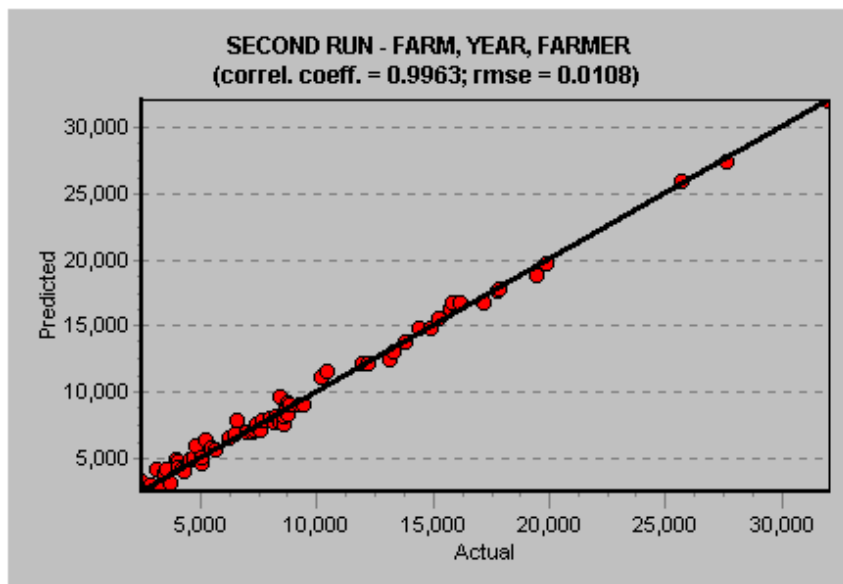
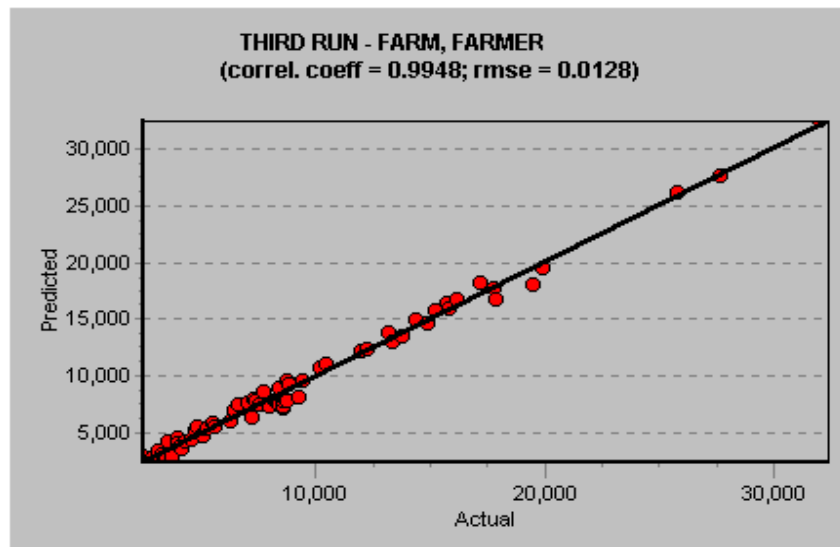


Figure 3



The minimum error is obtained when we considered the Farm, the Year and the Farmer and active explanatory variables. Other tests and data should be done in order to improve the quality of this first attempt to create a management regional model for Terceira Island dairy production.

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