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A Mixed Integer Linear Programming Machinery Selection Model for Multifarm Systems

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An integrated program, called MULTIPREDIO, was developed at University of Guanajuato and University Polytechnic of Valencia using mixed integer linear programming linked to several databases contained in spreadsheets to select agricultural machinery for a multifarm system. The program selects the machinery set for each farm, which corresponds to the lowest annual mechanisation cost of the multifarm system through time. The input information consists of variable and fixed costs for 12 yr from the multifarm, the schedule of operations and the different combinations of equipment and the area of each farm. The program works under the environment of the worksheet and the user does not require knowledge of linear programming to understand the input and output of the model program. The program is capable of calculating the number of working days required for each tractor–implement at each farm in the different periods, and also allows to study the effect of changing values on fixed and variable costs through time. A case in Guanajuato, Mexico, for five farms cultivating wheat and sorghum is used to demonstrate the model application because the mechanisation costs are reduced during the passage of time (at the present value), thus affecting the optimum solution in such a way that alternative solutions are found through time. The optimum solution of the machinery park selected for the first year is not the same as that selected through other years. For the studied case three optimal solutions were found, one of them for years 1–5, another one for years 6–8 and the last one for years 9–12. In case of machinery, the optimal solution is below the quantity of tractors available on the five farms.

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1. Introduction

One of the main problems of the agricultural mechanisation is investing wisely in farm equipment and making good use of them. Indeed, in any country, suitable machinery management is a very common problem, and there have been a number of research studies to optimise those factors involved in the selection of agricultural machinery.

The multifarm use of agricultural machinery was introduced to realise the benefits of high capacity but expensive machines that could not be used economically on individual farms. This multifarm use of machinery reduces mechanisation costs considerably. Multifarm use of machinery also allows farmers to apply the most advanced technology and environmentally friendly production techniques in their operations. However, these groups of machinery must be used efficiently because it is possible to have overlapped periods of operation.

The program presented in this paper has the following features.

(1) It uses a spreadsheet environment, which facilitates changes in any variable.
(2) The program can handle different field capacities for each farm.
(3) The user requires no knowledge of mixed integer linear programming.
(4) The solution time is relatively low, between 1 and 2 min.

The main objective of this paper is to present the program for making decisions on investing in machinery

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Notation

$A^{(h)}_{i,j,k,l}$	number of working days needed for rented equipment (i,j) in operation k at farm l for period h, day
B_j	disc plough type j
C_j	cultivator type j
C_m	marginal repair cost, pesos h^{-1}
D_j	rotary mower type j
F_j	spike harrow type j
H	total machine use, h
h	annual machine use during year, h
$L_{i,j,k,l}$	area of the operation k carried out by the matched equipment (i,j) at farm l, ha
M_j	number of implements type j that must be acquired (integer variable)
N_i	number of tractors type i that must be acquired (integer variable)
n	year when the marginal repair cost was estimated
n_1	number of types of tractors
n_2	number of types of implements for each operation matching tractor i
n_3	number of required operations in the period h
n_4	number of farms in the multifarm system that required operation k in the period h
n_5	number of periods in which operation k is required
R_j	disc harrow type j
r_H	repair factor
S_j	grain drill or planter type j
T_i	tractor type i
V_a	acquisition machinery value, pesos
$Y^{(h)}_{i,j,k,l}$	number of working days needed for own equipment (i,j) in operation k at farm l for period h, day (continued variable)
Z_{min}	objective function, pesos yr^{-1}
$\alpha^{(h)}_{i,j,k,l}$	worktime available for own matched equipment (i,j) in operation k at farm l for period h, h day^{-1}
$\beta_{i,j,k,l}$	capacity of the matched equipment (i,j) in operation k at farm l, h ha^{-1}
$\gamma^{(h)}_{i,j,k,l}$	variable cost per hour of own equipment (i,j) in operation k at farm l for the period h, pesos h^{-1}
δ_h	available time to work in the period h, days
$\varepsilon^{(h)}_{i,j,k,l}$	worktime available for the rented combination (i,j) in operation k at farm l for period h, h day^{-1}
η_{kl}	number of units in the operation k at farm l, ha
$\theta^{(h)}_{i,j,k,l}$	price per hour of rented equipment (i,j) in operation k at farm l for the period h, pesos h^{-1}
Π_i	annual fixed cost of tractor i, pesos
Π_j	annual fixed cost of implement j, pesos

Superscripts

h	period of the operation

Subscripts

i	tractor
j	implement
k	operation
l	farm

utilised in a multifarm system, assigning the correct machine at the correct time to each farm.

2. Literature review

Audsley (1981) developed a linear programming model for the use of researchers or engineers developing new machines and techniques. The model assesses, within a range of farm conditions, the economic and technical bounds within which a machine must operate, if it is to be commercially viable. The model is also useful for looking at different management strategies for individual farms.

Whitson *et al.* (1981) utilised a linear programming approach for the selection of machinery to evaluate crop alternatives of grain sorghum, cotton, soya bean and maize in Texas under weather risk.

Gracia *et al.* (1982) developed a mixed integer linear model that permits using previous knowledge of the characteristics of the farm such as culture, mechanised operations, periods of time in which it is possible to carry them out, field capacities of the different equipment, *etc.*, to choose the optimum agricultural equipment at its minimum cost for a sugar beet crop in Spain.

Ghassan *et al.* (1986) presented the use of a mixed integer linear program (MILP) to select the optimum harvesting method and machinery systems for two

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