Available online at www.sciencedirect.com
ScienceDirect
Agricultural Systems 94 (2007) 341–356
AGRICULTURAL SYSTEMS
www.elsevier.com/locate/agsy

LUSE, a decision support system for exploration of rural land use allocation: Application to the Terra Chá district of Galicia (N.W. Spain)

Inés Santé *, Rafael Crecente

Department of Agricultural and Forestry Engineering, University of Santiago de Compostela, Spain
Escuela Politécnica Superior, Campus Universitario s/n, Lugo 27002, Spain

Received 6 September 2005; received in revised form 8 August 2006; accepted 5 October 2006

Abstract

This article describes LUSE, a system for exploration of rural land use allocations (total area devoted to each kind of use) by multiobjective linear programming methods. The objectives pursued are maximization of gross margin, employment in agriculture, land use naturalness and traditional rural landscape, and minimization of production costs and use of agrochemicals. The constraints on the areas devoted to the land uses considered in addition to those imposed by their joint and individual availabilities, are that they must reach levels considered to satisfy existing demand for those uses or their products, and that the areas devoted to maize and fodder must be sufficient for maintenance of dairy farm production. The program generates comprehensive samples of the Pareto-optimal set, and also allows interactive convergence on a solution that is satisfactory to the decision-maker or interactive exploration of the Pareto-optimal set. The system is currently parameterized for use in an area of Galicia (N.W. Spain), but is easily adaptable to other geographic locations.

Keywords: Rural land use planning; Land use allocation; Multiobjective linear programming

1. Introduction

Like many other rural areas of Europe, Galicia (N.W. Spain) is undergoing rapid changes involving depopulation, reduction of agricultural activity, scattered house building, the destruction of the traditional landscape, and the reservation of land for recreational or conservational roles. In this context, there is an increasing demand for land use planning tools that are flexible enough to contribute usefully to the task of allocating land use in a way that reconciles, as much as possible, such frequently conflicting objectives as economic viability, maintenance of social structure, and environmental conservation. Formal multi-objective programming techniques allow the planner to gain pre-decision insight into the problem by examination of the advantages and disadvantages of potential allocation schemes and the consequences of giving priority to one or another objective (van Ittersum et al., 1998).

Most applications of mathematical programming to rural land use allocation have employed linear models. Examples of the use of single-objective linear programming models include that of Chuvieco (1993), designed to minimize rural unemployment by maximizing the area devoted to labour-intensive uses; and that of Campbell et al. (1992), designed to balance local production and imports in Antigua in such a way as to minimize overall cost while satisfying demand. In some models, the decision variables have not been the areas devoted to each kind of land use, but rather the areas that are to undergo a change of use (Shukla et al., 2003).

The increasing complexity involved in agricultural land planning makes multiobjective models increasingly necessary. When multiple objectives must be taken into account (total production, gross value, net profit, cost minimization,

* Corresponding author. Tel.: +34 982252231x23642/655191770; fax: +34 982285926.
E-mail address: isante@lugo.usc.es (I. Santé).

0308-521X/$ - see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.agsy.2006.10.004

prevention of erosion, self-sufficiency, etc), single-objective models are of limited help to the land use planner. Multi-objective linear programming and related techniques provide a methodology for analyzing the relationships and conflicts among these objectives. Although there is extensive literature available on linear programming applied to farm planning, models designed for optimization of rural land use areas in a multiobjective context are less common. One of the most widely employed multiobjective methods developed to tackle such situations is goal programming. This approach has been used, for example, by Ive and Cocks (1983) in Australia; by Giupponi and Rosato (1998), who considered the choice of land use and farming system in the Venice Lagoon Basin given the joint objectives of profit maximization and risk avoidance; by Oliveira et al. (2003) for management of a Brazilian estate combining forestry, buffalo breeding and tourism; and by Zander and Kächele (1999), whose overall concern was sustainable development. Multiobjective methods other than goal programming that have been employed include the generation of a comprehensive sample of the Pareto-optimal set by the weighting method (Shakya and Leuschner, 1990) or by the constraint method (van Leeuwen et al., 2001).

Comprehensive sampling of the Pareto-optimal set, the classical way of presenting the decision-maker with a panorama of candidate solutions, tends to generate a bewilderingly large amount of information. It is often more helpful to impose some scheme for combining the multiple objectives into one single objective, and then explore the consequences of varying the relative weights or priorities given to the various objectives within this scheme. This kind of procedure amounts to sampling only those regions of the Pareto-optimal set that correspond to a set of diverse management philosophies regarding the relative importance of different objectives, and is becoming increasingly useful with the growing involvement of stakeholders with conflicting interests in land use planning (van Ittersum et al., 2004). It can be especially enlightening when the exploration can proceed interactively, so that there is an exchange of information between the decision-maker and the system. This allows the decision-maker's preferred solution to be provided using implicit information supplied by him/her. This could be, for example, answers to questions such as "which objectives can be relaxed to improve others?" or "which solution is preferred in this group?". The particular approach known as Interactive Multiple Goal Linear Programming (IMGLP) has been used in this way for land use planning (Suhaedi et al., 2002), analysis of agricultural development policies (De Wit et al., 1988), evaluation of land use strategies (Lu et al., 2004), and has been even implemented in an application called GOAL-QUASI to explore future land use options in the European Union (van Ittersum, 1995). Another approach, Aspiration/Reservation-Based Decision Support (Fischer and Makowski, 1996), has been implemented in a tool called AEZWIN (Fischer et al., 1998) to expand FAO's Agro-Ecological Zoning (AEZ). The AEZ and a multi-objective linear programming model were used by Agrell et al. (2004) to develop a decision support system for exploration of crop areas. The ADELAIS multiobjective linear programming software has been applied by Siskos et al. (1994) to cropping pattern planning.

In this paper we describe LUSE, a system that allows the exploration of rural land use allocations by a variety of multiobjective linear programming methods. The objectives pursued are maximization of gross margin, employment in agriculture, land use naturalness and traditional rural landscape, and minimization of production costs and use of agrochemicals. The constraints on the areas devoted to the land uses considered, in addition to those imposed by their joint and individual availabilities, are that they must reach levels considered to satisfy existing demand for those uses or their products, and that the areas devoted to maize and fodder must be sufficient for maintenance of dairy farm production. LUSE is currently parameterized for use in the Terra Chá area of Galicia (N.W. Spain), but is easily adaptable to other geographic locations. We illustrate its use here by comparing the results afforded by the various methods it implements when three different objective-type priority philosophies are imposed: economic > social > environmental; social > economic > environmental; and environmental > social > economic.

2. The LUSE model

2.1. The study area

For better appreciation of the objectives and constraints incorporated in the model, it is perhaps helpful to be familiar with the general characteristics of the area to be analysed in Section 4, which is fairly representative of numerous other areas of Galicia and other regions of Spain. The 1832 km^2 of Terra Chá (Fig. 1) are distributed between a broad southern plain in which the main towns and most farming activity are located, and a more hilly northern area devoted predominantly to forestry and environmental protection. The farms of the southern plain are mostly dairy farms with their farmland devoted to fodder crops.

2.2. The decision variables

The decision variables handled by LUSE are the areas X_i devoted to the thirteen main agroforestry crops, products or uses registered in Terra Chá in 2001: maize, wheat, other cereals (rye, barley, oats), potatoes, perennial green fodder, other fodder crops (beet, turnip), vegetables, fruit, meadow, pasture, eucalyptus, softwoods, and hardwoods.

2.3. The objectives of the model

The LUSE model incorporates two objectives of each of three kinds: economic, social and environmental.