Agroforest Syst (2011) 82:225–237
DOI 10.1007/s10457-011-9373-8

Integrating differentiated landscape preferences in a decision support model for the multifunctional management of the Montado

Diana Surová · Peter Surový · Nuno de Almeida Ribeiro · Teresa Pinto-Correia

Received: 15 October 2009 / Accepted: 19 January 2011 / Published online: 12 February 2011

Abstract A great part of the Alentejo region in Southern Portugal is covered by an agro-silvo pastoral system, the Montado. This traditional land-use system is specific, inter alia, in its ability to join production with favorable conditions for non-production functions. At the present time, as society positively evaluates and even demands cultural and amenity functions from the countryside, the Montado management faces the challenge of integrating production with non-production functions in a way which will result in suitable multifunctionality, and a more sound viability of the whole system. The decision support tool (DST) for the cork oak Montado management, the CORKFITS, based on the single-tree growth model and working at the stand level, is oriented primarily to the management of the production functions, but it is able to integrate also other data that can contribute for a more multifunctionality oriented management. In this exploratory study, the integration in the DST, of the preference distribution, as expressed by landscape users is investigated. The aim was to test a more comprehensive functioning of this tool, where non-production functions are also integrated. The described integration intended to communicate to decision-makers how the change in management practices at tree and under cover level, might alter the satisfaction of expectations of different user groups, as such changes affect the composition of the Montado, at both levels. The users considered are those practicing non-production functions in the Montado. Preferences were assessed through a questionnaire survey applied in the region of Alentejo, in the area of dominance of the cork oak, in the Montado system. The non-production functions are, in this context, related particularly to hunting, aesthetic appreciation related to walking and other leisure activities, to life quality, and to tradition and identity, as well as bee-keeping and mushroom picking. This paper focuses on the description of the specific methodological steps applied for the successful integration of the landscape preferences of different user groups into the DST for the cork oak Montado. Integration has proved to be possible, even if some methodological challenges still need to be faced for a more consistent use of the proposed tool.

Keywords Cork oak Montado · Landscape preferences · Landscape user groups · Multifunctional management · Single tree grow model · CORKFITS

D. Surová (✉) · P. Surový · N. de Almeida Ribeiro · T. Pinto-Correia
Research Group on Mediterranean Ecosystems and Landscapes/ICAAM, University of Évora, Núcleo da Mitra, Apartado 94, 7002-774 Évora, Portugal
e-mail: dj@uevora.pt

Introduction

Challenges for the management of the cork oak Montado regarding cultural and amenity functions

The traditional Portuguese agroforestry system known as the Montado (dehesa in Spain) refers to open savannah-like oak woodlands, comprising cork oak (*Quercus suber* L.) and/or holm oak (*Quercus ilex rotundifolia* Lam., syn. *Q. rotundifolia*, *Q. ballota*). Portugal has approximately 33% of the world's total area covered by cork oak, around 23% of the country's forested land, corresponding to an area of approximately 730,000 hectares, mainly in Southern Portugal. About half of the Portuguese forests are included in agricultural holdings and about 70% of this in-farm forest area is occupied by the Montado (Coelho 2003). In this agroforestry system, open tree cover, in various densities, is combined with the use of undercover, in a rotation of cultivation, grazing and fallow land. The main product is cork, largely driving its industry with bottle stoppers. The Montado land-use system can vary from thick forest to more open grassland and scrub vegetation areas, interspersed with trees. The system is characterised by a multiple-resource production, low-input agriculture with a high variety of products harvested and a high level of self-sufficiency, well adapted to the Mediterranean climate and the poor soil conditions (Joffre et al. 1999). However, in the last decades, as in many traditional European land-use systems, there has been a putative shift from moderate human disturbance towards bipolar changes, such as intensification or extensification. These changes may cause instability of the Montado system and can thus also result in the rapid vanishing of its valuable landscape (Pinto-Correia 1993). From the point of view of biodiversity, socio–economic value and cultural heritage conservation, the system is regarded as highly valuable, which emphasises the importance of its maintenance (Pinto-Correia and Mascarenhas 1999). At present, the role of the Montado is gradually changing, with increasing attention being directed to its ecological and amenity functions and an important challenge is to find solutions for safeguarding its economic viability and maintaining the human land-use there. The open savannah-like appearance makes the Montado landscape highly attractive for recreation, hunting, aesthetic appreciation, supporting identity values, supplying diverse ecological services, regional diversity, coherence and identity, and is considered as traditional land-use in the region of Alentejo (Pinto-Correia and Vos 2004). Moreover, results of different management options in this land-use system results in a variety of landscape patterns.

In general, human use of the rural space is changing from formerly dominant production goals towards a variable mix of production, consumption (market-driven amenity use) and protection (e.g. biodiversity preservation and landscape protection) goals (Holmes 2006). Some authors call these processes a transition from a mainly productivist into a post-productivist paradigm (Wilson 2007; Robinson 2008). The newly-demanded rural functions relate to recreation activities, relaxation, cognitive development and spiritual reflection in landscapes. These new rural functions were defined by de Groot and Hein (2005), in the typology of ecosystem functions, goods and services, and as cultural and amenity functions. They have a social value and correspond thus to public services or goods. A range of today's amenity functions in rural areas has always been part of the agriculture or forest outputs, for example mushroom picking and hunting. Nevertheless, they are still lacking in most policy support tools (Pinto-Correia et al. 2006; Verje et al. 2007). The concept of multifunctionality was applied by OECD and EU in the sectoral context of agriculture; however, it has considerable importance in sustainable land development regarded cross-sectorally in the general perspective of land use and landscape (Wiggering et al. 2006). Recent perspective of the common agricultural policy recognises the full range of economic, social, cultural and environmental functions of agriculture. As Belletti et al. (2003) aver, all farms have some degree of multifunctionality, but few have embodied multifunctionality as a structuring principle. For some landscape types, depending on whether they are under-utilised as highly productive land-use systems, the value of the non-production functions may even be the future support needed for maintaining an integrated land-management system—as actual production-oriented systems may be severely threatened by globalisation processes, especially once specific protection measures may no longer be in place. As a consequence, new research approaches concerning the capacity of the landscape to supply societal demand for these functions and their possible integration with currently managed functions, is crucial. Pertinent research can be useful in supporting innovative ways of management, where commodity and non-commodity functions are paired in suitable ways and at suitable levels.

In the Montado case, the contemporary task of adapting management so that it incorporates multi-functional objectives, requires using recent knowledge and insight regarding social values and uses demanded in this specific land-use system, so that these new functions can be integrated more closely with production functions. In this context, more information, available to local managers, regarding social demand and what is valued by the various types of users, is essential. Not all users request the same appearance and structure of the Montado. Different management outcomes result in different patterns and internal structures of the Montado land cover, and can therefore ideally provide different functions. There is thus a need to produce knowledge on users' preferences, by function type, so that the related data can be incorporated into the knowledge support for informed decision-making. The local level approach is needed here as, despite the role of global drivers, market and policy impacts, management is also driven by local level conditions and variations within the farm unit, and its everyday decisions are locally shaped.

Landscape preferences in multifunctional management

After the millennium ecosystem assessment (MEA) (2005), landscape functions have become an important concept in policy-making. In this context, an increased research effort is expected regarding knowledge concerning the capacity of various land-use types and associated management options, to provide a range of landscape functions, and subsequently to introduce this information into the decision support systems. This practical application of the concept of landscape functions in planning, management and decision-making is still lacking (de Groot et al. 2010). The new multifunctional perspectives of agriculture have important implications for the scientific information that is required to efficiently integrate farm production management with information about management of cultural and amenity landscape functions. A variety of information is needed for successful management of non-production functions (de Groot and Hein 2005). Knowledge of peoples' values, expectations and appreciation of landscape has become very important for feasible measures of landscape protection, management and planning (e.g. Swanwick 2009). As these expectations are reflected in landscape preferences (Buijs et al. 2006; Egoz et al. 2001), relevant studies are pertinent. In order to suitably satisfy the variety of social expectations, the landscape preferences of different user groups should not be omitted in the management of related landscape functions. However, as far as the social value of the landscapes is concerned, there is still a clear lack of usable indicators, which really do express a demand, since this implies assessing this demand and cannot be extracted from current statistics. However, even when surveys are undertaken, as in the present research, the main challenge still lies in the production of relevant and adequate indicators, so that the distinctive characteristics of the landscapes that drive peoples' preferences are adequately considered.

Farm managers comprise a relatively small portion of the population that own or actively manage land. Thus, it is essential to allow them access to information about how their production management practices influence satisfaction of landscape users, and how to combine production with other functions in the same area. In this context, research can assess data about the up-to-date preferences of different user groups and subsequently communicate this knowledge to land managers by integration into decision support tools.

Decision support tools for agroforestry systems

In agroforestry systems are being developed and used various decision support tools (DSTs) with the aim of integrating information to facilitate the decision-making process that directs development, acceptance and management aspects. A detailed overview of existing computer-based tools for decision support, applied in agroforestry, was elaborated on by Ellis et al. (2004). These DSTs form part of adaptive management, which is considered the most effective approach to agroforestry (McNeely 2004). It involves available information, its implementation, associated research, systematic monitoring of results, and feeding the results of the monitoring back, to provide improved management of the system. This should not replace decision-making by the landowner or manager, but should facilitate decision-making by making the management process more informed and more objective (Grabaum and Meyer 1998). The major challenge in the development of effective DSTs for agroforestry is dealing with its complex nature. In addition to the production functions, agroforestry systems provide different functions to society and should thus be managed for multiple objectives, and multiple social interests and preferences. Moreover, there is also an important need for compatibility of databases introduced in specific models, with geographical regions and with users' needs and resources considered. Despite the social interest in agroforestry systems, a clear lack in integration of landscape preference data in DSTs can be observed.

Aims of the study

The central aim of this study is to describe and apply the methodological steps needed for the integration of landscape preferences in the existing DST for cork oak Montado management in Southern Portugal. The exploratory research design was applied for integration of preference distribution expressed by landscape users in the CORKFITS model system. Currently, this DST, based on the single-tree growth model and working at stand level, is up to date and oriented primarily toward the management of production functions. Integration of data regarding the landscape preferences of different user groups for landscape patterns resulting from different management options, intends to communicate to decision-makers how change of management practices at tree and understorey level might influence the preferences of different user groups, practising non-production functions in the Montado, and thereby help the management process of non-production functions to become more informed and objective. The non-production functions are, in this context, related particularly to hunting, aesthetic appreciation related to new uses and life quality, aesthetic appreciation related to tradition and identity, bee-keeping and mushroom picking. The paper focuses on the description and results of specific methodological steps applied for successful integration of the two components: landscape preferences of different user groups and DST, in the specific land-use system, cork oak Montado context, rather than to the development of a generally acceptable method regarding the integration of landscape preferences in decision support systems.

Methodological steps allowing integration of landscape preferences with decision support tool for the cork oak montado

The methodology applied in the study was adapted to exploratory investigation regarding possible integration of two principal components: landscape preferences and DST for cork oak Montado, based on the single-tree growth model. Based on the relevant existing literature and expert knowledge, the following methodological steps were applied in order to integrate the two principal components in the context of cork oak Montado in Southern Portugal.

Study area

The study focuses on the specific Montado type, where the principal tree species is the cork oak (*Quercus suber* L.). This Montado type predominates in the north-western part of the region of Alentejo. Here, the cork oak Montado has socio-economic importance due to cork production, but is also used in a multifunctional way by local inhabitants and urban dwellers from the metropolitan areas of Lisbon, as well as by foreign tourists. Private properties with dimensions greater than 100 ha prevail in this region. Usually, the farm manager is the primary decision-maker with regard to the management of an individual farm business, technical operations and in-farm innovation. The management decisions are usually based on commodity products, such as meat from livestock, cork or charcoal. The associations of farmers and forest producers, existing in each region of Portugal, tend to share the objectives of adequately evaluating the existing forest products, helping with more efficient management of the holdings and sharing general information about marketing, policy, economy and technology.

For data collection with regard to landscape preference, four towns, situated in this specific part of the region, were selected as main centres for the interview process: Alcácer de Sal, Montemor-o-Novo, Évora and Coruche. Furthermore, the interviews with urban dwellers were conducted in the metropolitan area of Lisbon.

Preparation of landscape preference database

Survey of landscape preferences of different user groups

Several studies investigated what type of landscape people prefer (e.g. Fanariotu and Skuras 2004; Hagerhall 2001; Kaplan 1995), specifically in the Mediterranean context (Arriaza et al. 2004; de la Fuente de Val et al. 2006), or relating scenic beauty to forest stand characteristics (e.g. Blasco et al. 2009; Pukkala et al. 1988). Their focus is however, on securing an empirical basis for public consensus. Less attention has been paid in the landscape preference models to the effect of different landscape types and to different ways of using landscapes. Yet, in more recent literature, evidence is found for differences in preference, instead of a unitary measure of landscape preference (e.g. Tveit 2009; Dramstad et al. 2006; Brush et al. 2000). This overview of the available literature revealed a lack of previous studies with regard to the preferences of different landscape user groups for landscape patterns that could be applied in tools supporting the management of cultural and amenity functions in the cork oak Montado. Due to this, the survey assessing landscape preferences of different user groups was undertaken. The results, expressing the preferences of different landscape user groups in relation to the cork oak Montado, were deemed fit for inclusion in a database for the CORKFITS model.

Instead of an overall model for mean public preferences (e.g. Canas et al. 2009; Sayadi et al. 2009), the preferences of different landscape user groups, corresponding to selected functions for a variety of management options, was surveyed. The differentiation of expectations of landscape user groups is believed to be important for the management of the specific landscape functions. This would apply to large-scale management, but also to the very local level, farm-unit scale. Preferences had to be surveyed at the very local scale, and therefore a locally implemented survey was the required data-gathering approach.

In order to obtain data on the landscape preferences of the Montado users, a combination of approaches from quantitative and qualitative research methods was selected. To obtain knowledge suitable for the use of tools in aiming for multifunctional management of the Montado, utilitarian overlay on landscape preferences was applied, considering explicit differentiation of the landscape user groups. For this, purposeful sampling (Patton 2002) was used in order to illustrate different user groups experiencing cultural and amenity functions in the countryside. For data collection, individual personal interviews, using photographs as the visual stimuli, were utilised. Personal interviews were chosen in order to have direct contact with respondents and to capture exact quotations about their perspectives and experiences, and highlight difficulties encountered in understanding questions, and thus assist respondents to answer the questions properly.

The photographs represented Montado landscape types. The main aspects influenced by landowners' management, which mostly influence landscape patterns in the Montado system, were illustrated in the photos. These included presence of shrubs, presence and type of livestock, density of trees and spatial distribution of trees. For tree cover, the survey considered three levels of density, two types of spatial tree composition—aligned and irregular, landscape patterns with and without shrubs and sheep, cows or non-livestock presence. Only the stands with adult trees were assessed. Quantitative data from the interviews were analysed quantitatively, using frequency and chi-square statistics. Results from the landscape preference survey are described in a previous paper (Surová and Pinto-Correia 2008).

Identification of landscape indicators

Information integrated in a decision support system needs to be easily understandable for the system users. Thus, the message needs to be simple, although retaining the essential meaning for the questions asked to this data. For the comprehensive description of the interaction between landscape users' preferences and management alternatives of production in a decision support system, defining a set of indicators was chosen as a suitable solution (e.g. OECD 2003). In spite of the enormous simplification of the reality, the indicators are still considered a suitable way to obtain valuable support for multiple-use management (Fry et al. 2009). An indicator quantifies and simplifies phenomena and aids the understanding of complex realities. In the world of social indicators, the most-advised approach is a combination of expert knowledge with surveys in case studies (Cloquell-Ballester et al. 2006; Ekos Research Associates 1998; Schafer et al. 2004). In this case, following the landscape preference survey, the quantitative data on landscape preferences were simplified in landscape indicators. The chi-square test calculation was applied, using the SPSS software. A hypothesis tested by the chi-square test assumes that all studied Montado landscape patterns (stands) are equally preferred by a particular user group (e.g. hunters). The expected (theoretical) value of the preferences for a specific landscape pattern was assigned as the average value of the preference choices in a specific landscape user group. The observed value for this calculation was the sum of respondents from the particular user group choosing the specific Montado pattern as the preferred one. The *P*-value obtained from the test was used as a division criterion for the numerical indicators. In statistical hypothesis testing, the *P*-value is the probability of obtaining a test statistic at least as extreme as the one that was actually observed, assuming that the tested hypothesis is true. The smaller the *P*-value, the more strongly the test rejects a tested hypothesis. It can mean that the landscape preferences of a particular user group are significantly high or significantly low for specific Montado type.

Decision support tool for the Montado management

For the DST to be integrated with landscape preference data, the CORKFITS model system was used. This DST is currently available for associations of forest producers and managers of the cork oak Montado in Southern Portugal. This administration assistance facilitates consultation regarding possible alternatives for the management options in cork oak stands. It is a software system for a single-tree spatial growth simulation model and was developed as an application of the SILVA model, available for use in operational or strategic forest planning in German conditions (Pretzsch et al. 2002), as well as for cork oak stands in Southern Portugal (Ribeiro et al. 2006). The empirical models for tree height, diameter, crown volume and surface, total cork weight and cork thickness are currently incorporated in the model system. It uses the potential growth of trees derived from stand conditions and adjusts it to match the current competition status for each tree. Currently, the model displays the stand status in individual years as a result of a chosen management option (e.g. no management interventions, artificial regeneration). The management alternatives can be changed at any stage of the simulation, with the option of saving previous management results. Apart from the management alternatives at the tree level, other options can be set before or during the simulation as well. These are related to economics, as in number of cattle per hectare, subsidy income for one cattle unit, cork price, labour productivity and costs, type and frequency of shrub management with related costs and finally, costs related to new tree planting. Empirical single-tree models provide outputs at the tree level. Stand characteristics can be derived using calculations from simple sum formulas, (in cases of production per hectare) to complex geometrical calculations (in cases of crown cover without overlapping). Outputs related to land-cover cork properties, production and economic results are illustrated through the use of charts and also saved in a database format. CORKFITS permits visualisation and comparison of different scenarios and management options in order to maximise stated objectives. The model system allows repeated use that includes accessible user interfaces for non-technical people to preview results of their decision-making. One of the new challenges for this system is to attempt to integrate components of production with non-production functions.

In the framework of preparation of DST for landscape preference data integration, a compatibility of parameters, describing stands in the single-tree growth model with landscape patterns, needs to be verified. For distinction of different landscape patterns in the CORKFITS, the specific combination of stand parameters needs to be attributed to each pattern.

Programming steps and visualisation of landscape preferences in the montado decision support tool

In order to connect the two components, landscape preferences and DST, the programming step was needed. In the programming step a Delphi 5 Enterprise programme was used.

Table 1 The Utilitarian Landscape Preference Model with indicators expressing a level of attractiveness for each of the fourteen Montado landscape patterns one indicator of landscape users' preferences was assigned

Type no														
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV
Montado patterns														
Livestock	No	Cows	Sheep	No	Cows	Sheep	No	Cows	Sheep	Sheep	No	Sheep	No	No
Trees' composition	Irregular			Regular			Irregular			Regular		Irregular		
Trees' density	Open			Dense										Highly dense
Shrubs	Without shrubs									With shrubs				
Functions represented by the respondents														
Hunting	5	3	3	4	1	2	4	1	1	2	4	2	3	3
Production	2	3	1	5	3	4	4	3	3	3	3	2	3	3
Aesthetic—tradition and identity	4	4	3	3	3	3	3	3	3	2	2	3	3	3
Aesthetic—new uses and life quality	3	3	3	3	2	2	4	3	3	3	2	3	3	5
Mushroom picking	1	1	1	3	1	1	4	3	3	1	4	3	4	4
Beekeeping	3	3	3	2	1	1	3	1	1	3	5	3	5	5

There were five numeric indicators *5* very often preferred, *4* often preferred, *3* sometimes preferred, *2* rarely preferred and *1* never preferred pattern by respondents from the particular landscape user group

The visualisation took into consideration the format for other results in the existing CORKFITS model. Thus, it was decided to illustrate the landscape preferences by the use of charts.

Results

Landscape preference indicators

According to congruence and dissimilarity in landscape preferences for Montado landscape patterns, six distinct user groups were revealed: hunters, Portuguese visitors looking for aesthetic functions connected with tradition and identity, foreign visitors looking for aesthetic functions connected with new uses and life quality, mushroom pickers, bee-keepers and landowners. These groups showed statistically significant differences with regard to preferences for the considered Montado types.

In the next step, in order to reduce the complexity of data available on landscape user preferences from previous study, the empirical data were simplified into the form of numerical indicators. In this study, derived indicators express the level of attractiveness of the specific cork oak Montado landscape pattern (stand) for a particular landscape user group. In this way, the quantitative preference data were divided into five categories assigned with ordinal numeric indicators and the Utilitarian Landscape Preference Model was constructed (Table 1). In the model, each studied Montado landscape pattern is cross-tabulated with the landscape function and labelled with one of the five numeric indicators, depending on the particular user group preferences for a given landscape pattern. Landscape patterns, significantly more frequently preferred than expected with P-value 0.000 obtained from the Chi-square test, were assigned as "very often preferred" by the particular landscape user group and labelled with indicator "5". The patterns significantly more frequently preferred than expected, with P value $< 0.05 > 0.000$, were assigned as "often preferred" by the specific user group and were labelled with indicator "4". The landscape patterns having P-value =>0.05 were labelled with indicator "3" and called "sometimes preferred". The "rarely preferred" Montado patterns were those significantly less preferred than expected by user group, with P value < 0.05, and received the indicator "2". Finally, the landscape patterns "never chosen as preferred" by respondents from the particular user group were labelled with the indicator "1".

CORKFITS performance

The original descriptors of the stand characteristics in the single-tree growth model, CORKFITS, included a set of parameters, including the number of trees per hectare, the stand diameter distribution representing the age structure, the spatial-structure type distinguishing random, regular, clusters or stripes structure, the livestock density, the frequency of shrub clearing, and the type of shrub clearing differing between ploughing and shrub cutting. The model automatically calculates several specific stand characteristics from the input parameters, for example the crown cover. However, the combination of the existing and calculated parameters originally used in the model, did not distinguish between all the Montado landscape patterns considered in the preference study. Thus, some new parameters needed to be adjusted to the original set, in order to suitably describe the existing Montado landscape patterns, and to subsequently connect these patterns with the indicators of attractiveness for different user groups.

One of the short-term management alternatives influencing landscape user preferences is the shrub height in the landscape pattern (stand). The shrubby Montado was defined by shrubs higher than 50 cm. The shrub height in the Montado areas usually depends on the clearing frequency. Nevertheless, its development speed can also be influenced by specific local conditions, for example, by the soil properties. Thus, information capturing these specific local differences was needed. As the farm managers knew the shrub growth speed in their managed locality, the added parameter was adapted to this fact. Therefore, the values used in the model correspond to (a) number of years needed till the shrubs attain about 50 cm in height in the specific area after shrub clearing and (b) a time period between the shrub clearings. Nine-year periods correspond to the time between the two debarkings of cork oaks in the specific stand. This time period is used in the CORKFITS model as a representation of one time period for management interventions. Based on theses values, the model calculates time period with shrubs higher than 50 cm in the area. The Montado pattern with shrubs was defined as a stand having mostly shrubs higher than 50 cm in the understorey; otherwise it is defined as a clear Montado type, without major shrubs. Equation 1 shows the calculation inserted into the CORKFITS model, estimating a time period in years of shrubs higher than 50 cm in a particular stand. If the time period when the shrubs are higher than 50 cm is equal to, or longer than, 5 years, the specific Montado stand is considered as the landscape pattern with shrubs. Otherwise, the stand is considered as landscape pattern without shrubs. The second new parameter added to the model was the livestock species definition. As the original model considered only cows as a livestock type, the parameter added to the model distinguished between sheep and cows.The calculation equation constructed and introduced into the CORKFITS model for estimating a time period in years of shrubs higher than 50 cm in a particular stand, where **a** is the number of years needed till the shrubs attain 50 cm in height in the specific area, **b** is the time period between two shrub clearings in years, and **s** is time in years with shrubs in the assigned area, during the nine-year period

$$(9/b) * (b - a) = s \tag{1}$$

Each Montado landscape pattern studied was described as one explicit combination of measurable components of management practices at the tree and the understorey level. A validated description of the fourteen Montado landscape patterns in the Corkfits model by measurable parameters is shown in Table 2.

Results of programming steps and the visualisation of landscape preferences in DST

For the integration of the utilitarian preference model with the single-tree growth model in CORKFITS, a Delphi 5 Enterprise programme was used. In Delphi code the "if then" statement was applied. The rule comprises "if" criteria and "then" the rule can be applied. The "if" statement is used to test for a condition and then execute sections of code based on whether that condition is true or false. In this integration the Montado types represented the conditions for preference outputs. The "if" criteria are the parameters of the Montado types landscape described in Table 2. Like the other models in the CORKFITS model system, the implemented utilitarian preference matrix can be revised or replaced as necessary. Figure 1 demonstrates the flow chart for data processing algorithm in the simulator with regard to preferences of different landscape user groups. After the introduction of the initial stand data there is a

Table 2 Classification of the Montado landscape patterns, using the measurable stand parameters in the CORKFITS model *I* open Montado without livestock, *II* open Montado with cows, *III* open Montado with sheep, *IV* dense Montado aligned without livestock, *V* dense Montado aligned with cows, *VI* dense Montado aligned with sheep, *VII* dense irregular Montado without livestock, *VIII* dense irregular Montado with cows, *IX* dense irregular Montado with sheep, *X* dense Montado aligned with sheep and shrubs, *XI* dense Montado aligned with shrubs, *XII* dense irregular Montado with sheep and shrubs, *XIII* dense irregular Montado with shrubs, *XIV* highly dense irregular Montado with shrubs

Montado Type	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV
Crown cover[A]	a	a	a	b	b	b	b	b	b	b	b	b	b	c
Range of trees' diameters	d	d	d	d	d	d	d	d	d	d	d	d	d	d
Trees' structure type	e	e	e	f	f	f	e	e	e	f	f	e	e	e
Pasture type	3	1	2	3	1	2	3	1	2	2	3	2	3	3
N° of years with shrubs'height > 50 cm in 9 year period	<5	<5	<5	<5	<5	<5	<5	<5	<5	> = 5	> = 5	> = 5	> = 5	> = 5

[A] The crown cover is expressed as a percentage and is calculated by the original CORKFITS model using several stand parameters *a* crown cover >=10 < 35, *b* crown cover >=35 <=65, *c* crown cover > 65. The trees diameter *d* in all patterns corresponded to dimensions between 70 and 160 cm. The spatial organisation of trees recognised two types *e* random and *f* in lines. The pasture type corresponded to *1* cows, *2* sheep, and *3* no livestock presence

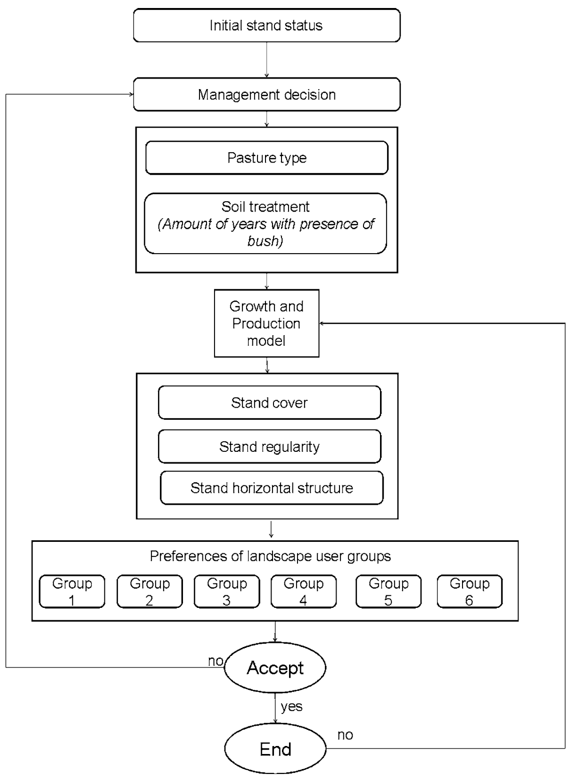

Fig. 1 Flow chart demonstrating the algorithm for data processing of the input stand

management option for a management, or no management scenario. The simulator updates the initial data, and variables necessary for the evaluation of preferences are obtained (stand cover, stand regularity, horizontal structure). These variables together with variables coming directly from management decisions (e.g. pasture type and shrubs treatment) create the base for determination of preferences. At the end of each loop the stand status is subsequently updated and/or the management decision can be changed.

For users of the CORKFITS decision support system, the results regarding preferences of different landscape user groups for specific stand types are represented by the charts. The landscape users' preference chart can be visualised for stands with parameters corresponding to one of the studied Montado landscape patterns (Table 2). For other stands, no chart is presented. Figure 2 shows an example of the simulated stand of cork oak trees and respective preferences of landscape users for related functions. This stand is characterised by irregular spatial composition of the adult trees and no livestock presence. In this simulated stand, time needed for shrub renewal with height 50 cm corresponds to two years, and the shrub clearing is executed every three years. Chart 1 shows the corresponding landscape users' preferences for this simulated stand. Charts 2 and 3 show the landscape preferences of different user groups when certain changes occur in the management options of original simulated stands. In the case of the introduction of cattle pasture in the area, the landscape user preferences will correspond with Chart 2. Thus, the preferences of most of the landscape user groups will be different in relation to the original stand. In the case

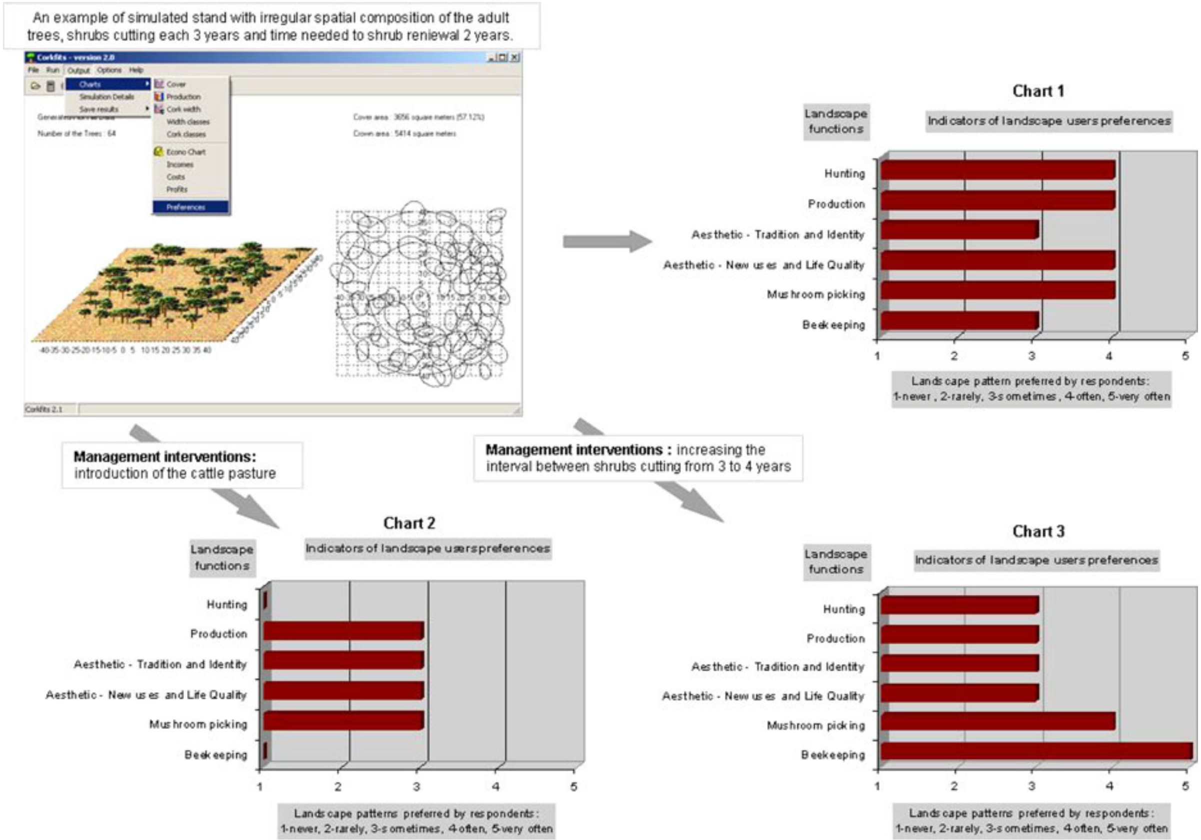

Fig. 2 Visualisation of the preferences of different landscape user groups in the Corkfits DST. In the *upper left part* is shown an example of the simulated cork oak stand. *Chart 1* shows the preferences of different landscape user groups for this simulated stand, *Chart 2* shows the landscape users preferences after the introduction of cattle pasture in the original stand, and *Chart 3* shows the landscape users' preferences after increasing the interval between shrub cutting from 3 to 4 years

of the extensification of the management interventions in the original stand by shrub clearance, executed regularly every four years, the landscape user preferences will correspond with Chart 3.

Discussion

This study demonstrates one possible way to integrate the preferences of landscape users with the single-tree growth DST. The CORKFITS, DST for the cork oak Montado management, based on several models, originally dealt with the production aspect of the land-use system, yet showed its flexibility in integrating landscape preferences, which is information important for the management of non-production functions.

A relatively simple way of integration of landscape preferences into the DST was demonstrated. A landscape preference database, transformed in the indicators, reflected the attractiveness of landscape patterns resulting from different management options in the Montado. This direct connection between preferences and management options is considered to be important for facilitating the integration process. Nevertheless, the integrated model of landscape users' preferences should be tested and continuously improved. The survey on users' preferences was limited to a specific study area and larger surveys would increase the reliability of the database. Furthermore, the real range of landscape patterns in the studied land-use system is much wider. There are more management options in the cork oak Montado than were surveyed in a previous study, for example open Montado landscape patterns with shrubs, patterns with trees from different age groups and cork oak stands mixed with other species, for example the stone pine (*Pinus pinea* L.). In addition, more precise distinctions among many varieties of the undercover structure would be useful in the future for studies regarding landscape preferences for results of management options. Henkin et al. (2007) consider a variety of types of grazing management and their visual results in Mediterranean landscapes that are related to recreational and aesthetic human use. Undercover structure represents powerful characteristics influencing landscape preferences and can be changed rapidly with time in the Montado land-use system, such as pasture and shrub presence. It is therefore important for decision-makers to understand and take this fact into consideration during a decision-making process.

Similar to this study, some other studies deal with modelling landscape preferences at the forest stand level. The study of Silvennoinen et al. (2001) deals with the prediction models of landscape preferences at the forest stand level, adapted to Finnish forest conditions. By comparison with the utilitarian landscape preference indicators applied in this study, the model of Silvennoinen et al. (2001) is focused on the scenic beauty of the stand, representing the public in general. However, his modelling technique should be tested in future in the Montado utilitarian context as well. Pukkala et al. (1995) proposed to integrate amenities into numerical forest planning by computing the amenity value of forest area by scenic and recreation value. Such a method is useful for identification of an amenity index suitable for numerical optimisation. In the multifunctional context of the Montado, this study could be important for computation of the amenity index of the cork oak stands considering, amongst others, different recreational activities.

In this study, the landscape indicators express the level of attractiveness of the specific cork oak Montado landscape pattern (stand) for the particular landscape user group. In terms of the non-production use of the landscape, these kinds of indicators can be defined as state indicators (de Groot and Hein 2005). These authors suggest two other indicators as important for measuring the availability of specific functions in the area. The performance indicator would assess the maximum suitable use of the landscape feature, attractive from a given point of view and the use indicator, the actual use (e.g. number of visitors). To date, these types of data are not available for most of the non-production functions in the Portuguese Montado.

To extend the CORKFITS model system to preferences for landscape patterns, it became necessary to incorporate new formulas for stand characteristics. The models for under-grove evolution and models for pasture type had to be introduced. After the integration of landscape preference data, the current version of the DST for the cork oak Montado allows for the assessing of user preferences for a variety of combinations of stand variables. The information available can be used particularly to predict the landscape user group preferences for the current management options for production functions of the stands, or future stands, after implementing alternative management plans. Further evaluation of the implemented landscape preference model is important for an assessment of the strengths, weaknesses, and utility of a model for a stated purpose.

The CORKFITS model is targeted in specific stand scale, where the focus of management alternatives is at the level of individual stands, and the context in which stands are located is not considered in estimation of landscape user preferences. The existing landscape decision models, for example LANDIS (Shifley et al. 2000), HARVEST (e.g. Gustafson et al. 2007), LANDSUM (e.g. Keane et al. 2006), and SIMPPLLE (e.g. Chew et al. 2004) are suitable for planning over large geographic areas as they are related to large-scale issues and explore the long-term management alternatives. The study presented should be viewed in an adaptive management framework, where the independent data at the necessary temporal and spatial scales reduce uncertainty and facilitates resource management (Shifley et al. 2000). At the landscape level, the main challenge is how to decide on the optimal allocation and management of the many different land-use options. This study deals specifically with the landscape user preferences at the stand level and can be used for answering questions such as how to combine management alternatives for production outputs in cork oak Montado in accordance with the landscape user expectations, rather than to solve tasks about optimal allocation of the non-production functions at the landscape scale.

A decision support tool is considered to be a good mediator between private sectors and scientific investigators. Nevertheless, as this work shows, the scientific knowledge needs practical simplification in order to be integrated into the support system, in ways comprehensible to its users. Integrating information from different research disciplines in this work required an interdisciplinary dialogue amongst foresters, programmers and landscape researchers. These communication skills still need to be improved amongst the scientists themselves and also amongst scientists and managers, planners and public sectors, in order to help with achieving the goals of multifunctionality in rural landscapes.

Conclusions

The Montado land-use system, with its uniqueness and combination of several layers of vegetation in changing densities, offers a landscape rich in biodiversity and amenity values. The aim of the study was to enrich the existing, primarily production-oriented, decision support system CORKFITS for management of the cork oak Montado in Southern Portugal, by providing information about the landscape preferences of different user groups of non-production functions. Integrated knowledge communicates to decision-makers about how change of management practices at tree and understorey level might influence the preferences of different user groups, practising non-production functions in the Montado. This study has reacted to increasing social demand for cultural and amenity functions in rural areas, and to the idea that these functions can represent the enrichment or alternative use of traditional land-use systems in the future, and thus contribute to their maintenance. Indeed, not all farms need to be multifunctional, although the farm managers wanting to combine production with other activities need to be supported by available information regarding possible non-production use of their farms. The local studies about connecting production with non-production landscape functions can help managers to practise adaptive management in specific local contexts, and moreover enhance their capacity to simultaneously achieve agroforestry production goals and social non-production needs.

Acknowledgments This study was elaborated in the framework of the AGROREG project (AGRO768) and doctoral thesis (SFRH/BD/18633/2004) of the first author financed by Fundaçao Para a Ciencia e a Tecnologia in Portugal.

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