Pinto-Correia, T., I. Ferraz-de-Oliveira, M. Guimarães, E. Sales-Baptista, C. Pinto-Cruz, C. Godinho, and R. Vieira Santos. 2022. Result-based payments as a tool to preserve the High Nature Value of complex silvo-pastoral systems: progress toward farm-based indicators. Ecology and Society 27(1):39. https://doi.org/10.5751/ES-12973-270139

Research, part of a Special Feature on High Nature Value Farming Systems in Europe

Result-based payments as a tool to preserve the High Nature Value of complex silvo-pastoral systems: progress toward farm-based indicators

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ABSTRACT. As shown by the Green Deal's ambition, the European Commission is progressively pushing for an environmental shift and climate action in Europe. For the Common Agricultural Policy (CAP), this involves a stronger focus on greening policy objectives. For agri-environmental schemes, this entails changes toward performance-based payments, partially replacing traditional activity-based payments. The CAP foresees greater flexibility in national programs and tailor-made solutions centered on results (i.e. environmental outcomes), benefiting farmers who go beyond the minimum environmental performance required. The environmental outcomes of farm practices must be assessed so that changes can be monitored over time and linked to payment delivery. This requires stakeholders to collaborate with researchers to identify farm-based indicators that are easily applicable, to achieve environmental results that are dependent on farm practices, and to assess and monitor changes in outcomes over time. The analysis in this paper is based on a transdisciplinary process that began in 2017 in a Natura 2000 site and its surroundings in Southern Portugal, to identify result-based measures for the Montado silvo-pastoral system. Farmers' understanding of how to adapt their practices to reach better environmental results was combined with scientific knowledge of the relevant environmental outcomes and how these can be assessed with indicators. Ten field-based visual indicators were defined, which farmers applied in the field, and validated by technical staff. These indicators are related to several aspects of the silvo-pastoral system: soil quality, pasture diversity, tree renewal, tree health, singular landscape elements, and biodiversity. The approach used in this process was innovative. We describe each step and present its advantages and drawbacks for designing and implementing result-based payments. Ultimately, their implementation is expected to lead to higher sustainability in the Montado.

Key Words: *agri-environmental measures; result-based payments; result-based indicators; silvo-pastoral; transdisciplinarity; Montado*

INTRODUCTION

The climate and sustainability ambition of the Green Deal (European Commission 2019) raised to the political agenda in all members states and citizens' awareness the need for an overarching transition in farming processes (Pe'er et al. 2020, Wiget et al. 2020). Strategies must be developed to simultaneously meet the world's future food security and sustainability needs while reducing agriculture's environmental footprint. However, this constitutes a formidable challenge. The call is for a new agricultural paradigm, with renewed and diverse market integration, a lower ecological footprint in Europe and elsewhere and new practices and business models that allow for the preservation or even regeneration of natural resources, biodiversity, and landscapes (Bouma 2021, Schröder et al. 2020).

For the Common Agricultural Policy (CAP), which influences land-use decisions throughout Europe (Lomba et al. 2020), this ambition requires a greater emphasis on greening policy objectives, particularly a renewed orientation toward rewarding higher and noticeable environmental outcomes (Schutter 2020). In recent years, increased internal heterogeneity in the EU composition, rising environmental concerns, and societal demands on legitimacy have all added to the CAP's complexity (Kuhmonen 2018). Concrete monitoring of environmental compliance outcomes has seldom been applied, and growing concerns about the efficiency of the instruments in place have been raised by different sectors of society (Pe'er et al. 2020). The CAP construction for the period post-2020 has again been reshaped. The higher environmental ambition and the complex negotiation process across member states and interest organizations translate into greater flexibility in national programs with new eco-schemes and tailor-made solutions that are focused on results or environmental outcomes instead of practices and processes (Dupraz and Guyomard 2019). This means that farmers who go beyond the minimum requirement, in terms of environmental performance, may benefit (Herzon et al. 2018).

In the next programming period, the more conventional agri-environmental schemes (AES) based on the payment for selected practices that are expected to benefit the environment will be partially replaced by payments for measurable outcomes in terms of biodiversity, soil degradation neutrality, climate change mitigation, and landscape quality. These are known as result-based models (RBMs) (Cullen et al. 2018, Herzon et al. 2018). RBMs require a paradigm shift regarding farm payment expectations, as farmers must step outside their comfort zone and adapt their management along the way to obtain the desired results (Wiget et al. 2020, Targetti et al. 2019). They also prompt farmers to be involved in the design of the tool to be used, fostering their engagement (Johnson et al. 2020). RBMs have been tried in particular circumstances, but many more modalities for the different contexts in the EU still need to be developed and tested (O'Rourke and Finn 2020). Furthermore, RBMs demand that result-based indicators (RBIs) are defined to measure the number of outcomes achieved yearly - not necessarily extremely sophisticated indicators, but robust ones that farmers may use to

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self-assess practices and outcomes as support for adaptive management (Targetti et al. 2019). One of the biggest challenges is to bridge the scientific knowledge gap to link agricultural practices to biodiversity and other ecosystem service outcomes at an appropriate spatial scale (i.e., at the farm level) (Cullen et al. 2018).

RBMs are particularly relevant in farming systems with High Nature Value (HNV). HNV farm systems have generally evolved as complex social-ecological systems in situations of natural resource scarcity, where production is integrated with biodiversity conservation and the delivery of ecosystem services to society (Pinto-Correia et al. 2018). However, HNV farmlands are vulnerable to socioeconomic changes; many of those that exist in Europe are under intensification or land abandonment trends (Lomba et al. 2020). One of these HNV systems is the Montado in Southern Portugal (Pinto-Correia et al. 2018). It is a silvo-pastoral system occupying more than one million hectares in Southern Portugal, similar to the Dehesa, which covers ca. three million hectares in Spain. A variable density of tree cover is combined with grazing and shrub dispersion in the undercover, resulting in high vertical and horizontal heterogeneity (Ferraz-de-Oliveira et al. 2016). Despite the Montado's multiple public advantages, its total area and tree cover density have been steadily decreasing since 1990 (Godinho et al. 2016). The Montado's successive agri-environmental payments have failed to change this trend (Pinto-Correia et al. 2018). This degradation is not due to other farm system replacements, but rather to a loss of system vitality, with openings in tree density and reduction in tree renewal and pasture diversity, resulting in a decrease in carrying capacity (Godinho et al. 2016). The Montado's increased vulnerability is attributable to a variety of factors, but a key common element is management decisions responsible for non-adapted grazing and soil management (Almeida et al. 2016, Guerra et al. 2016, Sales-Baptista et al. 2016). New policy mechanisms to compensate management models that ensure the delivery of societally desired public goods are particularly timely.

The purpose of this paper is twofold: i) to present a set of RBIs to be used in a pilot implementation of agri-environmental result-based payments for the Montado, covering the different dimensions of this silvo-pastoral system; and ii) to illustrate how RBIs can be built so that they are both scientifically sound and easy for farmers to apply in the field. A case-specific experimental process in a Montado area encompassing a Natura 2000 site served as the empirical ground for this paper. Besides presenting innovative agri-environmental result-based payments, this research explains the methodology employed: i) the co-construction process used to define the environmental outcomes that are linked to management practices and can be rewarded by agri-environmental support indicators; ii) the expert-based process that made it possible to link environmental outcomes to indicators; and iii) the validation of the indicators by fieldwork in a set of different farm units.

This paper also contributes to the scientific literature on result-based payments, which is even more limited than the material on traditional action-based agri-environmental payments and the evaluation of their effectiveness.

RESULT-BASED PAYMENTS AND RELATED INDICATORS

Thus far, the CAP's AES has been the largest source of funding for practical nature conservation in the EU, but their ecological performance and cost-effectiveness have not been established (O'Rourke and Finn 2020, Pe'er et al. 2020). Hence, the proposal for RBMs as a strategy to link payments with desirable environmental outcomes results from a call for integrating the ecosystem services approach into AES, which gained traction in policy and scientific debate (Cullen et al. 2018). RBM pilots have shown an improvement in the quality and quantity of ecosystem services provided by farmlands (Lomba et al. 2020). Replications across a broader range of environments and cultural contexts are now needed for a larger-scale assessment and the unlocking of the innovative potential of these measures.

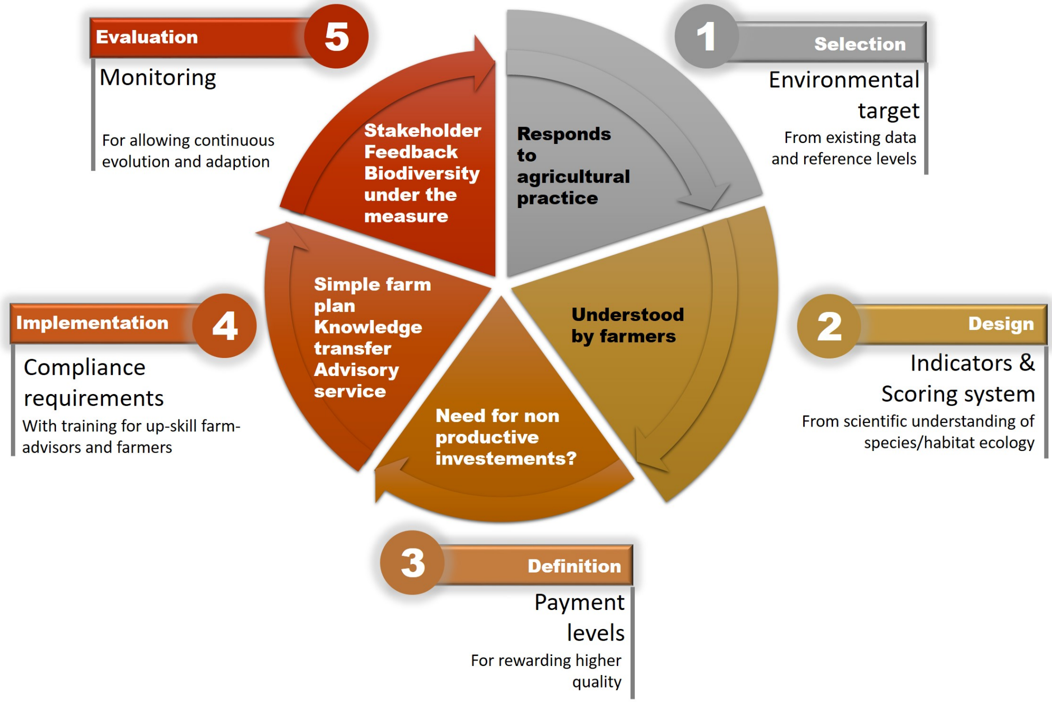
The focus on payment by results implies an increased effort by farmers who, with proper technical advice, make management decisions that are expected to lead to the defined results in each specific farm. The success of an RBM depends on farmers' engagement in ensuring delivery, innovation, and adaptive management (Ferraz-de-Oliveira et al. 2019, Cullen et al. 2018) and farmers' confidence in the indicators used.

An RBM's design is grounded on a 5-step process anchored on farmer practices and decisions (Fig. 1). A veritable co-construction process with farmers is key for success (Luján Soto et al. 2021, Cullen et al. 2018). Such endeavors require the use of transdisciplinary (TD) approaches that foster a shared sense of land stewardship among those involved (Cockburn et al. 2019, Boyle et al. 2015). The expected outcomes must be linked to and dependent on practices. The utilized indicators should enable easy assessment of results, allowing farmers, technicians, and all payment delivery participants to track changes over time. This necessitates the use of farm- or even field-based indicators that are straightforwardly applied and enable evaluation and monitoring of changes over time, including by non-specialists, which results in fewer resource demanding evaluations (Luján Soto et al. 2021, Sheperd et al. 2018).

As shown in Figure 1, to implement an RBM for the Montado, a clear description of an optimal level of environmental outcomes is first required. Second, RBIs should be defined to measure the number of outcomes achieved regularly. These two initial steps demand scientific knowledge in close collaboration with agricultural practices, with an emphasis on biodiversity and conservation outcomes at the farm and plot levels. Third, the score of these indicators for each farm or farm plot each year serves as the basis for a scoring system that is used to calculate the adequate payment. Above all, a well-designed and easy-to-use set of indicators is critical and strategic for the development of an RBM.

There is currently limited literature on field-level and easy-to-assess indicators, which are scientifically proven, can be visually determined by non-experts, integrated into an RBM, and applied to specific farm systems, particularly the Montado. Nonetheless, indicators that identify different health conditions in the Montado and management actions that contribute to its improvement or decline can be found in the literature (Guimarães et al. 2018, Pinto-Correia et al. 2018). Yet, the scale of these indicators hinders their direct transposition to an RBM.

Fig. 1. Overview of the 5-step design process for building a results-based model, based on the conceptual model of Maher et al. (2018). Step 1. Use data to select biodiversity outcomes that respond to agricultural practices; Step 2. Design of the scoring system based on indicators that reflect the biodiversity value; Step 3. Design the payment rates for each level of the scoring system; Step 4. Implement the RBM and set the eligibility criteria and conditions; Step 5. Set up monitoring and evaluating system. Steps 1 and 2 are the object of this paper.



Methodological approaches that go beyond the existing standard, such as adapting current information to an RBM and testing RBIs at the farm and plot levels, are highly needed.

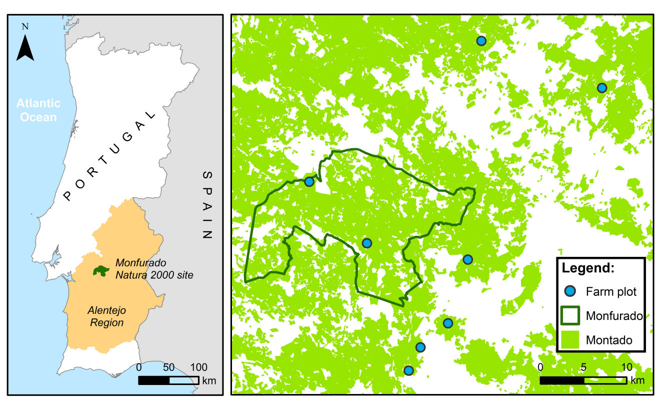
With the empirical work presented in this paper, which corresponds to steps 1 and 2 in Figure 1, we assemble and critically analyze a proposal for RBIs towards their potential integration into an RBM, substantially advancing the current state of the art.

METHODOLOGY

Result-based indicators must be SMART (i.e., Specific, Measurable, Achievable, Relevant, and Time-bound) and developed against clear baselines for specific farmlands (Sheperd et al. 2008). Consequently, we considered that the RBIs to be developed for the Montado should fulfill the following conditions: i) be responsive to agricultural practices (e.g. a variability that depends on the farmer's management options), ii) be able to indicate the evolution of the farm towards full delivery of the defined outcomes, iii) be evident through visual assessment (i.e., time-consuming measures must be avoided), iv) be evaluable by experts but also by non-experts after training, v) be cost-effective and vi) be socially accepted.

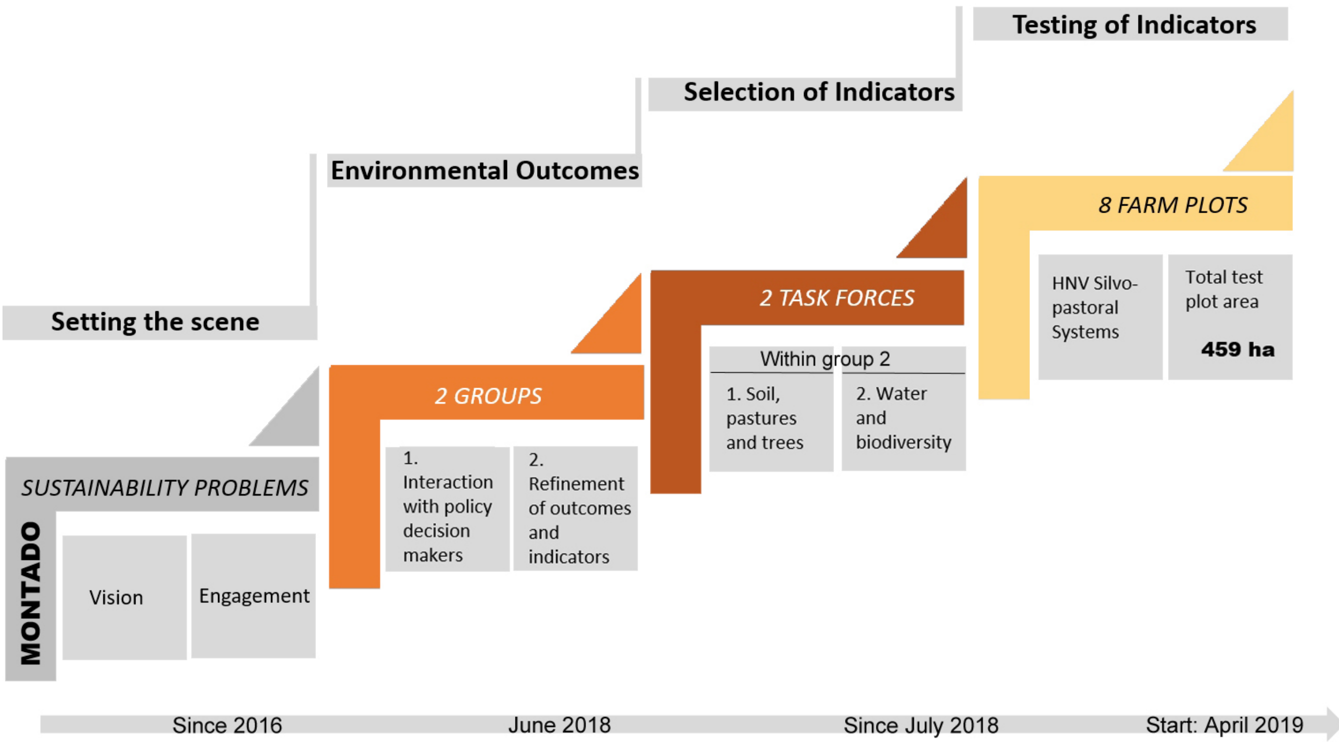
We selected the Monfurado Natura 2000 site because i) the Montado is the dominant land-use system and land cover (Fig. 2) and ii) the relationship with farmers and landowners was already established due to geographic proximity, past exchanges, and joint work.

Fig. 2. Location of the experimental farms, surrounding the Natura 2000 site of Monfurado, Southern Portugal: an area dominated by the silvo-pastoral system, Montado, with extensive grazing.



Our methodological approach aimed to translate the present knowledge into an RBM that may be implemented as a pilot for future agri-environmental policies that are feasible and appealing to farmers. This method was highly innovative: i) built upon a long-term interaction process between researchers and practitioners to facilitate the co-construction process; ii) shaped

Fig. 3. The stepwise approach used for the co-construction and testing of a RBM for the Montado. Base line with number of meetings, attendees and corresponding time-line at the bottom.



as continued process of interaction as a TD arena where our interdisciplinary research team, including researchers with different and relevant expertises, worked in a stepwise and interactive format with key stakeholders; and iii) tested RBI in the field at the farm and plot levels, whereby researchers worked alongside farmers.

We next present the different steps involved in the construction of RBIs for the Montado. This process was organized in a step-by-step format (Fig. 3). Each step included a sequence of interactions that considered the roles of each type of stakeholder.

Transdisciplinary arena setup

A TD arena can be described as a platform for dialogue among multiple stakeholders. It is considered essential for an RBM to achieve its goals (Wiget et al. 2020, Cullen et al. 2018). In our case, the existence and activation of a TD arena was a prerequisite for the co-construction of the RBM and the related RBIs. Throughout the process, the TD arena was maintained and enriched. It is based not only on tangible relations and shared goals among the different stakeholders and researchers but also on intangible links, values, and inspirations. Most of the people in the TD arena have been involved since 2016 in a regional-level dialogue initiative named, Tertúlias do Montado. This initiative has regular meetings in which a multi-stakeholder group comprised of researchers, farmers, landowners, and public officers address Montado sustainability issues in a structured format (more details in Guimarães et al. 2019)

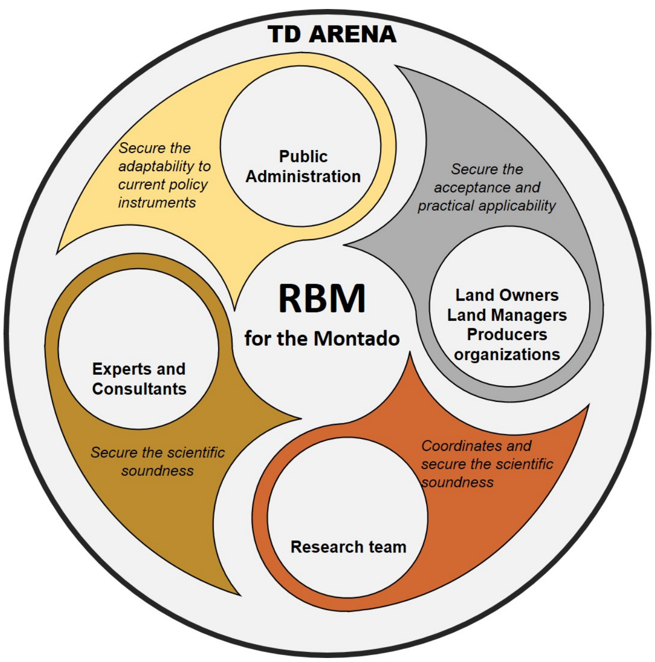
The TD arena was designed from the beginning with multiple tiers and different responsibilities in mind (Fig. 4); its structure proved vital in the process of constructing the RBIs. The core research team, composed of scholars from various backgrounds working in an interdisciplinary research unit on the outskirts of the case-study area, was responsible for coordinating the TD arena, including inviting stakeholders to participate. This core team also managed the work that enabled the identification of the RBIs' environmental results, definition, and testing. Other experts serving as project consultants intervened when the main research team needed to secure the scientific validity of proposals. This TD arena process included a group of land managers and owners who presented their preferences, concerns, and practical experience. The public administration officers oversaw the setting of boundaries and raising the administrative issues that such a program would bring to the current governance paradigm. Before proceeding to the next step, all decisions were taken collectively.

The visioning exercise: selecting environmental outcomes

The first step in building the RBIs was the setting of the scene, which included defining a vision for the future sustainability of the Montado in the study area and identifying the relevant environmental outcomes. In 2017, we organized a meeting in *Tertúlias do Montado* to discuss innovation possibilities in Montado management, supporting sustainability goals. Clear changes in management practices were determined (Guimarães et al. 2019). A priority ranking was established to facilitate such improvements, with the development of an RBM for the Montado at the top of the list. This was the starting point. The sequence of events that followed is detailed in Appendix 1. In June 2018, a group of 20, which included farmers, researchers, and technical staff from the public administration visited Ireland's Burren area to learn about an ongoing RBM. The Burren RBM has been in place for several years, with assessments indicating improved environmental outcomes along with an increasing number of participating farmers (Cullen et al. 2018). The Portuguese delegation reviewed the experience at the end of the three-day visit, and produced an action plan outline for the development of a pilot Montado RBM.

We were then ready to proceed with the second step of the process: selecting the environmental outcomes. Based on the shared vision developed in prior multi-stakeholder discussions, we were able to define a desirable ecological state of the Montado and identify the RBM's targeted environmental outcomes. This proposal was discussed with all TD arena members. We unanimously decided to proceed with the presented description and outcomes based on the inputs received. Two subgroups were formed because of this agreement. The first was dedicated to interacting with policy decision-makers, while the second was focused on the refinement of environmental outcomes and corresponding RBIs. In June 2018, two task forces were established within this group to better explore and discuss potential RBIs: one concerned with desired outcomes for soil, pastures, and trees, and the other with water and biodiversity.

Fig. 4. The design of the transdisciplinary (TD) arena around the development of a Result-Based Model (RBM) for the Montado.



Following a stepwise consultation of experts in the different fields, the outcomes emerged from discussions within each of the two task forces. The literature also supported the relevance of each outcome identified by the task forces. After each thematic task force reached a consensus, the final selected outcomes were presented to the whole TD arena for approval. After discussing the practicalities of the proposed implementation, and resulting from the clarifications and comments supporting the TD arena's RBI selection, the final RBIs were approved.

Indicator identification and selection

The third step of the process involved identifying and selecting the indicators that would be used to track the achievement of the environmental outcomes. The above-mentioned specialized task forces played a key role in this process. First, they produced a list of possible indicators. A shortlist of indicators was identified through discussions with experts, feedback from the iterative process in the TD arena, and consultation of previous thematic projects' literature and results where indicators were also tested. A key factor for selection was the relationship between each environmental outcome and related management practices. The possibility of correlating the outcome to potential indicators was also considered. This investigation implied several information exchanges in the TD arena, which are summarized in Appendix 1. In each task force, the connection between the targeted environmental outcome and farm practices was defined through a triangulation of literature review, expert empirical knowledge, and farmer's validation. By April 2019, we had established ten RBIs, which were tailored to the environmental outcomes and ready for a preliminary test on eight real farm plots.

Field testing of indicators (RBIs)

The fourth step was the testing of the RBIs. The defined indicators were evaluated on eight Montado farm plots, each on a distinct farm. The eight farms belong to seven different landowners. The farms are located in the Monfurado Natura 2000 site (PTCON0031) and its surroundings (Fig. 2). The test plots were selected in collaboration with landowners, ensuring the widespread presence of Montados with natural or semi-natural pasture and extensive grazing as listed under the EU Habitats Directive (habitat 6310). Furthermore, the inclusion of at least one distinct landscape element in each test plot was favored. The landscape elements can be small woodlots, riparian corridors, and hedges or any other diversifying factor that contributes to increased biodiversity. All test plots were also already fenced. Appendix 2 lists the farm and test plot locations (average plot size was 57 hectares). Between April and August 2020, researchers from the core research team conducted fieldwork for the RBI assessment. Some landowners accompanied the researchers during the site visits. The amount of time spent in each plot was recorded to determine the capacity to complete the assessment in one day. This was possible in all plots, with the time needed decreasing as experience increased.

A map of each test plot was created (example in Fig. 5). A five-hectare square grid was then superimposed on the map to define the indicator's assessment route. There are two types of sampling points: i) regular sampling points for quantifying RBIs related to soil, pasture, and tree layers; and ii) biodiversity sampling points for quantifying RBIs connected to particular landscape elements. The overall classification of each plot's indicator stemmed from weighing its attributes against all assessment points by using the mode (i.e., the most frequent classification value).

RESULTS AND INTERPRETATION

The environmental outcomes

The environmental outcomes established in step 2 are strategic for the Montado's equilibrium: i) maintenance or improvement of healthy and functional soil, ii) conservation of biodiverse Mediterranean pastures, iii) promotion of the Montado's long-

Fig. 5. Experimental plots with fence limits (yellow line) and RBIs assessment route (green line). Indicators assessment spots are PA1 to PA4 for RBIs related to soil, pasture, and tree layers; and PE1 to PE5 for RBIs related to the landscape elements that promote biodiversity (blue lines).

term viability through oak tree regeneration and, iv) conservation of singular landscape elements.

Healthy and functional soil can be regarded as a structural environmental outcome (Bouma 2021); healthy soil promotes biodiversity, retains water, maintains water quality, and prevents erosion. One of the major problems in the Montado is soil degradation (Guerra et al. 2014). Climate can affect soil health and management practices, mainly in farming and livestock production, and can mean the difference between healthy and poor soil (Bouma 2021).

Tree regeneration is crucial because the tree cover must be replenished as older trees disappear. With decreasing tree density, there is a tipping point below which recovery is almost impossible since young trees depend on the shade of others and mycorrhiza interactions to survive in their early stages of life (Costa et al. 2014, Pinto-Correia et al. 2011).

Montado's natural or semi-natural pastures support a diverse range of species; maintaining this diversity is essential to the system's resilience (Hernández-Esteban et al. 2019, Jongen et al. 2019). Biodiverse pastures sustain soil health by increasing the amount of organic material and nitrogen available. Pastures also help with carbon sequestration and improve soil structure, increasing the soil's capacity to retain water.

Finally, we decided to include the maintenance of singular landscape elements, such as temporary ponds, woodlots of *Quercineas* and *Pinus*, patches of shrubs, and waterlines with riparian galleries, as an environmental outcome. Each of these elements may be considered an environmental outcome per se, but they often coexist and together contribute to higher landscape heterogeneity, which in turn supports biodiversity. These unique elements include biodiversity hotspots and habitats for rare and protected species (Pereira et al. 2019, Moreno et al. 2016). These patches also represent remnants of Natura 2000 natural habitats (Commission 2013) that constitute refuges of singular biodiversity in the Montado matrix, both for flora and fauna species (Pereira et al. 2015). Furthermore, these elements provide multiple ecosystem services by participating in the water and nutrient cycles, reducing the risk of erosion, and controlling pests; therefore, they contribute to the overall regulation of the Montado system (Moreno et al. 2018, Guerra et al. 2014).

Table 1. The Result-Based Indicators issued of the co-construction process for the Montado RBM.

Result-Based Indicators	Environmental outcomes	Levels
A1 - Degree of soil coverage by *Rumex bucephalophorus* and *Chamaemelum mixtum*	A - Healthy and functional soil	1 - High (>50%), 2 - Medium-high (>25% to ≤50%), 3 - Medium-low (>10 to ≤25%), 4 - Low (≤10%); percent of coverage.
A2 - Extent of bare soil		
B1 - Density of tree cover regeneration with trees in the second stage of development	B - Quercus regeneration	1 - High (>100%), 2 - Medium-high (>50 to ≤100%), 3 - Medium-low (>10 to ≤=50%), 4 - Low (≤10%); percent in relation to the density of adult trees.
B2 - Conservation state of the tree cover regeneration		Bad (>50%), 2 - Medium (>25% to ≤50%), 3 - Good (>10% to ≤25%), 4 - Excellent (≤10%); percent of canopy lost.
C1 - Balanced between plant herbaceous groups	C - Mediterranean biodiverse pastures	1 - Low (Lack or residual presence of at least one of the botanic groups (<5%)), 2 - Medium-low (Presence of all the groups with dominance of the group “others” (>60%)), 3 - Medium-high (Presence of the 3 groups with dominance of grasses or leguminous (> 60%)), 4 - High (Presence of all 3 groups in balanced proportions); Groups: grass, leguminous, others.
C2 - Degree of soil coverage by thistles (mainly *Carduus tenuiflorus, Carduus bourgeanus*)		1 - High (>50%), 2 - Medium-high (>25 to ≤50%), 3 - Medium-low (>10 to ≤25%), 4- Low (≤10%); percent of coverage.
C3 - Degree of soil coverage by shrubs		
D1 - Diversity level	D - Conservation of singular landscape elements	1 - Null (No elements), 2 - Low (1 element), 3 - Medium (At least 2 terrestrials or aquatics elements), 4 - High (At least 1 terrestrial element and 1 aquatic element).
D2 - Representativeness of each singular element		1 - Low (≤0.30%), 2 - Medium-low (>0.30 to <0.65%), 3 - Medium-high (0.65 to ≤1.00%), 4 - High (>1.00%); percent area in relation to the total area.
D3 - State of conservation of elements		1 - Bad (>50%), 2 - Medium (>25% to ≤50%), 3 - Good (>10% to ≤25%), 4 - Excellent (≤10%); percent of difference in relation to the reference state about vegetation structure, species distribution, and presence of invasive species.

The result-based indicators

In total, ten RBIs were identified (Table 1) and will be studied in the field. Each indicator assesses or is related to at least one environmental outcome; its definition is supported by scientific literature, and its performance is dependent on a set of management actions that induce changes. Additionally, they can all be evaluated visually and are operational. The RBIs were evaluated in each of the eight test plots. We limited the number of indicators to ten due to the cognitive burden of this evaluation, which must be accomplished in one day and necessitates visits to several points within one plot. However, this selection is not yet complete; future developments may result in the replacement of certain indicators or the addition of a few more. Appendix 3 contains more details, including a list of all the references used to target each indicator.

Two RBIs were defined to measure the state of soil health: A1 and A2. A1 relates to the degree of coverage by *Rumex bucephalophorus* and *Chamaemelum mixtum* (Fig. 6). One of the most frequent health issues in Montado soil is manganese toxicity. Most plants struggle to develop in such a toxic soil environment, except for *Rumex*, which has a strong tolerance to significant amounts of manganese. The presence of this indicator plant, with its distinctive red color, denotes an elevated level of soil toxicity. *Chamaemelum mixtum* also tolerates manganese but indicates lower soil toxicity levels than *Rumex*. It has a distinguishing white color. In addition to color, A1 is also measured by comparing the difference in vegetation under the tree canopy and outside that range. Under the tree canopy, the soil is more fertile because of shade and moisture levels; consequently, the vegetation can give the appearance of the soil being healthier than what truly is the case. Hence, visual differences in the vegetation cover within and beyond the canopy range indicate soil imbalance, most frequently toxicity levels. As for A2, it refers to the cover of bare soil in each examined plot. Soil devoid of vegetation results from management actions (e.g. intensive trampling by livestock) and is highly susceptible to erosion.

Fig. 6. Example of RBIs: Degree of coverage by *Rumex bucephalophorus* and *Chamaemelum mixtum*. Left image shows a pasture with a reddish sward canopy with white patches. The color red came from a high level of coverage by *Rumex bucephalophorus* (2 in detail) and the white patches resulting from *Chamaemelum* coverage (1 in detail); Right image shows a low level of coverage (3 in detail: mix of grasses, legumes, and forbs).

Two RBIs were selected concerning tree regeneration: B1 is associated with the density of tree regeneration in its second stage of development. The second stage of tree development (i.e., saplings 50 to 200 cm long) was chosen because the tree is well established in the soil at this point; the surviving rate is high with proper management action. Soil tillage harms young tree survival, but bush density, healthy soil, and livestock management have a positive impact. To assess regeneration density, the number of saplings is compared to the number of adult trees. B2 is concerned with the conservation status of regeneration, which is evaluated based on the degree of physical damage to the canopy and young tree leaves. Herbivory and livestock trampling can endanger the survival of seedlings and saplings, especially in areas with high grazing pressure. In addition to managing stocking density, the use of tree protectors can secure tree survival.

Three RBIs were proposed to evaluate the conservation status of the Mediterranean biodiverse pastures: C1 attempts to balance herbaceous group species; C2 intends to monitor thistle coverage; and C3 aims to track shrub coverage. A well-preserved biodiverse pasture does not suggest a dominance of any of the sward's main plant functional groups, implying that grasses, legumes, and forbs are balanced; C1 measures the balance in pasture species composition. This indicator is observed within and beyond the tree canopy range since the effect of light exposure influences the preponderance of each plant functional group. For example, even when the pasture is healthy and biodiverse, there may be a prevalence of leguminous plants beneath the tree canopy, which are more tolerant to shade. C2 estimates the extension of thistle coverage (e.g., *Galactites tomentosus*) as an indicator of unbalanced pastures. Thistle patches are a common pasture visual attribute in overgrazing situations because they withstand significant amounts of nitrogen, which is frequently a consequence of excessive grazing pressure. They are also unpalatable to most grazing animals and tend to persist and increase across years. Finally, the state of the pastures is evaluated using C3's coverage of shrubs. Shrub occurrence in pastures is considered to reduce the forage mass, and indicates that sward vegetation biodiversity is unbalanced. We propose a threshold of 10% occurrence of shrubs in the pasture (excluding shrub patches targeted by RBIs D1, D2, and D3), above which they contribute to a poorer environmental condition of the pasture. Nonetheless, shrubs are central components of the Montado system, because they support biodiversity (e.g., insects, birds) and protect saplings. In this context, shrub patches have been considered as singular landscape elements that promote biodiversity and are targeted by the D1, D2, and D3 RBIs

To assess the maintenance and conservation of singular landscape elements, we defined three RBIs from a larger set. The selected indicators do not aim to assess the diversity of singular elements in detail, but rather to recognize their existence and visually consider their conservation status. The existence and conservation of these elements are heavily reliant on management actions. D1 aims to measure the diversity of singular elements; considering a minimum area for each type of singular element as a requirement. Management decisions, such as the artificial implementation of terrestrial or aquatic singular elements, can increase diversity. D2 examines the representativeness of each singular element in relation to the total plot area under consideration. D3 assesses the conservation status of each singular element present in the plot.

There are guidelines for assessing each indicator. For each state and element, there is a detailed visual assessment sheet based on vegetation structure and density, species heterogeneity in comparison to the Montado matrix, and presence of invasive species presence. All the RBIs described above have been evaluated in the field. All of them could be assessed in a reasonable amount of time and we were able to differentiate the levels within each indicator. Figure 7 depicts the variance in the assessment of each RBI in our samples' plots. Even though there are no significant differences in soils, there are marked differences in tree regeneration and the singular landscape elements. The evaluation process normally took between 2 to 6 hours, depending on paddock's size and topography.

DISCUSSION AND CONCLUSION

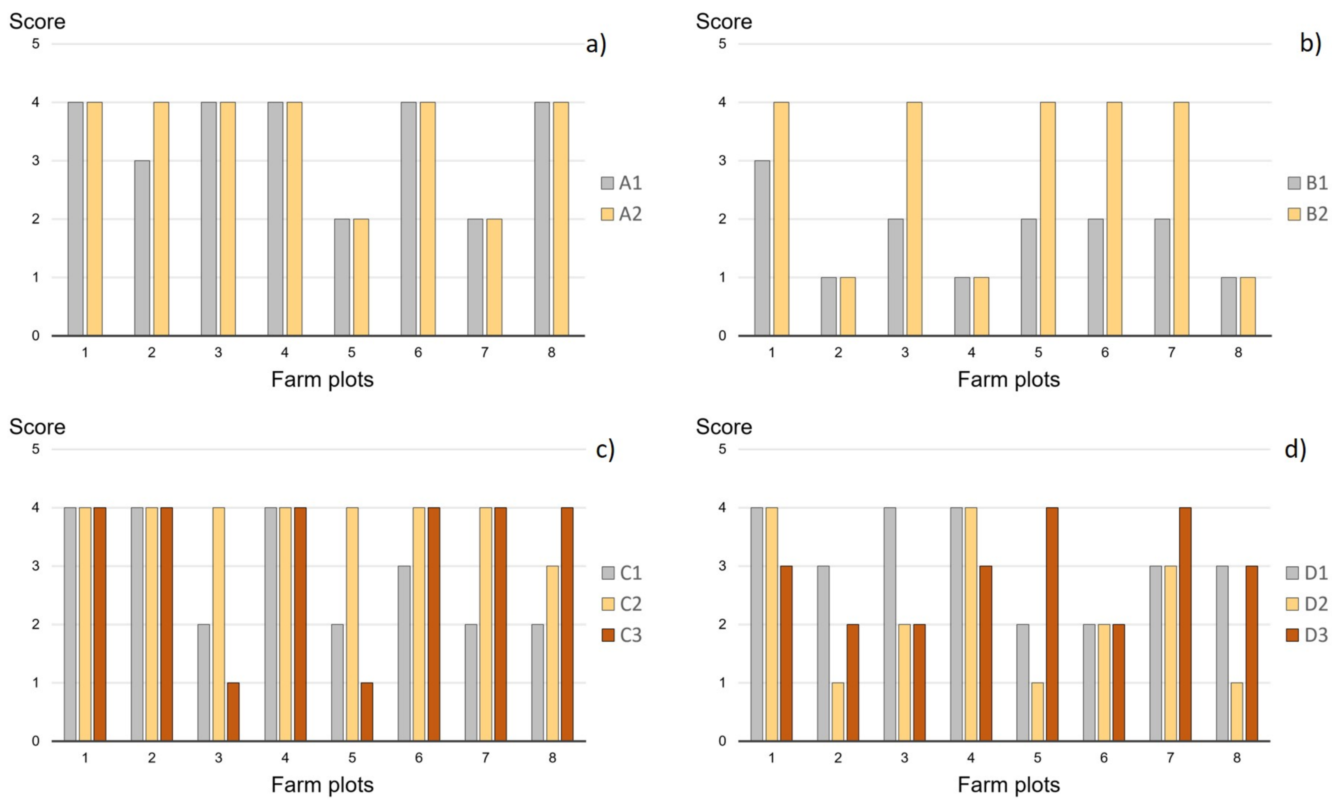
The process outlined here led to the identification of RBIs that are scientifically based, understandable, applicable at the farm and plot levels, accepted and used by land managers, and recommended for public administration. So far, the relevant public services in the Ministry of Agriculture have been informed and involved in various stages of the proposal; they have expressed their interest in launching a pilot initiative to put the RBM for the Montado into effect using the RBIs hereby defined.

Without question, such a set of qualities is grounded on the long-term TD arena, facilitating trust and collaboration among individuals with vastly different perspectives and knowledge bases on the Montado (Wiget et al. 2020). Multiple discussions over time, with a joint assessment of advantages and difficulties, clarification and resolution of disagreements, and field testing, led to results that are owned by all those involved and continue to be those required for the implementation phase. The local scale of the application area, centered on the Natura 2000 site with multiple and acknowledged nature values associated with farming, and the long history of debates on the conciliation of farming and nature in this site, have undoubtedly added to the success of this multi-stakeholder engagement (Cockburn et al. 2019).

The indicators achieved the SMART targets: Specific, Measurable, Achievable, Relevant and Time-bound. They are detailed field-based indicators. Their application requires fieldwork, which is resource-intensive, both for farmers and for those who will routinely monitor the farmers' assessments. However, as other authors have highlighted, 20 years of agri-environmental measures with no evidence of results necessitate a fresh approach (Schutter 2020). This empirical work is well-positioned to be regarded as a preliminary study and process that still needs to be fully implemented in one or several pilot areas before its full potential and drawbacks can be properly appraised.

As we can now assess after the four-step co-construction process, which was conducted within the framework of a well-functioning TD arena, these indicators serve three fundamental purposes. First, they accurately assess environmental outcomes of farming practices, thereby promoting value for money in the application of environmental payments and targeted use of public funds. Second, they keep farmers involved, growing their stewardship over the environmental services provided by their Montado (Johnson et al. 2020). Third, they increase dialogue and exchange

Fig. 7. Evaluation of the Result-Based Indicators (RBIs) in each farm plot: A1) Degree of soil coverage by *Rumex bucephalophorus* and *Chamaemelum mixtum*, A2) Extent of bare soil, B1) Density of tree cover regeneration with trees in the second stage of development, B2) Conservation state of the tree cover regeneration, C1) Balanced between botanic herbaceous groups, C2) Degree of soil coverage by thistles, C3) Degree of soil coverage by shrubs, D1) Diversity level, D2) Representativeness of each singular element, D3) State of conservation of elements.



practices between farmers and researchers and foster farmers' collective actions (Cockburn et al. 2019).

As to the quality of the indicators for measuring the environmental outcomes, the triangulation of expert consultation, review of the literature, field testing in different plots, and participation of various experts and farmers with different profiles, together provide a comprehensive quality check (O'Rourke and Finn 2020). Our transdisciplinary process involving multiple steps over several years ensures farmers' continuous involvement, in which they always maintain interest, and in some cases, even leadership. We have also strengthened dialogue and exchange, not only between farmers and researchers but also with administrative representatives. With this process, farmers will be better qualified or positioned to venture outside their comfort zone and start adaptive management aimed at achieving the expected outcomes (Targetti et al. 2019). This research is also done in response to the explicit calls made by the European Green Deal, Farm to Fork, and the EU Biodiversity Strategy for 2030 (European Commission 2020b, 2020a).

Moreover, this work answers the EU's call for experimentation on RBM modalities in various contexts (O'Rourke and Finn 2020). The indicators presented are certainly innovative in terms of measuring the environmental outcomes of farming systems and farming practices. The literature on RBIs is scarce; to the best of our knowledge, no indicators have been proposed or tested for the complex Iberian silvo-pastoral systems thus far. Burton and Schwarz (2013) discussed the difficulties in ascertaining reliable indicators for RBM and in convincing farmers to accept the increased risk associated with switching to result-based payments rather than practice-oriented incentives. Since then, local schemes have emerged that have applied and tested RBIs and showed how farmers might be motivated to integrate such systems (O'Rourke and Finn 2020, Varela et al. 2020, Wiget et al. 2020, Herzon et al. 2018). In our case, the farmers participating in the co-construction and TD arena are likewise motivated. Progress is currently expected through the implementation of a trial RBM for the Montado, which is planned to be set up as a pilot under Portugal's upcoming CAP implementation.

Future research could target the testing of these RBIs in a wide range of conditions and a comparative analysis between such assessment with sampling strategies, such as soil analysis and species identification by experts.

Responses to this article can be read online at:
https://www.ecologyandsociety.org/issues/responses.php/12973

Acknowledgments:

Special thanks to all land managers, experts, and administration officers that are actively participating in the construction process of the RBM. This work was partially funded by National Funds through FCT - Foundation for Science and Technology under the Project UIDB/05183/2020. It was also supported by H2020 funds within the project HNV-Link, "High Nature Value Farming: Learning, Innovation and Knowledge" EU grant nr. 696391, H2020-ISIB-02-2015 and by the Portuguese Rural Development Program 2014-2020 under the project InovMontado - "Gesto de Recursos Partilhados para o Desenvolvimento do Montado", PDR2020-2024-FEADER-032930.

Data Availability:

The data that support the findings of this study are available on request from the corresponding author, [Maria Helena Guimaraes].

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Appendix 1

Table A1.1 Sequence of activities that convened to the design of a RBM for the Montado, including the exchanges between stakeholders – researchers with expertise in different fields, farmers and officers of the administration.

Nº of meetings	Total nº participations	Activities	Nº of participants	Date
		STEP 1 - Setting the scene		
8	171	**Interviews with key stakeholders** framed by the H2020 project "HNV-Link": Shared vision for the future of the Montado. Innovations and needs for innovation in the Montado.	**15**	Jan-Mar / 17
		Innovation seminar (Tertúlias do Montado): Discussion and prioritization of needs for innovation in the Montado. Top ranking for the development of an RBM for the Montado.	**25**	Jun / 17
		Bilateral meetings with Office for Planning and Policy, Ministry of Agriculture (GPP).	**5**	Sep / 17
		Tertúlia do Montado: Agro-environmental measures for the agro-silvo-pastoral system Montado	**27**	Sep / 17
		Inovation Fair framed by the H2020 project "HNV-Link": Exchange of innovations among different HNV farmland areas. Contact with the Burren program	**45**	Oct / 17
		Bilateral meetings with GPP: Approach to the preliminary design of RBM for the Montado.	**4**	Nov / 17
		Tertúlia do Montado: Second discussion on agro-environmental measures for the agro-silvo-pastoral Montado	**30**	Nov / 17
		Visit to the Burren: Learning from the experience of development and co-construction of RBPS in The Burren	**20**	Jun / 18
		STEP 2 - Identification of environmental outcomes		
3	37	**Reflexion on the Cross visit to the Burren:** Setting up of 2 working groups: WG 1 – Policy and required conditions for the implementation of the RBM; WG 2 - Technical design of a draft RBM for the Montado.	**19**	Jun / 18
		Organization of the Montado Program (WG 1 and 2): Identification of environmental outcomes; Planning of the next steps of the process	**11**	Jun / 18
		Agreement on working methodology in WG2. Definition of 2 Task forces: Task force 1 – Soil, pasture and trees; Task force 2 – Water and biodiversity	**7**	Jun / 18

Table A1.1 (continued).

Nº of meetings	Total nº participations	Activities	Nº of participants	Date
		STEP 3 – Selection of indicators		
12	121	**Task force 1 - Soil, pasture and trees**: Identification of specific environmental results and relationship with management actions.	**4**	Jul / 18
		Task force 2 - Water and biodiversity: Identification of specific environmental results and relationship with management actions.	**4**	Jul / 18
		Task force 2 - Water and biodiversity: Identification of target objectives for each environmental result.	**6**	Set / 18
		Task force 1 - Soil, pastures and trees: Review of the strategy to progress towards the proposed environmental results and indicators.	**4**	Set / 18
		Task force 2 - Water and biodiversity: Discussion of environmental results, management practices that affect those results and possible visual indicators to assess the results.	**3**	Out / 18
		Task force 1 - Pastures: Discussion with experts on the definition of environmental results to be achieved, agricultural practices affecting them and visual indicators to measure the environmental results defined for pastures.	**4**	Out / 18
		Task force 1 - Soil: Discussion with expert (researcher) on the definition of environmental results to be achieved, agricultural practices affecting them and visual indicators to measure the environmental results defined for soils.	**5**	Out / 18
		Task force 1 - Trees: Discussion with expert(researcher) on the definition of environmental results to be achieved, agricultural practices affecting them and visual indicators to measure the environmental results defined for oak trees.	**4**	Out / 18
		WG 1 Discussion on the requirements to set up a results' based pilot program for the Montado	**5**	Out / 18
		WG 1 and 2 - Review, discussion and harmonization of environmental results and indicators;	**10**	Nov / 18
		WG 1 and 2 meeting with GPP (Ministry of Agriculture) to discuss the opportunity to develop a pilot results based program for the Montado.	**12**	Nov / 18
		Public presentation of the results based payments for Montado adaptive management in post 2020 CAP	**60**	Nov / 18
		STEP 4 – Testing of indicators		
18	49	**Review meeting** of WG 1 + WG 2: first attempt to test the visual indicators in a real farm	**12**	Apr / 19
		Field work- Visits to the 2 experimental plots to define in detail the plot assessment method	**5**	Mar / 20
		Field work – Visits to all experimental plot for RBIs assessment (2 persons x 2 visits x 8 plots)	**32**	Apr-Aug / 20

Appendix 2

Table A2.1 List of farm and plot areas used for the verification of the RBIs

Farm	Farm area (ha)	Test plot area (ha)
1	489	89
2	442	64
3	205	96
4	283	25
5	305	70
6	521	66
7	187	13
8	297	37

Appendix 3

Table A3.1 The Result-Based Indicators, their expected environmental outcomes and possible management actions leading to desirable outcomes. References that support the construction of each indicator are also stated.

Result-Based Indicators	Environmental outcomes	Possible management actions	References
A1 Degree of soil coverage by *Rumex bucephalophorus* and *Chamaemelum mixtum* A2 Extension of bare soil	A Healthy and functional soil	Application of dolomitic limestone; Soil fertility improvement; Livestock management; Creation of drainage systems.	Bilotta et al. 2007; Marcos et al. 2007; Benavides et al. 2009; Brito et al. 2014; Carvalho et al. 2015; Sales-Baptista et al. 2016; Serrano et al. 2017; Serrano et al. 2020.
B1 Density of tree cover regeneration with trees in the second stage of development B2 Conservation state of the tree cover regeneration	B Quercus regeneration	Livestock management; Elimination of soil tillage practices; Utilization of tree protectors.	Pulido and Díaz 2005; Acácio et al. 2007; Plieninger et al. 2010; Pinto-Correia et al. 2011; Arosa et al. 2015; Simões et al. 2016; Arosa et al. 2017.
C1 Balanced between botanic herbaceous groups C2 Degree of soil coverage by thistles C3 Degree of soil coverage by schrubs	C Mediterranean biodiverse pastures	Livestock management; Pasture seeding; Soil fertility improvement; Shrubs encroachment control.	Pinto-Correia and Mascarenhas 1999; Plieninger et al. 2004; Ferraz-de-Oliveira et al. 2013; Lüscher et al. 2014; Kairis et al. 2015; Ferraz-de-Oliveira et al. 2016; Sales et al. 2016; Simões et al. 2016; Sevov et al. 2017; Waters et al. 2017; Abdalla et al. 2018; Listopad et al. 2018; Hernández-Esteban et al. 2019; Jongen et al. 2019.
D1 Diversity level D2 Representativeness of each singular element D3 State of conservation of elements	D conservation of singular landscape elements	Isolated landscape elements management; Natural habitat restoration; Livestock management; Fencing; Watering systems establishment	Williams et al. 2004; Arizpe et al. 2008; Pinto-Cruz et al. 2009; Godinho et al. 2011; Rosset et al. 2013; Pereira et al. 2015; Catarino el al. 2016; Lumbreras et al. 2016; Simões et al. 2016; Tulloch et al. 2016; Hunter Jr et al. 2017; Macek et al. 2018; Varela et al. 2018.

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