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Abstract. To date, scientific literature provided a vast amount of studies on Ecosystem Services (ES) underpinning their benefits to human well-being. Livestock grazing systems occupy a vast area of the terrestrial surface and are essential to the livelihood especially for vulnerable communities. Grazinglands are able to provide a wide array of ES depending on management practices and intensity. In this perspective and according to the Millennium Ecosystem Assessment (MA) framework, the paper reviews the methods and the approaches used in the analysis of the main ES provided by grazing systems. The search criteria produced a scarce amount of papers (few referred to Mediterranean climate areas), also because many authors did not consider 'goods' or 'benefits' (e.g. food) as ES. The bibliography review highlighted that: i) some papers misunderstood the concept of ES as defined by MA (e.g. biodiversity considered as ES; lack of anthropocentric vision); ii) ES planning need management and development options to be based on systems' internal dynamics; iii) ES multiscale and multisectoral analysis emerged in many papers but just few included stakeholder (SHs) involvement; iv) a better SHs awareness of the well-being provided by ES in livestock grazing systems could foster agri-environmental schemes and the willingness to pay for their services.

Keywords. *Grazinglands – Livestock – Primary production – Habitat – Food – Land degradation – Water quality and flow – Climate regulation.*

Méthodes et approches utilisées pour évaluer les services écosystémiques fournis par les systèmes pastoraux

Résumé. *À ce jour, la littérature scientifique a fourni une grande quantité d'études sur les services écosystémiques (SE) qui montrent leurs avantages pour le bien-être humain. Les systèmes pastoraux occupent une vaste zone de la surface terrestre et sont essentiels à la subsistance en particulier pour les communautés vulnérables. Les pâturages sont en mesure de fournir un large éventail de SE en fonction des pratiques et de l'intensité de gestion. Dans cette perspective et conformément au cadre Millennium Ecosystem Assessment (MA), le document passe en revue les méthodes et les approches utilisées dans l'analyse des principaux SE fournis par les systèmes de pâturage. D'après les résultats, l'examen fournit des recommandations pour les recherches futures dans les régions méditerranéennes. Les critères de recherche ont produit une quantité insuffisante de documents (quelques-uns visant les zones à climat méditerranéen), en partie parce que de nombreux auteurs ne considèrent pas les «biens» ou «avantages» (par exemple aliments) en tant que SE. L'examen de la bibliographie a souligné que: i) des articles ont mal compris le concept de SE tel que défini par la MA (par exemple biodiversité considérée comme SE, manque de vision anthropocentrique); ii) la planification des SE a besoin d'options de gestion et de développement pour être basée sur la dynamique interne des systèmes; iii) l'analyse multisectorielle multi-échelle des SE a émergé dans de nombreux documents, mais seulement quelques-uns ont inclus l'implication des parties prenantes (SHs); iv) une meilleure prise de conscience des parties prenantes sur le bien-être fourni par les SE dans les systèmes pastoraux pourrait favoriser des programmes agroenvironnementaux et la volonté de payer pour leurs services.*

Mots-clés. *Pâturages – Élevage – Production primaire – Habitat – Aliment – Dégradation des terres – Qualité de l'eau et débit – Régulation du climat.*

I – Introduction

Although the first references about the concept of 'ecosystem functions, services and values' are dated around 1960s, the amount of scientific publications concerning Ecosystem Services (ES) grew exponentially in the last few decades (de Groot *et al.*, 2002). The Millennium Ecosystem Assessment (MA, 2003; 2005) represents one of the most extensive and accepted ever study on the links between human well-being and the world's ecosystems. The MA defines i) the ecosystem as *"a dynamic complex of plant, animal* (including humans), *and microorganism communities and the non-living environment interacting as a functional unit"* and ii) the ecosystem services as "*the benefits people obtain from ecosystems"*.

MA distinguished four groups of ES: i) Supporting: services necessary for the production of all other ES (e.g. soil formation and nutrient cycling) whose impacts on people are either indirect or occur over a very long time; ii) Provisioning: products obtained from ecosystems, such as food and fresh water; ii) Regulating: benefits obtained from the regulation of ecosystem processes, such as climate and disease regulation; iii) Cultural: non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences.

A second key study concerning ES is the Economics of Ecosystems and Biodiversity (TEEB, 2010) which defines ES as *'the direct and indirect contributions of ecosystems to human well-being'*, separates the concept of services from benefits (welfare gains generated by ES) and considers supporting services just as ecological processes and not strictly as ES.

If in one hand every ecosystem is able to produce a large amount of ES (MA, 2003; 2005), on the other hand, ecosystems may also produce Ecosystem Disservices that are harmful or detrimental to human well-being (von Döhren and Haase, 2015). Thus, the term "ecosystem service" is anthropocentric and to be intended with a positive sense.

ES are spatial-scale and time-scale dependent and the risk of scale mismatch between ecological processes and decision-making is likely to occur. For these reasons the need of an integrated approach that takes into account also the local knowledge of stakeholders (SHs) is a key requirement in assessing ES (MA, 2003; 2005; Reed *et al.*, 2008; Tarrasón *et al.*, 2016).

According to MA (2003) and TEEB (2010), ecosystems and biodiversity are closely related concepts although the latter it is not considered strictly an ES but rather a source or a regulator of the former (Harrison *et al.*, 2014). The gap of knowledge on the linkages or difficulties in understanding the relationships between ES and biodiversity was highlighted by many authors (e.g. Jax and Heink, 2015; Sircely and Naeem, 2012; Harrison *et al.*, 2014).

Livestock systems occupy about a third of the planet's ice-free terrestrial surface and represent an important source of income or even are essential for vulnerable human communities' survival. In these systems, grazinglands could deliver a large and differentiated amount of ES. These services in turn are dependent on different management practices (Fischer *et al.*, 2010; Steiner *et al.*, 2014), such as different grazing regimes (Ford *et al.*, 2012).

The aim of this paper is to review the methods and the approaches used in the analysis and planning of the main ES provided by grazing systems and to derive recommendations for future research in Mediterranean areas.

II – Grazing systems: classification criteria and terminology

To date no unique classification of livestock systems is available (Robinson *et al.*, 2011). Broadly defined, livestock systems are a subset of farming systems (Ruthenberg, 1980), in which livestock contribute more than 10 percent to total farm output (Seré and Steinfeld, 1996), with similar enterprise patterns, livelihoods and resource base (Dixon *et al.*, 2001).
A more livestock-oriented classification of farming systems was developed by Seré and

Steinfeld (1996) for solely livestock systems split into grassland-based (LG) and landless (LL) systems. LG and LL systems are those in which dry matter fed to animals is higher and lower than 10 percent produced in the farm, respectively; and in which annual average stocking rates are below and above 10 standard livestock units per hectare of agriculture land, respectively. An interactive map of their distribution is provided by Global Livestock Production and Health Atlas (GLiPHA) of FAO (2016).

Ecosystem classification is performed according to the various fields of research. Biomes are the most basic units that ecology use to describe global patterns of ecosystem form, process, and biodiversity (Ellis and Ramankutty, 2008). Historically, biomes were identified and mapped based on general differences in vegetation type associated with regional variations in climate (Matthews, 1983; Olson *et al.*, 2001). Further classifications dealing with the potential land uses for agriculture in a geographical context are agro-ecological zones devised by FAO, which found a wide range of applications at global, regional and national levels (FAO, 2011; FAO and IIASA, 2007). Considering the first classification just some biomes provide the necessary conditions for livestock systems (e.g. tundra, taiga, steppe, savanna). In the second classification, ecological zones are divided based on the length of the grazing period and potential evapotranspiration.

In the attempt to relate livestock systems and agro-ecosystems, land use types emerge. ‘Rangelands’ include land on which the indigenous vegetation (climax or subclimax) is predominantly grasses, grass-like plants, forbs or shrubs that are grazed or have the potential to be grazed, and which is used as a natural ecosystem for the production of grazing livestock and wildlife (natural grasslands, savannas, shrublands, many deserts, steppes, tundras, alpine communities and marshes). ‘Grazinglands’ extend the potential land use from natural compositions to any vegetated land that is grazed or has the potential to be grazed by animals (domestic and wild) (Allen *et al.*, 2011). This term is all-inclusive and covers all kinds and types of land that can be grazed (rangelands and artificial pastures).

Within both the ecosystem and the agro-ecological classifications, a set of terms is in use to distinguish between systems and management practises. The applied terms mainly reflect the relationship between the exploitation of land and vegetation type, such as pastoralism (Land-use systems in which grasslands and shrublands are exploited through grazing) and silvopastoralism (Land-use systems and practices in which trees and pastures are deliberately integrated with livestock components). While the first and second terms relate directly to the management practice, agroforestry (Land-use systems or practices in which trees are deliberately integrated with crops and/or animals on the same land management unit) indicates just a relationship between forestry and agriculture on a territorial unit.

In the context of this review, grazing systems include the production systems in which grazing is one of the main management practices adopted through all the grazing lands.

III – Linkages between biodiversity and ecosystem services

Biodiversity is the variability among living organisms and includes diversity within and among species and ecosystems. It is the source of many goods and services, such as food and genetic resources, and changes in biodiversity can influence the supply of ES (MA, 2003). Later the MA (2005) defined biodiversity as a necessary condition for the delivery of all ES and, in most cases, greater level of biodiversity is associated with a larger or more dependable supply of ES.

According to MA (2005) biodiversity is both a response variable affected by global change drivers (e.g. climate or land use change) and a factor modifying ecosystem processes and services and indirectly, human well-being (e.g. health or freedom of choice and action). Changes in human well-being may lead to modify management practices with direct effects on ecosystem processes and biodiversity (Fig. 1).

Despite MA describes a unilateral relationship between biodiversity and ES, some authors consider biodiversity as a service in its own right and for example, as the basis of nature-based tourism (van Wilgen *et al.*, 2008), while some others consider biodiversity and ES as synonyms (Mace *et al.*, 2012).

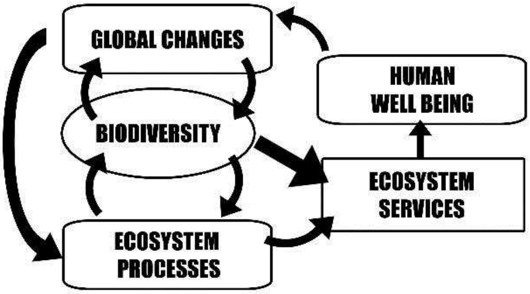

Fig.1. Interrelation among biodiversity, ecosystem functioning and ES (modified from MA, 2005).

Habitat provisioning is one of the main ecosystems services linking the effects of livestock grazing to the biodiversity of the host ecosystem (FAO, 2014). Habitat services arise from the direct interaction of animals with their environments, hence are related to land management practices, especially in grazing systems. Despite MA (2003, 2005), the TEEB (2010) considers Habitat services as a separate category. In accordance with these documents, this review considers habitat services within supporting services, because of their interconnected nature, as well as their shared roles in underpinning the delivery of the other services.

IV – Bibliography analysis: methods and tools

The review is based on the ES provided by grazing systems as categorised and found to be prominent by FAO (2014) (Tab. 1). Among those, the ES on the base of the expertise and background of the authors were analysed in detail.

A general database of papers dealing with ES was created using the Web of Science^{TM} in January 2016 selecting ‘topic’ as the searching option. The basic string: *"ecosystem service*" and ("grassland*" or "rangeland*" or "shrubland*" or "scrubland*") and "grazing"* was used as input in the ‘field search’ (‘basic search’) including ‘all years’ as ‘timespan’. The term “*mediterranean*” was than added to understand how deeply the ES were studied within Mediterranean climate areas. In order to select papers for each analysed ES, specific search terms were added to the basic string according to the keywords (Tab. 1) included in FAO (2014). The search terms are reported in detail in each ES section.

The query returned a total of 157 papers of which only 10 were referred to Mediterranean (MED) areas. Multiple occurrence of different ES within single papers (more than 50% of the papers deals with two and three ES simultaneously) result in a total amount of 531 findings (40 in MED areas) (Table 1).

This review did not take into account: i) papers dealing with ES not analysed, ii) reviews and meta-analysis, and iii) papers not adopting the MA framework.

The methods used for assessing ES (e.g. direct, indirect, modelling, indicators), applied treatments and the spatial and temporal scale of assessment were examined in the analysed papers. The use of multiscale and multisectoral assessment framework (MA, 2003) or other approaches (e.g. participatory), especially regarding those dealing with planning and providing of ES was analysed

Table 1. Number of papers returned by the search strings used for each ES, provided by grazing systems (modified from FAO, 2014)

ES group	Ecosystem service[1]	Description	N° of papers[2,3]
Supporting	Maintenance of soil structure and fertility (n.a.)	Nutrient cycling on farm and across landscapes, soil formation	12 (1)
	Primary production	Improving vegetation growth/cover	73 (7)
	Habitat services *(as part of supporting services)*		
	Maintenance of life cycles of species	Habitat for species, especially migratory species	79 (5)
	Habitat connectivity (n.a.)	Seed dispersal in guts and coats	2 (0)
	Maintenance of genetic diversity	Gene pool protection and conservation	0
Provisioning	Food	Meat, milk, eggs, honey, wool, leather, hides, skins, etc.	12 (2)
	Fertilizer (n.a.)	Manure and urine for fertilizer	9 (0)
	Fuel (n.a.)	Manure and CH_4 for energy, manure biogas, etc.	11 (0)
	Power	Draught animal power	0
	Genetic resources (n.a.)	Basis for breed improvement and medicinal purposes	10 (0)
	Biotechnical/Medicinal resources	Lab. animals, test-organisms, biochemical products	0
Regulating	Waste recycling and conversion of non-human edible feed (n.a.)	Recycling of crop residues, household waste, swill, primary vegetation consumption	1 (0)
	Land degradation and erosion prevention	Maintenance of vegetation cover	26 (5)
	Water quality regulation/purification	Water purification/filtering in soils	8 (1)
	Regulation of water flows	Natural drainage and drought prevention, influence of vegetation on rainfall, timing/magnitude of runoff/flooding	44 (4)
	Climate regulation	Soil C sequestration, GHG mitigation	60 (4)
	Moderation of extreme events	Avalanche and fire control	19 (3)
	Pollination (n.a.)	Yield/seed quality in crops and natural vegetation; genetic diversity	17 (0)
	Biological control and animal/human disease regulation (n.a.)	Destruction of habitats of pest and disease vectors; yields	3 (0)
Cultural	Opportunities for recreation (n.a.)	Eco/agro-tourism, sports, shows and other recreational activities involving specific animal breeds	50 (1)
	Knowledge systems and educational values (n.a.)	Traditional and formal knowledge about the breed, the grazing and socio-cultural systems of the area	23 (0)
	Cultural and historic heritage (n.a.)	Presence of the breed in the area helps to maintain elements of the local and/or culture that are valued as part of local heritage; cultural identity	21 (2)
	Inspiration for culture, art and design (n.a.)	Traditional art /handicraft; fashion; cultural, intellectual and spiritual enrichment and inspiration; pet animals, advertising	12 (0)
	Natural (Landscape) heritage	Values associated with landscape as shaped by animals themselves or as a part of landscape, e.g. aesthetic values, sense of place, inspiration	39 (5)
	Spiritual and religious experience	Values related to religious rituals, human life-cycle such as religious ceremonies, funerals or weddings	0

[1] n.a.: ES not analysed; [2] between parentheses, papers within Mediterranean climate areas; [3] multiple occurrence of different ES within single papers present.

V – Ecosystem services

Primary production (PP) is a fundamental supporting service defined in MA (2003) as assimilation (gross) or accumulation (net) of energy and nutrients by green plants. Maintaining or enhancing the productive capacity and resilience of grazingland ecosystems is critical for the continued support of livelihoods and the ES that benefit society at large (Teague *et al*., 2015). We extracted papers according to the additional string *("primary production" or "vegetation growth" or "vegetation cover" or "vegetation" or "NPP" or "net primary production")*. The analysis resulted of 73 papers of which 7 in Mediterranean area. In the analysed papers PP in grazinglands is commonly recognised as basic ES for the livestock systems functioning (e.g. Loucougaray *et al*., 2015), but few researches refer to the approach and the classification as provided by MA (e.g. Oñatibia *et al*., 2015). PP was mainly assessed as aboveground biomass, often in combination with other characteristics (e.g., mainly belowground component, but also litter, vegetation cover, herbage nutritive value, etc.) in several rangeland ecosystems, under different site, climate and management conditions.

Different methods and approaches were used for assessing PP. Direct field-based surveys (e.g. Oñatibia *et al*., 2015), but also calibrated measurements (e.g. Loucougaray *et al*., 2015), were used at different spatial and temporal scale. Field-plots experiments assessed the effects of different management (e.g. mowing, grazing and undisturbed or abandonment) and intensities on PP in short (e.g. Zeng *et al*., 2015) but also long-term (e.g. Marriot *et al*., 2010) monitoring. In these researches, plots dimensions varied from minimum of 0.45 (Marriot *et al*., 2010) up to 170 ha (Medina-Roldán *et al*., 2012) in designs with 2-4 replicates and included enough heterogeneity to reduce pseudo-replication effects. In other cases, landscape scale was applied to take into account management or site conditions in farms (Loucougaray *et al*., 2015) or along transects. In multiple zonal grazinglands along climatic and management gradients (e.g. Bai *et al*., 2012; Medina-Roldán *et al*., 2012; Sasaki *et al*., 2012), transects were used to assess the effects of grazing on the PP (e.g. above- and below-ground and litter biomass, C : N : P stoichiometry). The same methodologies were used to assess the dynamic trade-offs, synergies and relationships of PP with other ES in response to diverse site-specific, land use and management conditions to provide support for the sustainable development of production systems and grazinglands conservation. Examples are the analysis of the effect of vegetation cover on the soil loss and run off (van Oudenhoven *et al*., 2015) and on drought (Gaitán *et al*., 2014) or the CO_2 enrichment on the plant composition and production under grazing (Newton *et al*., 2014).

To overcome the limits to account for spatial and temporal variation of the field-based methods remote sensing and simulation models were used to assess and monitor grazinglands dynamics and their ability to provide ES according to management strategies. Sant *et al.* (2014) used high resolution imagery as enhanced ground samples to assess the vegetation cover as indicator of range condition to develop improved management prescriptions. On other sites, several authors (Lima *et al*., 2011; Schaldach *et al*., 2013; Teague *et al*., 2015), used models both for the simulation of ecological, environmental and economic effects under various combinations of changing livestock, climate and management conditions and for an integrated analysis of land cover changes. The results of the simulation approach resulted as useful tools allowing a more complete analysis of the impacts of different management when integrated with field data. ES method is recognised as a suitable tool (e.g. Schaldach *et al*., 2013) to support climate adaptation strategies integrating both ecological and socio-economic aspects. Neverthelss, none of the analysed papers highlighted the inclusion of participatory process or stakeholder involvement as done by Tarrasón *et al.* (2016).

Habitat services (HS) facilitate the life cycles of animals and plants, the prevention of succession to less valuable ecological states through encroachment of bush and/or invasive species, and the conservation of wildlife and protected areas found in coevolved landscapes (FAO, 2014). The most important clusters of HS provided by livestock are those that support the

maintenance of species life cycles and those related to the connection of habitats (FAO, 2014). We extracted papers according to the additional criteria *("species" or "habitat" or "life cycle")* and obtained 79 papers. Plants resulted the most studied (e.g. Duru *et al.*, 2015) followed by pollinator (e.g. Cole *et al.*, 2015) and not pollinator (e.g. Cole *et al.*, 2012) insects; earthworms (e.g. Kovács-Hostyánszki *et al.*, 2013) and arbuscular mycorrhizal (e.g. Morris *et al.*, 2013).
The literature review highlighted that HS assessment methods are species (animal, plants, etc.) and mainly spatial-scale dependent. Transect surveys were mostly used for species sampling at different scales, varying from 16 m (e.g. for carabidae diversity, Cole *et al.*, 2012) to 700 km along a precipitation gradient (e.g. for botanical composition, Bai *et al.*, 2012). Random sampling was used in field-plot experiments (e.g. Boughton *et al.*, 2013) or at farm level (Loucougaray *et al.*, 2015) for assessing species diversity/abundance and vegetation cover. Point quadrat method (e.g. Klumpp and Soussana, 2009) and abundance/dominance method (Fontana *et al.*, 2014; Bagella *et al.*, 2013) were the main used for vegetation survey. Most frequent indicators used both for plant and animal species were: species richness (e.g. Duru *et al.*, 2013), abundance (e.g. Stein *et al.*, 2014), Shannon diversity (e.g. Fontana *et al.*, 2014), Eveness (e.g. Cole *et al.*, 2015) and Simpson (e.g. Franzén and Nilsson, 2008). GIS, sometimes in combination with remote sensing technologies were used to analyse land use (e.g. Fontana *et al.*, 2014) and diachronic vegetation changes (e.g. Su *et al.*, 2015) or for identifying scenarios of biodiversity trajectories (e.g. Lindborg *et al.*, 2009). Modelling was used to simulate vegetation dynamics, also in relation with other ES (e.g. cattle grazing and elk hunting, Hussain and Tschirhart, 2013), and to identify scenarios related to climate change (e.g. Peringer *et al.*, 2013) or to land use management options (e.g. for the biodiversity conservation, Lindborg *et al.*, 2009). Others researches used SHs involvement to provide supporting tools for the sustainable management of grazinglands (Fisher *et al.*, 2011).

Food and other livestock related products (FP) in grazed ecosystems include provision of high-protein meat and dairy products along with leather and other by-products of livestock production (Steiner *et al.*, 2014). A main effect of grazing for livestock is a clear positive impact on the nutritive quality of the resulting products, especially regarding antioxidants, lipid quality and fat soluble vitamins. The quality is clearly related to the botanical biodiversity of the pastures that is associated with a diversity of plant active compounds influencing the animals' metabolism (Leiber *et al.*, 2014).

From this analysis, extraction string *("meat" or "milk" or "honey" or "wool" or "leather" or "hide" or "skin" or "wax")* revealed 12 publications out of which 10 were not relevant, while just two of them were conceived in the ES framework. Both publications (Bagella *et al.*, 2013 and Koniak *et al.*, 2011) are from Mediterranean area and address issues related to honey production. Koniak *et al.* (2011) developed a mathematical model which predicts the dynamics of multiple services in response to management scenarios (grazing, fire and their combination), mediated by vegetation changes. In this paper, the potential contribution to honey production was combined with other ES from different groups, despite their different nature, into one 'ES basket'. Bagella *et al.* (2013) monitored honey production and the quality of pollen present in its sediments in an experimental apiary in a typical Mediterranean agro-pastoral system. The research was performed to identify the most effective plant communities for honeybee foraging by highlighting the relationship between flowering phenology and pollen occurring in honey sediments.

Land degradation and soil erosion (LD) are not seen just as a loss of soil and fertility but also as deterioration of balanced ecosystems and the loss of ES (Nachtergaele *et al.*, 2011). The additional string *("land degradation" or "erosion" or "cover crop*" or "vegetation cover")* resulted of 26 papers of which 5 in Mediterranean areas. According to the analysis criteria, just 3 out of 26 papers were eligible for this review because LD was not analysed as an ES.

A participatory methodological framework was used to identify features of LD and linkages with ES provision (Tarrasón *et al.*, 2016). This study designed a four-step methodological framework to integrate local and scientific knowledge within a participatory assessment of land degradation in a pastoral system. Field visits, in-depth interviews with key informants and farmers produced information that was integrated with scientific knowledge, validated by focus groups and then used in a state-and-transition conceptual model. Field data on cover vegetation and plot life forms were used in thematic working groups with different SHs to discuss about the results of previous phase and to develop adaptive management options to maintain or improve ES. The same model was validated by Miller *et al.* (2011) with field studies conducted in a semiarid grassland ecosystem of USA quantifying structural and functional attributes related to the states and processes represented in the model. Moreover, a wind erosion simulation model was used to investigate effects of measured biophysical attributes on predicted rates of wind-driven soil movement at plot scale. A global scale research was performed by Petz *et al.* (2014a) using a combined approach of literature review, data and models (e.g. 'IMAGE-USLE') to study the interactions between input data, livestock density and ES.

Water quality regulation/purification (WQ) is an ES that directly links human populations' welfare. Ecosystems can be a source of impurities in fresh water but also can help to filter out and decompose organic wastes introduced into inland waters (MA, 2003). The additional extraction string *("water quality" or "water regulation" or "water purification" or "water filtering in soil")* resulted of 8 papers of which 3 were eligible for the analysis.

Fisher *et al.* (2011) explored the variation in ES delivery resulting from different management practices in UK wetlands. In particular, the role of species-led (both animals and plants) management on biodiversity was focused. In a following step, a consultation of the SHs and experts was done through workshops and meetings to elaborate specific details of management impacts on ES, including hydrology. Three categories of key ES (and disservices) were identified and linked to the range of management. These results are particularly relevant for the drafting of management plans that should carefully balance the effects of management practices. For example taking into account grazing-related effects on some ES such as water-quality parameters like turbidity and temperature (Van Horn *et al.*, 2012).

Other authors examined the effects of grazing management at plot scale (Jackson *et al.*, 2006), analysing the consequence of grazing and un-grazing on nitrate concentrations of the leachate from annual grassland.

Regulation of water flows (WF) in MA (2003) deals with the timing and magnitude of runoff, flooding, and aquifer recharge that can be strongly influenced by changes in land cover, including alterations of the water storage potential of the system. The specific search terms *("water" or "natural drainage" or "drought prevention" or "runoff" or "rainfall" or "flooding")* added to the basic string produced 44 papers.

To avoid potential mismatches between the scales at which ecological process occurs and at which management decisions are taken ES assessment requires the use of a proper scale (MA, 2003). In this view the analysis revealed different approaches used in the papers. At large scale, Fisher *et al.* (2011) analysed WF with WQ by using the same approach previously described in WQ. At catchment scale, Petz *et al.* (2014b) evaluated alternative land management scenarios with SHs involvement by mapping and modeling multiple ES, including water supply. The latter was estimated using the long-term average annual water yield as an indicator and the InVEST tool (Kareiva *et al.*, 2011) to quantify and map water yield using hydrological and vegetation data. Other authors used the InVEST model to assess water supply. At catchment scale Pan *et al.* (2015) studied the effects of spatial/temporal variation and the effects of land use change on water supply. The input variables and parameters for InVEST were land use and cover and the territorial characteristics derived by a digital elevation model (DEM).

Field experiments were conducted by Ford *et al.* (2012) to estimate ES from grasslands in three replicate experimental blocks, each containing three 10x10 m plots identifying different management treatments (different grazing animals and stocking, un-grazed). Soil/vegetation characteristics and invertebrates were analysed to assess the effects of management on WF. Inauen *et al.* (2013) studied the effect of the reduction of the grazing in four alpine grasslands types on the water balance and consequence the provisioning of fresh water and on the potential of hydroelectric power production. Lysimeters were used in field experiments under free-air CO_2 enrichment, to solve the hydrological water balance.

Climate regulation (CR) is a service obtained by the regulation of ecosystem processes. It is receiving increasing attention since the effects of climate change over the next century is projected to affect, directly and indirectly all types of ecosystems and ES (MA, 2005). The extraction string *("climate" or "soil carbon" or "greenhouse gas*" or "GHG" or "CO_2" or "CH_4" or "N_2O")* provided 59 papers mostly dealing with climate change scenarios.

Many papers conducted field experiments dealing with soil C pool at different scales. For example, in fixed sand dune grasslands of UK, Ford *et al.* (2012) used replicate experimental blocks investigating C stock from soil, roots, litter and shoots under different management. Marriott *et al.* (2010) investigated soil total C and N in pastures under different management options with an automated Dumas combustion technique. Other field experiments were carried out by Bagchi and Ritchie (2010) assessing soil C input (plant tissue plus the amount returned as dung) and soil C stock under different grazing conditions in Trans-Himalayas of northern India. Landscape scale approach was used for assessing N and C cycling in grazed and non-grazed upland grassland of northern England (Medina-Roldán *et al.*, 2012). Transect analysis was carried out by Farley *et al.* (2013) to examine soil and aboveground C in 8 sites in Ecuador.

Some authors perfomed mesocosms experiments in greenhouses for quantification of N_2O emissions using a closed flux chamber (Abalos *et al.*, 2014). Klumpp and Soussana (2009) extracted monoliths from two contrasted long-term field treatments (high vs. low grazing disturbance) and exposed to both low and high (simulated grazing) disturbance during a 2 years experiment. Subsequently, a mathematical framework was used to predict changes in C fluxes after grazing disturbance.

Predictive models for grasslands dynamics were used by Peringer *et al.* (2013) in pasture-woodlands while Scheiter *et al.* (2015) used a dynamic vegetation model to project how climate change and fire management might influence future vegetation in northern Australian savannas. C fluxes from natural grasslands under different grazing pressures were assessed by dynamic carbon models (Dong *et al.*, 2012). Koniak *et al.* (2011) applied a mathematical model to study the relationships between C retention in woody plants and other ES. Concerning the expected progressive increment of CO_2 concentration in atmosphere experiments related to changes in botanical composition in grassland were carried out by Newton *et al.* (2014) and Inauen *et al.* (2013) using Free Air Carbon Dioxide Enrichment (FACE) technique.

To identify the most desirable management options for lowland wet grassland, Fisher *et al.* (2011) analysed management plans and annual reports of 22 UK reserves. Service and disservices including GHG fluxes were used in SHs meetings as support tools to the discussion and learning. Lavorel *et al.* (2015) compared four Australian ecosystems using a four-step framework based on the identification of adaptation services under different scenarios of climate and management change.

From the literature review emerges a deep analysis of soil C pool and CO_2 fluxes while other GHG like CH_4 and N_2O were less investigated.

Moderation of extreme events (EE) is mainly referred to the ability of livestock grazing to provide prevention of landslides, avalanches and wildfires (FAO, 2014). The additional string *("avalanche*" or "fire" or "extreme event*")* produced 19 papers of which 3 in Mediterranean areas. The extracted papers deal just with ‘fire’ highlighting a lack of studies on other EE.

Rather than an ‘extreme event’, fire is analysed by the papers as a management tool to enhance ES (e.g. habitat provisioning, prevention of wildfires, etc.). Joubert *et al.* (2014)

investigated the effect of annual burning on plant species richness, composition and turnover in three firebreak types under different cattle grazing levels. Boughton *et al.* (2013) conducted an 8 year split-plot experiment studying the effect of season of burn on plant composition in semi-natural grassland of Florida (USA) where, in addition to prescribed winter burns, natural historical wildfires occur in abandoned ranchlands. The responses of vegetation disturbance was studied by Hancock and Legg (2012) with prescribed fire managements in pine forests and ericaceous heathlands of UK.

Other approaches compared tree canopy cover and height distributions between areas of contrasting management in the Lowveld savanna with LiDAR (Wessels *et al.*, 2011); survey-based choice experiments where SHs focused on the prevention of forest fires is a key ES delivered by grazing agroecosystems. A mathematical model was developed to simulate the vegetation dynamics and ES in response to management scenarios involving grazing, fire and their combinations in Israel as tools for land managers (Koniak *et al.*, 2011).

Landscape (LS) is mentioned in MA among cultural services and includes the values as shaped by the animals themselves or as a part of the landscape e.g. aesthetic values (FAO, 2014). In this sense, and not in others, it was analysed in the bibliography review. The additional string *("landscape" or "aesthetic" or "inspiration")* produced 39 publications of which just 2 analysed the landscape as a cultural service (Bernués *et al.*, 2014; Fontana *et al.*, 2014). In the others papers landscape was considered: i) for the effects that could have on biodiversity (e.g. Bagella *et al.*, 2013; Cole *et al.*, 2015; Kearns and Oliveras, 2009; Lindborg *et al.*, 2009; Littlewood *et al.*, 2012; Sanderson *et al.*, 2007); ii) as support for improving or maintaining other ES (e.g. Lavorel *et al.*, 2011, 2015; Schaldach *et al.*, 2013); iii) as an assessment scale of other ES (e.g. Hussain and Tschirhart, 2013**;** Peringer *et al.*, 2013; Kimoto *et al.*, 2012); iv) for the effects that different drivers had on it without directly analysing the consequences on its cultural value (e.g. Cousins *et al.*, 2015; Lamarque *et al.*, 2014; Schaich *et al.*, 2015).

The low number of papers dealing with landscape as cultural ES has to be related to its difficult measurement and to the still low number of available indicators (Feld *et al.*, 2009; TEEB, 2010).

Fontana *et al.* (2014) analysed the effects of management changes of larch grasslands in the Italian Alps (abandonment and intensification vs. traditional management) also on the valuable cultural ES (scenic beauty and traditional healing plants). They conducted a phyto-sociological study on plots randomly selected by using GIS. For each plant species recorded, three out of eight plant traits were chosen explicitly for their relevance for ES provision: flower colour, high diversity of pollination agents and occurrence of edible or healing value for traditional meals and medicines. The provision of scenic beauty and other ES were associated to specific management to be addressed to future subsidies planning and specific financial support towards traditional agro-forestry system. Bernués *et al.* (2014) tried to elucidate the socio-cultural and economic value of some ES (e.g. aesthetic and recreational values of the landscape) delivered by mountain agroecosystems in northeast Spain by identifying the SHs willingness to pay for their provision. Focus groups and survey-based stated-preference methods were combined to identify the effects on ES of three different scenarios deriving from different policies and to test the willingness to pay for ES compared to the current EU agro-environmental payments.

VI – Conclusions

The extraction criteria used for the bibliography review produced a scarce amount of papers of which just ten clearly to be referred to the Mediterranean climate areas and even less to Mediterranean basin. ES was the divide term between a vast literature and the minimal results obtained. Indeed, if some other terms would have been added to the basic string other results would have been obtained. For example, adding *or "good*"* to the string used for 'Food and other livestock related products', the total amount of papers will increase from 12 to 38. This fact highlights that many authors did not consider food as an ES limiting the ability of these products to be included in a process of enhancement at the level of the overall production system. Similar consideration could be stated for the other analysed ES.

Despite the Millennium Ecosystem Assessment is the largest accepted ES assessment framework since 2003, the analysis of the extracted papers highlighted misunderstandings concerning the concept of ES. A clear example is the confusion around biodiversity that in several papers, contrary to MA, it is considered as an ES *per se* (e.g. Lindborg *et al.*, 2009).

The anthropocentric vision is one of the recurring critiques of the concept of ES. According to Schröter *et al.* (2014) the ES concept is not meant to replace biocentric arguments but bundles a broad variety of anthropocentric arguments for protection and sustainable human use of ecosystems. Not in all the analysed papers this view is understood or accepted. For example some authors propose biocentric solution to reverse inner dynamics of systems without taking into account SHs opinions or needs (e.g. Bai *et al.*, 2012).

ES were analysed in several ecosystems, under many site, climate and management conditions with different but also contrasting results. A clear example are the contrasting effect of grazing on primary production reported by Oñatibia *et al.* (2015) and mentioned by Bai *et al.* (2012). These considerations highlight as management and development options should take into account the internal dynamics of systems. Biophysical components, but also socio-economics, socio-cultural and institutional features should be considered (Caballero and Fernández-Santos, 2009). In this vision, most of the analysed ES were assessed according to different spatial and temporal scales. To reduce the risk of scale mismatches between ecological processes and decision-making the adoption of a proper assessment scale seems to be crucial. In this respect, Loucougaray *et al.* (2015) applied a landscape scale but at the same time identified both farm and field scale as key features for grassland conservation management.

The need to examine the supply and condition of each ES as well as the trade-offs (e.g. Marriot *et al.*, 2010; Oñatibia *et al.*, 2015) and interactions among them as requested by MA (2003) was applied in many of the analysed papers (e.g. Gaitán *et al.*, 2016; Koiniak *et al.*, 2011; Newton *et al.*, 2014; van Oudenhoven *et al.*, 2015; Petz *et al.*, 2014a).

Just few authors integrated a multi-stakeholders approach in the analysis of ES and their interactions (Bernués *et al.*, 2014; Petz *et al.*, 2014b; Tarrasón *et al.*, 2016). Many tools commonly used also in the scientific activity like mathematical models, indicators and biophysical data were used by the authors to engage the SHs. In other papers, future scenarios were generated from scientific data to facilitate the discussion with and among SHs. The effects of different management options on their well-being were discussed by using ES as focus lens. The need of SHs involvement emerged in some papers that underpinned how the ES concept was not familiar to SHs (e.g. Bernués *et al.*, 2014; Tarrasón *et al.*, 2016) and often confused, for example with responsibility of humans to preserve nature. The integration of local and scientific knowledge generated hybrid knowledge encouraging ownership of local SHs in the decision-making process. This allowed the identification of adaptive strategies for key services to be maintained in future (Lamarque *et al.*, 2014; Francioni *et al.*, 2014), for example through the implementation of in-situ experiments on native pasture management (Tarrasón *et al.*, 2016).

In the analysed literature cultural ES were poorly studied despite considered the most relevant for local and general SHs (Bernués *et al.*, 2014), constraining the ES framework only to agricultural related aspects. A better SHs awareness of the well-being provided by ES in livestock grazing systems could foster agri-environmental schemes and the willingness to pay for their services.

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