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The evolution of soil conservation policies targeting land abandonment and soil erosion in Spain: A review

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ABSTRACT

Land degradation affects natural and cultivated socio-ecosystems worldwide. Soil erosion is one of the main processes leading to land degradation, and the process is accelerated by human actions. Spain is dealing with extensive land degradation caused by land use and land cover change (LULCC), for instance by land abandonment, and local geo-ecological conditions. Recent land abandonment in Spain can be largely related to changing policies and international market development, which have resulted in the reallocation of agriculture and a shift from traditional rainfed crops to intensification of irrigated agriculture. This radical change in LULCC by land abandonment resulted in two opposite trends, towards greening-up and towards land degradation, each with enormous consequences for the environment by its effects on soil hydrology, runoff, sediment sources, soil erosion, fluvial channel adjustments and forest fire risks. To mitigate negative effects, appropriate management and conservation strategies are necessary.

In this review, we analyze the top-down policy framework of soil conservation in Spain, with a specific focus on the Region of Murcia. We found that multiple international policies, i.e. the United Nations Convention to Combat Desertification, the European Water Framework Directive and the European Common Agricultural Policy (CAP), contribute to soil and water conservation at the national level, where the national administration selects most appropriate measures according to the country's current state. These measures are incorporated in national policies, such as the National Action Plan to Combat Desertification and the National Rural Development Programme. In case of the CAP, agro-environmental subsidies are an instrument to promote soil protection at a national level. Regionally adjusted sub-measures, based on regional environmental characteristics, are then integrated in the Regional Rural Development Programmes of the Spanish Autonomous Communities. The application of subsidies, related to soil protection, is found to be controversial, as studies do not agree upon its effect on soil erosion and land degradation control. To improve decision-making, concepts such as the ecosystem service approach and nature-based solutions are suggested to be included in future policies, as these concepts aim to improve the status of the entire ecosystem in a more holistic manner than is currently the case.

1. Introduction

Land degradation is a major environmental problem affecting natural and cultivated socio-ecosystems worldwide, with negative consequences for the well-being of least 3.2 billion people (IPBES, 2018). Land degradation is defined as the process leading to persistent reduction of land's productivity (MEA, 2005a, 2005b) expressed by a declining provision of the land's ecosystem services (Sanz et al., 2017). Soil erosion is one of the main processes leading to land degradation and is accelerated under anthropogenic influence. This is very well illustrated in Mediterranean landscapes, where often many factors inducing soil erosion converge. Agricultural activities and abandonment of agriculture are both important drivers of soil erosion and land degradation. Other environmental factors, such as lithology, topography and climate, influence erosion and sedimentation rates, and have a large impact on the soil quality in general (Vanmaercke et al., 2011). It is important to realize that soil erosion is a natural process and not always damaging to an ecosystem. However, in the last 50 years natural erosion rates are being accelerated by a large number of socioeconomic drivers, with land use and land cover change (LULCC) identified as

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most important (García-Ruiz, 2010). Land use intensification and extensification are the main contributors to abrupt LULCC and are driven by local and global socioeconomic conditions (Martínez-Valderrama et al., 2016; Serra et al., 2014). Droughts, loss of soil organic matter, soil erosion, overexploitation of aquifers and salinization of agricultural fields are some examples of consequences of LULCC that can potentially lead to land degradation and desertification (Symeonakis et al., 2007).

Within the Mediterranean, Spain has a long LULCC history, characterized by land abandonment, and together with local geoecological conditions these changes have often resulted in relatively high soil erosion rates (García-Ruiz, 2010; García-Ruiz et al., 2013). During the mid-20th century, the Spanish government started funding hydraulic infrastructures to improve agricultural production from more profitable irrigated agriculture, mostly for international markets. In south and southeastern Spain, climate conditions combined with irrigation resulted in significantly higher yields compared to other rural areas (Alonso-Sarría et al., 2016). After the implementation of the Common Agricultural Policy (CAP) in 1986, several striking changes in the Spanish agricultural sector took place. Integration of European markets proved huge opportunities including olives, water-demanding crops, such as fruit trees, and horticulture, while discouraging the production of traditional, rainfed crops, such as potatoes, cereals and fodder crops (Cazcarro et al., 2015). These factors have enabled the reallocation of agricultural production from the humid north to the (semi-)arid south of Spain between 1930 and 2005 (Cazcarro et al., 2015; Alonso-Sarría et al., 2016). Low economic agricultural competitiveness of the northern mountainous areas resulted in strong urbanization. About 22% of the Spanish Pyrenees was classified as abandoned fields (Lasanta-Martínez et al., 2005). While land abandonment because of reallocation occurred, the CAP started subsidizing partial land abandonment to control production levels in 1992 (Lasanta et al., 2017). Pointereau et al. (2008) found a reduction in utilized agricultural area (UUA) of 28.9% between 1973 and 2005, which can be linked to the reallocation of agriculture and the influence of CAP.

Intensification of irrigated areas in the driest parts of Spain resulted in many cases in land degradation through over-exploitation of groundwater resources, causing water scarcity and salinization of agricultural fields (Alonso-Sarría et al., 2016). This also implies large changes in the landscape, eliminating traditional conservation measures such as terraces, by transforming them in levelled land to facilitate mechanization and industrial crop production. Approximately 3.8 million ha of land is being irrigated, representing 23% of the national cropland area (MAPAMA, 2016a, 2016b). Rapid depletion of groundwater resources and the large area of rainfed cropland makes Spanish agriculture highly vulnerable to climate change. Between 1950 and 2002, the whole Mediterranean faced increased drought (García-Ruiz et al., 2011). A further decrease in precipitation is projected for the period 2040–2070 (Kovats et al., 2014). The severest reduction is expected in southern Spain, with an average decline of 15% (García-Ruiz et al., 2011), combined with increased precipitation intensity and longer drought periods (Eekhout et al., 2018). Rainfed agriculture will become less and less suitable, while the demand for crop irrigation will increase. However, because of depletion of groundwater resources, degradation of soil and high dependence on monocrop systems, this is not a feasible long-term solution. Furthermore, reforestation of abandoned fields results in higher evapotranspiration and increased water consumption, placing higher pressure on surface and groundwater resources (García-Ruiz et al., 2011; Pérez-Cutillas et al., 2018). Climate change induced water stress, sometimes locally strengthened by LULCC, can thus be considered as a large driver of land abandonment when water management is not improved (Kovats et al., 2014; Eekhout et al., 2018).

Abandonment of agricultural fields has had enormous environmental consequences in Spain, due to its effects on soil hydrology, runoff, sediment sources, soil erosion, fluvial channel adjustments and forest fire risks (García-Ruiz and Lana-Renault, 2011). As climate change is likely to intensify the process of land abandonment, proper environmental management is essential to prevent further land degradation by LULCC. Environmental management consists of a combination of formal governance through local, regional, national and international policy frameworks, but also often includes local bottom-up initiatives.

Here we review the characteristics, views and effectiveness of top-down implemented policies to tackle land degradation driven by farmland abandonment in Spain. The objective of the paper is to analyze soil conservation policies in Spain, with special emphasis on environmental and socioeconomic drivers of land abandonment as driver of land degradation and soil erosion. The paper moves through different spatial scales of policy implementation, where the most detailed level focuses on the Region of Murcia and the highest level refers to the United Nations Convention to Combat Desertification (UNCCD). Since bottom-up restoration initiatives can be just as important as formal policy levels, we also review the changing social perception of natural resource conservation.

2. Impacts of the abandonment of agriculture

Farmland abandonment is a widely spread process in Spain, which has enormous socio-economic and environmental consequences (García-Ruiz and Lana-Renault, 2011). Drivers of land abandonment can be divided in four categories: (1) environmental factors, (2) socioeconomic status, (3) regional conditions and (4) mismanagement (Terres et al., 2015; Benayas et al., 2007). Negative environmental factors, such as poor soil quality or a highly seasonal climate (Gellrich and Zimmermann, 2007; Vicente-Serrano et al., 2011), can reduce the land's suitability for agriculture. Furthermore, low socioeconomic status, expressed by low farm viability and stability (Romero-Calcerrada and Perry, 2004), is considered another driver for abandonment. Regional conditions, such as low regional income, labour shortages and a weak market (Terres et al., 2015), and mismanagement of soil and water resources, leading to land degradation and water scarcity (Benayas et al., 2007), are also drivers that cause farmers to leave their land. After the abandonment of agricultural activities, the land can evolve in two ways: towards land degradation and towards greening-up.

2.1. Towards land degradation

Farmland abandonment can lead to soil erosion when there is lack of adequate management after abandonment, especially when environmental conditions hamper restoration of natural vegetation, for example by low precipitation or degraded soils. Fields that are permanently abandoned after decades of shifting agriculture are often affected by erosion as well (Lasanta-Martínez et al., 2005). A large area of Spanish mountainous regions has been cultivated using shifting agriculture until 25 years ago. It dominated 33.3% of the cultivated area in the Central Pyrenees (Lasanta et al., 2017). Overexploitation during this period has degraded the soil to such an extent that plant-colonization is difficult, causing completely bare soil in the years after abandonment. When plants eventually succeed to establish themselves, the cover is not dense enough to protect the soil, resulting in severe erosion and ultimately a stone pavement.

Furthermore, lack of maintenance of conservation structures, such as terraces and drainage ditches, causes them to break down after abandonment (Benayas et al., 2007). Failure of these structures concentrates runoff from the terraced fields, leading to erosion downslope. The CAP has also influenced plant colonization and erosion rates by its set-aside policy. This policy requires farmers to maintain their set-aside fields as seeded fallow land with non-food crops, or as unseeded fallow land by continuous ploughing to prevent plant colonization, if they want to receive subsidies (García-Ruiz and Lana-Renault, 2011). Therefore, it is suggested that the set-aside policy of the CAP increased the area that is at risk of severe erosion.

Climate and lithology are also factors that influence erosion rates after abandonment. In semi-arid climates, plant colonization is slower because of the irregular seasonal distribution of precipitation, with intense events in autumn after a dry summer period, resulting in the development of structural and sedimentary surface crusts (García-Ruiz and Lana-Renault, 2011). Considering lithology, soils developed on marly substrates are particularly vulnerable due to their impermeability (Robledano-Aymerich et al., 2014) and due to the occurrence of pipe erosion (Romero Díaz et al., 2007). The absence of vegetation causes these soils to have a low organic matter and nutrient content, which leads to restricting conditions for plant colonization, thus creating a negative feedback loop (García-Ruiz et al., 2013).

2.2. Towards greening-up

Under favourable environmental conditions, land abandonment often leads to revegetation, either through secondary succession or by reforestation (Arnáez et al., 2011). The extent of plant colonization depends on several factors, including soil fertility and depth, hillslope aspect, climate, distance to surrounding vegetated fields and post-abandonment land management (García-Ruiz and Lana-Renault, 2011). In general, plant colonization eventually leads to the establishment of a stable shrub cover, or even forest after a few decades, and thus higher soil protection. The process has a positive effect on erosion rates, since higher soil coverage by a dense plant cover produces a higher soil organic matter content, and a higher infiltration and water retention capacity, limiting the hydrological response and runoff after extreme rainfall (Cerdà, 1997). Furthermore, sediment transport decreases because of lower particle detachment by rain splash erosion or runoff (García-Ruiz and Lana-Renault, 2011).

A major drawback of plant colonization in abandoned fields is its influence on the availability of water resources (Beguería et al., 2006). The establishment of a dense vegetation cover influences evapotranspiration, and the interception and redistribution of rainfall (Llorens and Domingo, 2007). Higher evapotranspiration and increased rainfall interception can result in a decrease of surface flow, followed by a fall in groundwater recharge (Gallart and Llorens, 2003). Combined with a dry climate, increased water consumption induces changes in the basin hydrology (García-Ruiz et al., 2011). As shrub and forest cover increases, a decreased river discharge can be observed over time (Martínez-Fernández et al., 2013; Pérez-Cutillas et al., 2018).

Increased vegetation cover can also affect the fluvial geomorphological dynamics because of decreased runoff and sediment input from hillslopes. As the vegetation offers soil protection, hillslope erosion rates will decrease, thus limiting the transport of sediment towards channels (García-Ruiz and Lana-Renault, 2011). A low sediment supply from the slopes generally leads to channel degradation if there is sufficient discharge. In several catchments in the Region of Murcia, it has been observed that erosion processes can be triggered as channel and bank erosion, together with large geomorphological changes, occur in the fluvial channels and adjacent areas (Boix-Fayos et al., 2007, 2008, 2017). Furthermore, vegetation encroachment on the banks and floodplains results in channel narrowing. (Liébault and Piégay, 2001; Boix-Fayos et al., 2007; Quiñonero-Rubio et al., 2016).

The expansion of forests and shrub lands may increase the risk of wildfires. Many revegetated fields are relatively homogeneous regarding plant species, and stretch out over a large area, therefore facilitating the spreading of fire (Puigdefábregas and Mendizabal, 1998; García-Ruiz and Lana-Renault, 2011). During the immediate period after a fire, soil loss is often increased until new vegetation development (Andreu et al., 2001).

3. Historic perspective: a changing perception on soil conservation

3.1. Phase 1: soil resources for a growing population

Human impact on the natural landscape of Spain started in prehistorical times. Archaeological research shows that agricultural terraces were abundant in hilly areas from the Bronze Age onwards (Grau Mira and Pérez Rodríguez, 2008). These terraces served to capture and transport water for irrigation purposes, and when in balance with socioeconomic development they can be considered as sustainable and efficient. Until the late 16th century, exploitation of soil and water resources was necessary to feed the growing population. Episodes of extensive erosion were experienced, as cereal agriculture, nomadic livestock farming and logging activities further expanded, partly due to the growing demand for food, wool and building materials from the American colonies in the 1500s (García-Ruiz, 2010; Puigdefábregas and Mendizabal, 1998). The expansion of farmland is connected to the need to increase yields, often without apparent awareness of the need to conserve soil resources (Fernández Mier et al., 2013).

3.2. Phase 2: from high agricultural production to environmental conscience

The second phase of perception refers to the period between the 17th and mid-20th century. This period is also characterized by intensive agricultural land use and ploughing as the need for increasing production for direct economic benefits was still present. Between 1766 and 1924, high demographic pressures occurred in the northern Mediterranean area, which resulted in increased deforestation in mountainous areas, affecting 19.9 million ha of forest (Vadell et al., 2016). Additionally, an increase of farming on steep slopes and overgrazing was observed. Combined with excessive rainfall events, these activities eventually resulted in extreme soil erosion (García-Ruiz and Lana-Renault, 2011). At the same time environmental consciousness progressively appeared. Land users started to notice the negative consequences of overexploitation of soil resources, and constructed a large number of terraces on steep slopes to stop further soil erosion.

Policy changes also affected the quality of soil resources. Following a general economic crisis, the 'Mendizábal Disentailment' was put into place from 1836 to 1841 (Vaccaro, 2005). Land owned by the church and municipalities was sold to private parties, which often exploited their new property intensively, resulting in strongly increased erosion rates (García-Ruiz, 2010). However, in this phase progressive environmental awareness started to make its appearance. At the start of the 16th century, the first documented institutional recognition of the damage done to soil resources in mountainous areas appeared (De Graaff et al., 2013). Over the centuries, awareness increased, and after the division of Spain into watersheds by the Royal Order of 1865 hydrological protection initiatives were established (De Graaff et al., 2013). Overexploitation of soil resources was recognized as a cause for the extreme erosion occurring in the country. Valencia was the first autonomous community to include this statement in their 1932 Forest District Plan (Montiel Molina, 1994). The increasing awareness of the damage done to the country's resources resulted in the establishment of the Central Service for Soil Conservation, which is part of the Ministry of Agriculture, in 1955 (Boletín Oficial del Estado, 1955) (Fig. 1).

3.3. Phase 3: towards full social and environmental awareness

In the third phase, starting during the mid-20th century, there is a further changing paradigm towards social and environmental awareness, and recognition of the problem of land degradation and the need for sustainable development. Undoubtedly, the 1930s 'Dust Bowl' in the United States (US) initiated a crucial change in perception and priorities, bringing the importance of soil and water conservation measures for both the environment and a sustainable society under national and

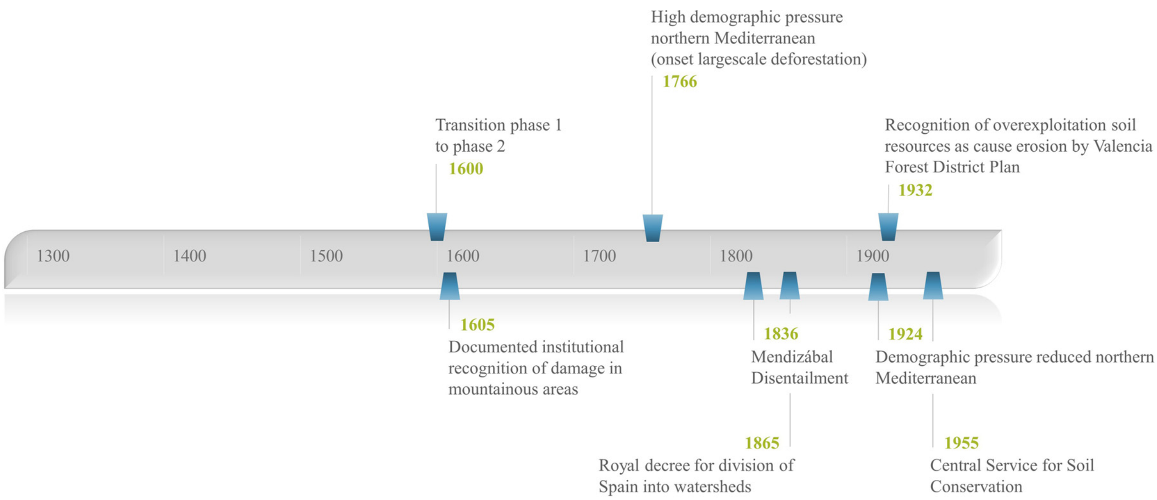

Fig. 1. Chronology of the second phase (1600 to 1950s). The second phase is characterized by a shift from high agricultural production towards environmental conscience.

international attention (McLeman et al., 2014).

Since the Dust Bowl, a large data collection and research programme on erosion processes and possible measures of soil and water conservation was initiated in the US. In Spain, notable effects of land degradation, combined with the experiences during the US Dust Bowl, also resulted in the development of laws and institutions to protect soil and water resources (De Graaff et al., 2013). In this period, the main actions, both in the US and Spain, consisted of reforestation, and the construction of terraces and sediment retention dams. In Spain, large-scale reforestation projects were started in which between 1940 and 1984 approximately 3.4 million ha were reforested (Vadell et al., 2016). The 1992 United Nations (UN) Earth Summit in Rio de Janeiro resulted in strongly increased environmental awareness at the international level on issues related to nature conservation. During this summit, three environmental conventions were defined: the United Nations Convention to Combat Desertification (UNCCD), the Convention on Biological Diversity (CBD), and the United Nations Framework Convention on Climate Change (UNFCCC).

During the 1990s active research on desertification and the conservation of soil and water resources, financed by the EU and in Spain also by different Ministries, was carried out. The entry of Spain into the European Union (EU) and adoption of the CAP meant the introduction of different actions of conservation with a focus on agricultural areas (De Graaff et al., 2013) and since 2003, through the CAP reform, with special emphasis on the adoption of good agricultural practices (Panagos et al., 2016). Initiated by the Rio Earth Summit, and Agenda 21, the original 'top-down' approach in conservation policies evolved into an 'ecosystem-based approach' with special emphasis on assessing the services provided by ecosystems and for participatory decision making. The increasing interest to quantify the value of ecosystem services led to the Millennium Ecosystem Assessment (MEA, 2005a, 2005b). The conservation of soil and water resources is considered as progressive because of its interdisciplinary approach, including biophysical, socioeconomic and cultural aspects, with emphasis on the functions and services provided by soils and including participatory processes for the selection of conservation practices (Reed, 2008). Since 2002, the European Commision started to legislate soil protection through the Soil Thematic Strategy, although the Soil Framework Directive was finally not adopted. Due to the potential of soil for carbon sequestration, protecting biodiversity and for increasing the resilience of agro-ecosystems to external changes like climate change, soil and water conservation has been progressively a central theme in the three environmental conventions of the UN (UNCCD, CBD, UNFCCC).

This interest in soil conservation is also reflected in the recent launch of the 'Global Soil Partnership' by the Food and Agriculture Organization (FAO) and the 'Science-Policy Interface' of the UNCCD to facilitate the knowledge transfer between science and policy on issues of soil and water conservation. In addition, 2015 was declared international year of soils, and the 'Sustainable Development Goals (SDG)' of the UN, adopted in 2015, refer to the goal to strive for Land Degradation Neutrality (SDG 15.3). In 2018, IPBES launched the assessment report on land degradation and restoration. Over the years, science has played an essential role to understand agricultural sustainability and the conservation of soil and water and has led to the

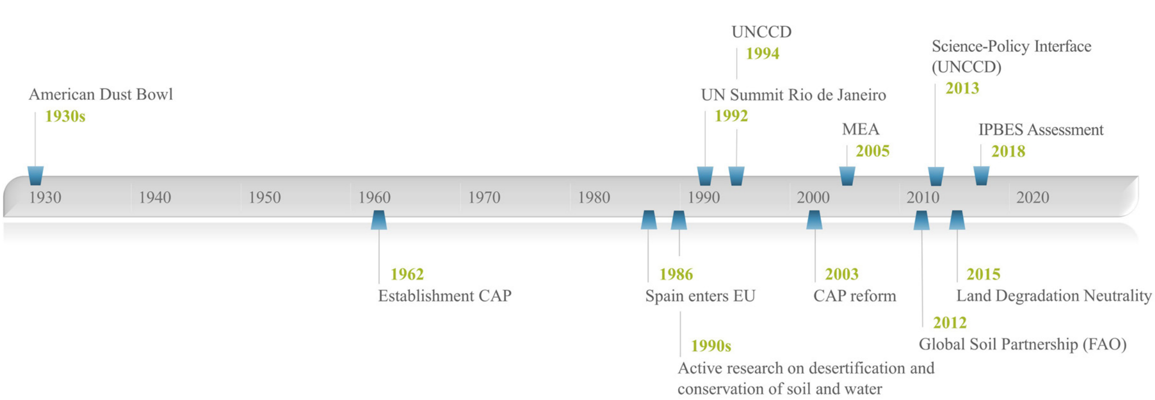

Fig. 2. Chronology of the third phase (mid-1900s). This phase is characterized by an increasing social and environmental awareness.

development of many conservation practices. However, challenges such as population growth and climate change require continued translational research on sustainable land and water management and effective transference of knowledge to the society (Fig. 2).

4. Influence of policies on land abandonment

4.1. European common agricultural policy

The entry of Spain into the EU in 1986 was followed by the adoption of the CAP, which resulted in land management focussing on the conservation of valuable agricultural land. The CAP, launched in 1962, initially aimed to increase agricultural productivity, secure high living standards for farmers, and to stabilize agricultural markets and farmers' incomes. Following post-war food shortages, the policy aimed for self-sufficiency of agricultural production, and thus became a major incentive for the intensification of agriculture in Europe (Van Zanten et al., 2014). In the 1960s and 1970s this growth was experienced as a positive effect, but by the 1980s the negative environmental effects of overproduction started to become visible through water pollution and soil erosion (Delayen, 2007). During the crisis years in the 1980s, the EU started to reform the CAP to deal with overproduction, dumping of excess food and the negative effects on the environment (Delayen, 2007). These efforts resulted in the 1992 reform, where the influence of world market prices was included to lower production levels. The focus of the CAP shifted from product support to producer support, where the reduced price support was compensated by the introduction of an income subsidy system based on direct payments (Delayen, 2007). In addition, set-aside payments were introduced, aiming for the withdrawal of less suitable agricultural land.

The introduction of direct payments was the first movement towards market reformation, included in the Agenda 2000 reforms. Next to reforming the first pillar of this agenda, named 'market support and direct farmer income', a second pillar was created, called 'rural development', which consisted of three axes; competitiveness, environment and land management, and economic diversification and quality of life (European Commission, 2013a, 2013b). To establish suitable policy-making, member states get to choose sub-objectives that best fit their economic, environmental and social conditions from the three axes to implement.

The next movement came in the 2003 CAP reform, by introducing the single payment scheme by which farmers received a decoupled single payment. Prior to this reform, direct payments were associated with a particular line of production, meaning that farmers could receive multiple direct payments. The 2003 reform decoupled subsidy payments from production and incorporated multiple direct payments into one single payment (European Commission, 2013a, 2013b). Farmers received this type of income support if they applied proper land management and met food safety, environmental, animal health and rural welfare targets.

The latest reform of the CAP was presented in 2013 and covers the period 2014–2020. The 2013 reform continues to focus on providing high-quality and safe food, while maintaining stable prices. There are also some new aspects incorporated in the reform (European Commission, 2013a, 2013b). First, the "greening" of single payments. Payments are provided to farms that use sustainable farming practices and maintain ecologically rich landscapes. Second, the reform aims for more equality between farmers regarding income support. Large differences need to be reduced, for instance by lower payments for larger farms. Last, the targeting of income support towards vulnerable groups, such as young farmers and those located in areas with low environmental suitability, needs to be improved (European Union, 2013). Furthermore, the pillar structure is maintained, but the link between the two pillars is being strengthened, resulting in an integrated approach.

The first implementation, and the following reforms, of the CAP (Fig. 3), apparently and theoretically was supposed to have positive effects on the Spanish agricultural sector by offering greater stability, predictability and support from within the EU. However, as the world market has opened for Spanish agriculture, so has the competitiveness under farmers. Combined with new regulations for animal welfare and food quality, this has put severe stress on marginal producers. Small producers had difficulties adapting to these requirements, while staying competitive with larger enterprises, eventually leading to land abandonment as it is no longer economical beneficial to stay in business (Van Dijk et al., 2005). A large part of rural Spain still deals with land abandonment, with an annual decline in utilized agricultural area (UAA) of 0.7% for arable land and 1.3% for pastures between 1973 and 2005. During the period 1989–1999, the rural areas that were dealing with UAA loss represented 32.5% of the total Spanish territory. In 1999, estimates were made that 6 million ha were at risk of further UUA loss (Pointereau et al., 2008).

4.2. Farmer subsidies: towards coupling agriculture and environment in Spain

Subsidies form one of the instruments of the European CAP to involve progressively more environmental issues in agriculture. Over the last two decades the subsidy policies had an important influence on the configuration of agricultural and semi-natural landscapes, and directly and indirectly on soil erosion and land degradation control.

Over the last two decades, the CAP gradually integrated environmental requirements through different instruments. Before the reform of the CAP in 1999, there was an integration on environmental issues through various regulations (for instance the "Green Book 1985", "Orientations for a Sustainable Agriculture" and "Agenda 2000"). Since 1999, there were two main instruments: the cross-compliance, which acts as a baseline for measures, and the agro-environmental measures itself (Cantó López, 2016). By the introduction of these instruments, farmers were forced to respect basic laws regarding environment, public health, and animal health and welfare. Ignorance of these European laws leads to reduction of support of the EU. The integration of environmental issues within the CAP continued in the green system, introduced in the CAP reform of 2003 (Cantó López, 2016). Concepts such as "ecosystem services" and "crop diversification" were not explicitly included but were underlying many of the agro-environmental measures in the last decade and started to be progressively introduced. In the last CAP reform for 2014–2020, environmental and agricultural issues are further integrated. The different instruments of the reform of the CAP 2014–2020 (cross-compliance, greening and supports for rural development) are orientated towards achieving the objectives of climate action (Cantó López, 2016). Nowadays CAP tries to achieve sustainable, smart and inclusive growth contributing directly to objectives of Climate Change adaptation and mitigation.

Regarding land abandonment as a driver of soil degradation and erosion processes, the subsidies, specifically related to reforestation, in the CAP have had a leading role in combating land degradation and soil erosion. These subsidies were integrated through the Rural Development Programs (RDP) of the last two decades; 1994–1999; 2000–2006; 2007–2013 and 2014–2020 (Comunidad Autónoma 1 - Asturias, 2016; Comunidad Autónoma 2 - Canarias, 2016; Comunidad Autónoma 3 - Cantabria, 2016; Comunidad Autónoma 4 - Castilla-La Mancha, 2016; Comunidad Autónoma 5 - Castilla-León, 2016; Comunidad Autónoma 6 - Cataluña, 2016; Comunidad Autónoma 7 - Andalucía, 2016; Comunidad Autónoma 8 - Extremadura, 2016; Comunidad Autónoma 9 - Galicia, 2016; Comunidad Autónoma 10 - Illes Balears, 2016; Comunidad Autónoma 11 - La Rioja, 2016; Comunidad Autónoma 12 - Madrid, 2016; Comunidad Autónoma 13 - Navarra, 2016; Comunidad Autónoma 14 - País Vasco, 2016; Comunidad Autónoma 15 - Región de Murcia, 2016; Comunidad Autónoma 1–16, 2016). Besides those, there were other specific subsidies directly or indirectly related to soil erosion control. For instance,

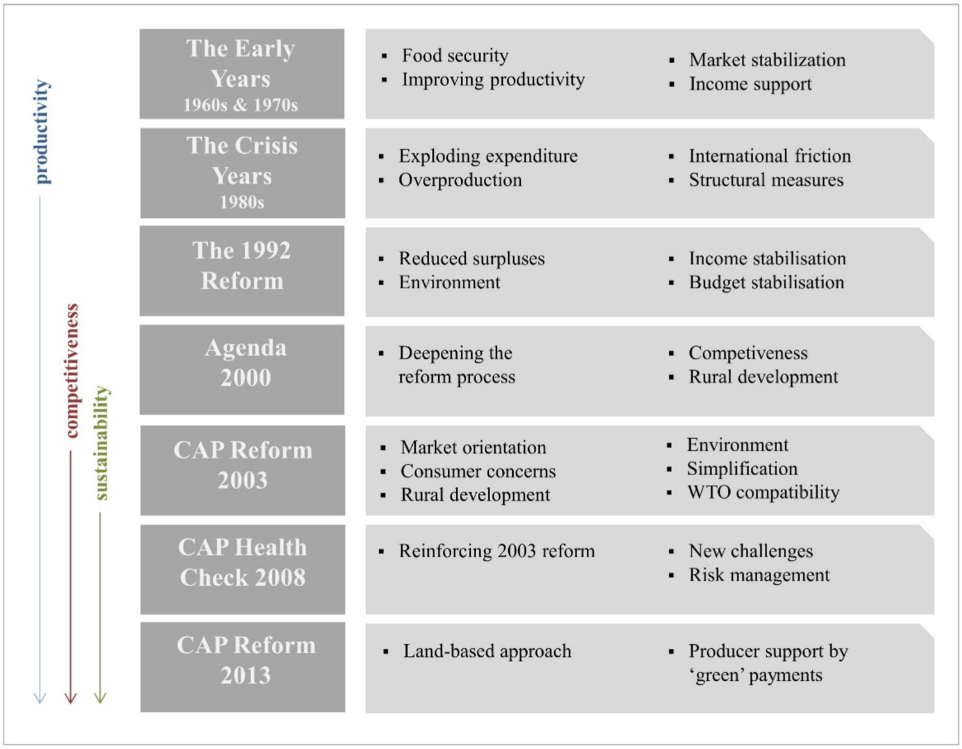

Fig. 3. Historical development of the CAP. Redrawn from the European Commission (2011). Completed with European Commission (2013a, 2013b).

subsidies addressing the protection of natural resources, including soil, belonged to Axis 2: "Improving the environment and the rural environment" of the RDP 2007–2013. This axis contained measures that promoted sustainable management practices in both agricultural and forest land and conservation of biodiversity. To achieve these objectives, it provided subsidies to compensate farmers affected by natural limitations for farming, as well as compensating farmers who adopted agri-environmental commitments. Not all the regions applied the same subsidies. Fig. 4 shows the application at the regional level of subsidies related directly or indirectly with erosion control and land degradation.

Many regions financed reforestation of agricultural and non-agricultural land, actions that promoted the recovery of forest potential and the implementation of preventive measures against fires and the conservation and development of the Natura 2000 Network. For instance, measure 221 provided subsidies for forestation of agricultural land based on payment per hectare. The subsidy was given for planting forest species during the first year, maintenance cost for 5 years and compensation costs for the loss of the agricultural income for a maximum of 15 years, with some variations depending on the species introduced (Fernández et al., 2016). A similar subsidy was introduced already in the former RDP 1994–1999.

Other measures introduced in the RDP 2007–2013 were measures 222 and 223. The first one focussed on combining agricultural land and forest to improve landscape diversity and biodiversity. The second one, 223, was specifically oriented to the reforestation of abandoned agricultural land mainly to fight against erosion and land degradation in areas where measure 221 was not applied (Fernández et al., 2016). A wider and very powerful instrument with important economic resources was measure 214 (Table 1, Fig. 4), concerning agro-environmental subsidies including many different specific sub-measures related to ecological agricultural production, biodiversity and erosion control.

Agro-environmental subsidies were widely applied in all Spanish regions financing different sub-measures depending on the regional environmental characteristics. The average investment per region was 145 million euros with large variations between regions (Table 1). Measure 221, directly related with soil erosion control was widely applied in many regions with an average investment of 32 million euros but with large variations among regions (Fig. 4). Measure 223, also directly related with erosion control in abandoned agricultural fields, was only applied in some regions (Fig. 4) with an average investment of 6 million euros per region and also large variation among regions (Table 1). Table 1 also shows the national costs of the application of those measures and the level of execution of the programmed initial investments.

Assessments of the environmental impact of CAP subsidies are scarce and sometimes contradictory. Some point out to a positive impact of reforestation measures on the conservation of agricultural land and abandoned agricultural fields (González Botía et al., 2012; Solana Gutiérrez et al., 2010). Other studies related to erosion control do not recommend policy measures based on subsidies because they do not adequately encourage the environmental awareness of farmers but perverts it (Franco, 2009). However, there is also evidence that subsidy reforms to reward management practices that sustain ecosystem services and eco-labelling are pointed as promising instruments to slow down or reverse land abandonment (Gaitán-Cremaschi et al., 2017).

5. Policies to mitigate desertification and land degradation

Effective mitigation and prevention of land degradation, desertification and deterioration of water resources resulting from climate change and human impacts, including land abandonment, requires a careful coordination between different international conventions, and national and regional administrative levels. However, the complexity of the policy space and sometimes opposing interests can make this coordination especially difficult. To make the different interacting policies more transparent, we analyzed the top-down movement of policies from the international level towards national, and eventually regional level. The outcome is a policy analysis, visualized in Fig. 5. In the next paragraphs we discuss each policy level and interaction. Some of them with a direct impact on soil conservation, while others have a more indirect impact, but all have influences at the political and management level.

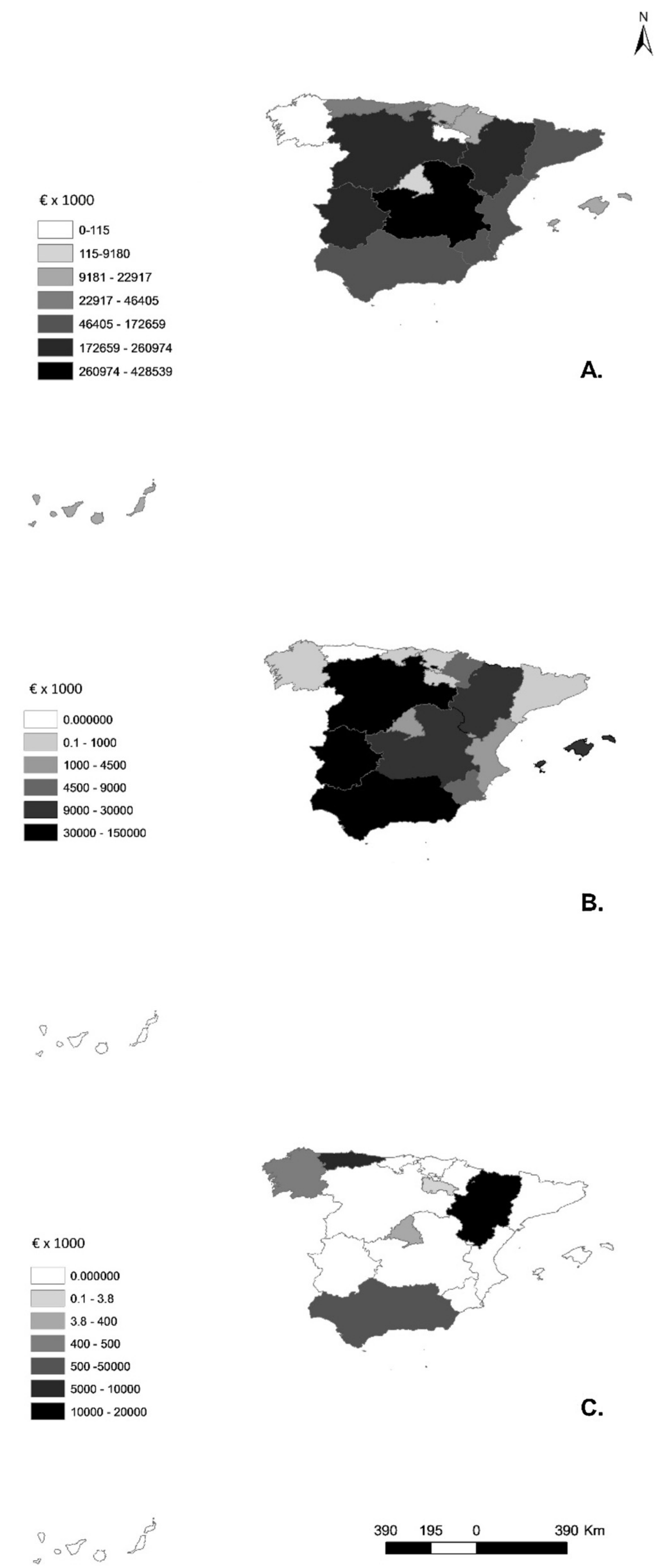

Fig. 4. Distribution of some CAP subsidies related to soil erosion control and biodiversity by autonomous regions in Spain (Comunidades Autónomas 1–16, 2016), according to the evaluation reports of the Rural development Plan 2007–2013 of each region: (a) Subsidy 214 "Agroenvironmental measures"; (b) Subsidy 221 "First forestation of agricultural land"; (c) Subsidy 223 "First forestation of non-agricultural land". Table 1. National investment in subsidies related to biodiversity and erosion control (Comunidades Autónomas 1–16, 2016).

Table 1
Spanish National investment in subsidies related to biodiversity and erosion control (Comunidad Autónoma 1–16, 2016).

Measures	Total programmed investment (€)	% Investment from FEADER funds	Average investment per region (€×1,000,000)	% Executed investment
Measure 214 "Agro-environmental measures"	2,467,570,345	54.6	145 ± 189	96.44 ± 4.81
Measure 221 "First forestation of agricultural land"	493,551,932	27.2	32 ± 53	96.12 ± 16.06
Measure 223 "First forestation of non-agricultural land"	35,566,418	40.3	6 ± 7	102.94 ± 21.99

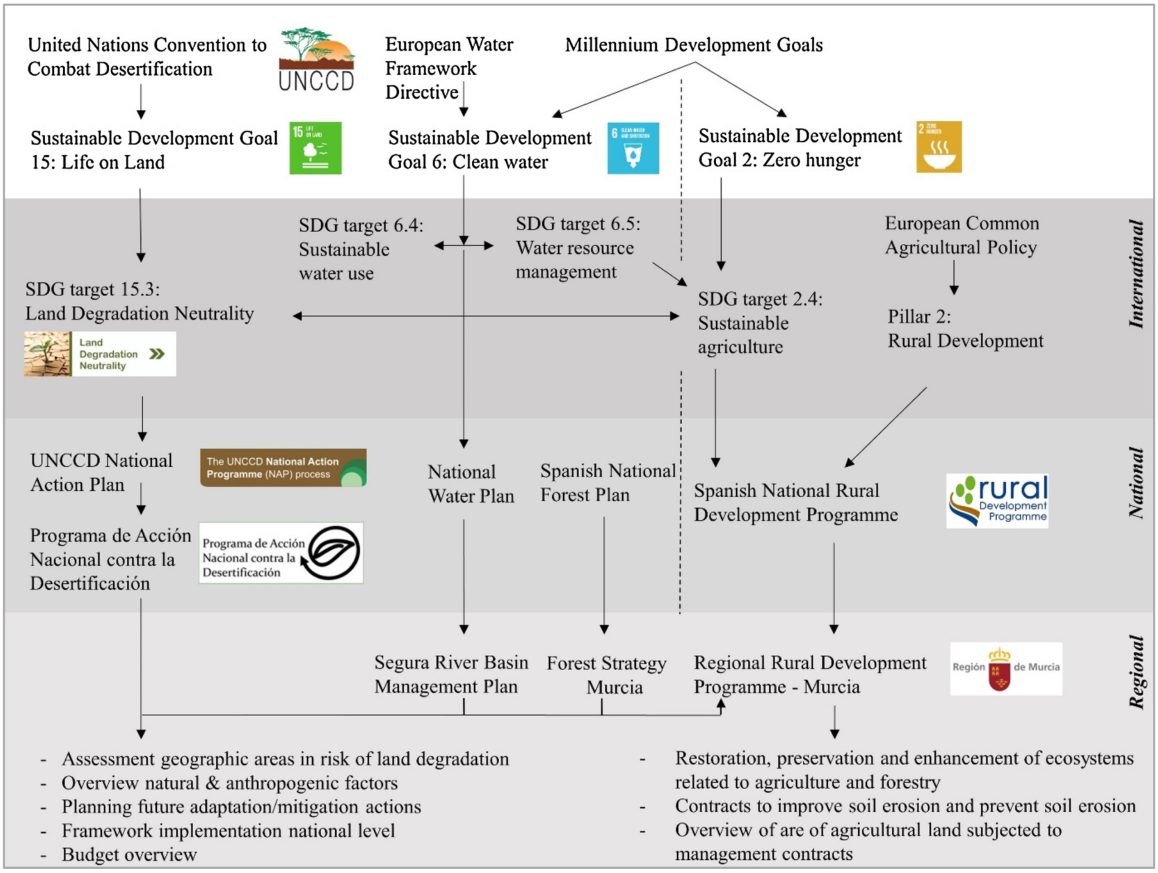

Fig. 5. Policy analysis, visualizing the top-down implementation of policies through different administrative levels. Division made between policies focusing on soil and water conservation, and on the development of agriculture and rural areas.

5.1. International policies

5.1.1. United Nations convention to combat desertification

The UNCCD, established in 1994, is the main international body aiming to fight land degradation, desertification and drought. Their aim is "*to forge a global partnership to reverse and prevent desertification/land degradation and to mitigate the effects of drought in affected areas in order to support poverty reduction and environmental sustainability*" (United Nations General Assembly, 2007). During the 2007 8th Conference of the Parties (COP-8) in Madrid, the 10-Year Strategy Framework was adopted by the UNCCD. This plan covers the period 2008–2018 and is adopted as a review process to resolve implementation deficits of the UNCCD (Benson and Xie, 2014). In 2018, a revised Strategic Framework of the UNCCD was established, covering the period 2018–2030. The Convention recognized that a more targeted, effective and efficient implementation was necessary, together with the assessment of progress (UNCCD, 2017). The new Strategic Framework aims to achieve objectives of the UNCCD and the 2030 Agenda for Sustainable Development, particularly in regard to SDG 15; Life on Land, one of the 17 SDGs adopted in 2015 by the UN General Assembly. SDG 15 aims to "*protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.*" (UNDP, 2014a, 2014b, 2014c). This SDG was established after a call of the international community for a global goal, specifically focusing on land degradation and desertification.

UNCCD's main objectives are captured by SDG target 15.3, which aims to "*by 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world.*" (Orr et al., 2017). The UNCCD officially adopted the concept of Land Degradation Neutrality (LDN) at the 12th session of the Conference of the Parties (COP-12) and defined this as "*a state whereby the amount and quality of land resources necessary to support ecosystem functions and services and enhance food security remains stable or increases within specified temporal and spatial scales and ecosystems*" (UNDP, 2017). Objectives of LDN are: (1) to maintain or improve the sustainable delivery of ecosystem services, (2) to maintain or improve productivity, in order to enhance food security, (3) to increase resilience of land and populations dependent on the land, (4) to seek synergies with other social, economic and environmental objectives, and (5) to reinforce responsible and inclusive governance of land (UNDP, 2017). The UNCCD aims to implement the concept at different administrative levels to achieve these objectives. To achieve LDN, support of all member states is vital. Currently, 120 countries have participated in the LDN Target Setting Programme (UNCCD, 2018). The Secretariat and the Global Mechanism of the UNCCD support participants in the LDN target setting process by defining the LDN frame of reference, establishing the mechanism for neutrality, providing a suitable monitoring process and by presenting the needed elements to achieve LDN in 2030 (Cowie et al., 2018).

5.1.2. European Water Framework Directive

The European Water Framework Directive (WFD) was established in 2000 by the European Commission. In contrary with previous legislation, this approach is not based on national boundaries, but on geographical and hydrological formations (European Commission, 2010). The WFD comprises several other policies, being the Groundwater Directive, Environmental Quality Standards Directive and two Commission Decisions on ecological status, to include specific aspects of water use. Special emphasis is placed on the maintenance and improvement of water bodies, together with sustainable use of water resources (Suárez-Varela and Martínez-Espiñeira, 2017). The WFD's original aim was to obtain a "good status" for all European water bodies in 2015. However, as objectives were not met, second and third management cycles were introduced, extending from 2015 to 2021 and 2021 to 2027 respectively (Voulvoulis et al., 2017). The WFD plays an important role in achieving SDG 6. This particular SDG aims "*to ensure availability and sustainable management of water and sanitation for all*" (UNDP, 2014a, 2014b, 2014c).

5.1.3. European Common Agricultural Policy

After the last CAP Reform in 2013, the policy aims "*to strengthen the competitiveness of the sector, promote sustainable farming and innovation, to support jobs and growth in rural areas and to move financial assistance towards the productive use of land*" (European Commission, 2017). Climate change and sustainable management of natural resources are considered to be relatively new challenges. Fundamental objectives of the CAP are included as targets in SDG 2: zero hunger. This SDG aims to "*end hunger, achieve food security and improved nutrition, and promote sustainable agriculture*" (UNDP, 2014a, 2014b, 2014c). Therefore, the CAP can be considered as crucial for achieving this SDG. Regarding sustainable agriculture and challenges posed by climate change, target 2.4 is interesting. This target aims to "*by 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters, and that progressively improve land and soil quality*" (UNDP, 2014a, 2014b, 2014c). The implementation of LDN by target 15.3 is expected to act as an accelerator to achieve target 2.4 (Global Mechanism of the UNCCD, 2016).

5.2. National policies

5.2.1. National Action Plan to Combat Desertification

The Spanish National Action Programme to Combat Desertification (PAND) is the main instrument for soil conservation in Spain. Most countries affected by land degradation and desertification have developed national action programmes, which are aligned with the objectives of the UNCCD Strategic Framework (UNCCD, 2017). The PAND aims to contribute to achieving sustainable development of arid, semi-arid and dry sub-humid areas of the Spanish territory and, in particular, the prevention or reduction of land degradation, the rehabilitation of partially degraded lands and the recovery of desertified lands (MMAMRM, 2008). As a frame of reference, PAND assesses the geographic areas that are at risk of desertification. Both physical factors, e.g. aridity, drought, soil erosion and forest fires, and anthropogenic factors, e.g. unsustainable use of water resources and socioeconomic drivers, are considered. This data is used to support the development of a national framework, together with a budget overview for implementation of the framework (MMAMRM, 2008).

5.2.2. National Rural Development Programme

The CAP of the 1980s, largely focused on economic growth, is considered as driver of land abandonment in Spain. To achieve more sustainable agriculture, the second pillar 'rural development' was implemented in the existing policy. The pillar aims to enhance economic viability of agriculture by stimulating investments and modernization in order to stay competitive, to preserve the rural environment by well-considered land management choices and to support wider rural economy by diversification of production (European Commission, 2011). To achieve this aim, each participating European country is provided with a national Rural Development Programme (RDP). The latest version for Spain was adopted by the European Commission in 2015, which outlines priorities for the period 2014–2020. As the Spanish agricultural sector and rural areas face many challenges, the national RDP addresses only those that can be tackled on the national level to have maximal impact. Therefore, the RDP is divided into 6 rural development priorities (MAPAMA, 2016a, 2016b). Priority 4, target 4.C., soil erosion and management, includes measures to address land issues, such as erosion and land abandonment, salinization and nutrient increase in irrigated fields, desertification, deforestation and reduced carbon stock.

5.2.3. Spanish National Forest Programme

The Spanish National Forest Programme (SNFP) finds its origin in 1999 with the approval of the Spanish Forest Strategy (SFS). The aim of this strategy was to "*change the perception and culture concerning the forest sector*". Objectives of forest policies at the national level were defined by the SFS, together with the establishment of working groups to identify stakeholders. The following years focused on the planning process and legislation (Humphreys, 2004). In 2002, the SNFP was approved as the result of different policy outputs, being forest plans, forest strategies and forest laws. The SNFP has a 30-year time span, in which it aims to establish a forest policy while taking into account sustainable development, the multi-functionality of landscapes, ecological cohesion and public participation (MAPAMA, 2002a, 2002b). The SNFP mainly focuses on forest protection, regarding erosion and fire, and plans to increase the total area of forested land (Yudego, 2002).

5.2.4. National Water Plan

With the adoption of the Spanish National Water Plan, the national administrative level became exclusively in charge of the continental waters, and covers surface and ground waters as public domain while maintaining state control over access (Garrido and Llamas, 2009). The 1985 Water Act resulted in water boards of river basins designing their own hydrological managements plans, of which the responsibility of approval lies with the Spanish Ministry of Public Works (Grindlay et al., 2011). This process has led to an unequal division of water resources, for instance regarding inter-basin water transference, as the ministry determined which agricultural field had access to water, and thus irrigation (Boix-Fayos et al., 2006). Consequently, in semi-arid regions farmers progressively abandoned traditional rainfed farming, while the area of irrigated fields increased with the associated consequences on land degradation as a result. High insolation and the construction of irrigation schemes meant the creation of an attractive environment to grow commercial fruit species. Farmers changed their traditional land management from a terraced landscape to a levelled-irrigated landscape, triggering soil erosion (Boix-Fayos et al., 2006). Furthermore, this land use change has resulted in extreme pressure on groundwater resources. In 2004, the Ministry of Environment adopted the AGUA Programme (*Actuaciones para la gestión y el uso del agua*), which makes a special reference to the WFD by promoting water savings and the reusage of water, as well as the aim to provide desalinated water to meet the growing demand by the agricultural, urban and tourism sector (Grindlay et al., 2011; March et al., 2014).

5.3. Regional policies

5.3.1. Regional Rural Development Programme for Region of Murcia

As the problems and optimal solutions are different for each Spanish autonomous region, Rural Development Programmes for the period 2014–2020 are developed regionally following national guidelines (MAPAMA, 2014). The Region of Murcia is among the European regions that are most affected by land degradation and soil erosion processes. The highest erosion rates are measured on bare soil and soft lithology, such as marls, which have absence of vegetation cover. In addition, areas with rainfed crops on steep slopes, such as olives and almonds, are affected by water erosion after intense rainfall, frequently resulting in large gullies. However, in the last eight years, the soil erosion process has been reported to decrease with 0.6% per year (MAPAMA, 2002a, 2002b), although more detailed research is required to confirm this. The Region of Murcia receives 2.2 million euros to outline and tackle erosion-related problems occurring in the area (European Commission, 2014). Again, rural development priority, target 4C, soil erosion and management, is applicable. To keep track of progress, in the Region of Murcia the following indicators are used: (1) percentage of agricultural land subjected to management contracts to improve soil management and to prevent soil erosion, and (2) the area of agricultural land subjected to management contracts to improve soil management and to prevent soil erosion. These values are respectively 26% and 102.488 ha (of the total UAA, being 394.540 ha). The declined soil erosion rates are likely to be assigned to the regional RDPs of the past few years (MAPAMA, 2002a, 2002b).

5.3.2. Forest strategy for Region of Murcia

The SNFP has been divided into Regional Forest Programmes (RFP), where each autonomous community has developed its own strategy by adopting the principles provided by European and Spanish forest programmes which are applicable to the region. The Murcia RFP aims to "*guarantee an ecological forest management that is economically sustainable*" (Montiel Molina and Galiana, 2005). In 2003, the Forest Strategy of the Region of Murcia was established. In this strategy, the so-called territorial model is implemented, which assigns resources to the territory. Currently the strategy is implemented through the last Action Plan of Forestry of the Murcia Region 2016–2020. The general objective of the plan links with the concept of ecosystem services provided by forests and points out the importance of recreational and protection services (Consejería de Agua, Agricultura y Medioambiente, 2016). Works on soil conservation are planned under programme 5 of the plan "Hydrological restoration and soil conservation", linking with the National programme of Forest and Hydrological Actions. Hydrological control and restoration, performed by the Forestry Planning Group, benefits soil conservation and strengthens the fight against desertification. This programme promotes direct actions for soil conservation and their "synergic effects" (ecosystem benefits).

5.3.3. Segura river basin management plan

The Spanish National Water Plan is divided in River Basin Management Plans for the period 2009–2021 (RBMP's). Practically the entire Region of Murcia falls within the catchment of the Segura River. The Segura RBMP is divided in two periods; 2009–2015 and 2016–2021. The plan was reviewed in 2016, by the Royal Decree 1/2016. The planning of the Segura RBMP aligns with initiatives of the National Water Plan, and is public and binding. The main objectives of Segura RBMP aim to protect water resources and water bodies. There are two groups of measures in relation to soil and sediment conservation planned, which aim to accomplish the environmental objectives designed for the water bodies: (1) measures for improvement of morphological conditions and (2) measures for protection against floods (Confederación Hidrográfica del Segura, 2015).

6. Concepts to include in future policies

Translational science and integration into policies stimulates the development of soil conservation and is crucial to bridge the gap between science and policy-making. A good example of this is the diversification of agricultural or economic activities within farms to help optimizing economic and environmental benefits. This research topic is being studied under different EU Horizon 2020 projects, such as Diverfarming (www.diverfarming.eu) and several others. Bottom-up participatory approaches have shown to increase awareness and co-responsibility by involved stakeholders regarding soil conservation (De Vente et al., 2016). Furthermore, concepts as ecosystem services and nature-based solutions are starting to be introduced in soil conservation policies but would deserve a deeper integration in environmental policy plans.

6.1. Ecosystem services

Over the past two decades, the value of ecosystem services has been widely recognized, and many efforts have been made to establish conservation strategies to protect them. Linking a monetary value to a particular service can help individuals and institutions to recognize its value, which would lead to investments in conservation and restoration (Daily et al., 2009). The process to include an ecosystem service assessment in environmental research and policy-making accelerated with the publication of the Millennium Ecosystem Assessment (MEA) in 2005 (Martín-López et al., 2014). Here, ecosystem services were defined as "*the benefits people obtain from ecosystems*" and are divided into four categories: supporting, provisioning, regulating and cultural services (MEA, 2005a, 2005b). Since this time, many studies have been performed on ecosystem and landscape functions and services. However, full integration of the ecosystem services concept in landscape planning, management and decision-making still requires more research (De Groot et al., 2010). Agricultural landscapes generally are managed to maximize provisioning services, being the production of food, fibres and fuel. Agricultural ecosystems are highly dependent on supporting and regulating services to achieve high production rates (Zhang et al., 2007). Supporting services, such as soil structure and fertility, nutrient cycling, water provision and genetic biodiversity, are the basis of all ecosystems, while their provisioning services, as they provide living spaces for plants and animals, maintain genetic diversity (MEA, 2005a, 2005b). Regulating services, such as soil retention, climate regulation, natural control of pests, water purification and atmospheric regulation, are mostly invisible processes and are often taken for granted. However, when these processes are damaged, losses can be substantial and difficult to restore (MEA, 2005a, 2005b).

Land degradation after land abandonment, water scarcity after regreening and overexploitation of soil and water resources by agriculture can damage ecosystem services significantly. Revegetation on degraded soils can improve soil fertility (supporting), and thus agricultural productivity (provisioning), while also strengthen biodiversity (supporting) (Chazdon, 2008). It is therefore important to consider an ecosystem service approach in land management and decision-making. Key challenge in this process is to determine which biophysical, sociocultural, and monetary values can be integrated, to enable successful implementation (Martín-López et al., 2014). To ensure conservation, and sometimes improvement, of ecosystem services, payments for ecosystem services have emerged as policy solution. Costa Rica, China and Mexico have created large-scale programmes that provide direct payments to landowners who apply land management that increases the quality of ecosystem services (Jack et al., 2008). Previous experience with incentive-based payments, such as by the CAP, has shown that it is difficult for this approach to improve livelihoods and ecosystem services, while maintaining low costs. Therefore, more research is needed to the value and mapping of ecosystem services, as well as to incentives to achieve suitable conservation strategies.

6.2. Nature-based solutions

Nature-based solutions (NBS) is a concept that was introduced in the late 2000s, and can be defined as "*actions to protect, sustainable manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits*" (Cohen-Shacham et al., 2016). The concept arose in environmental science as international institutions, such as the International Union for Conservation of Nature (IUCN) and the World Bank, were exploring solutions for environmental issues that work together with ecosystems, instead of relying on conventional technical interventions (Cohen-Shacham et al., 2016). Over time, there is increasing evidence that NBS often are more cost-efficient than grey infrastructure (Maes et al., 2012). NBS can be considered as an 'umbrella-concept', as there are many similar concepts, all covering another aspect. Nesshöver et al. (2017) have divided NBS in four categories: ecological engineering, ecosystem approach, ecosystem service management and ecological restoration. To implement this concept successfully in all four areas, a transdisciplinary approach is needed.

An example of an NBS to reduce soil erosion at fields in risk of abandonment, is the application of agronomic measures that use the protective effect of plant cover (Morgan, 2015). Crop rotation schemes are often a good start to reduce soil loss in cultivated fields. Row crops are characterized by a large bare surface between the plants, which makes the soil highly susceptible to erosion. By rotating these crops with legumes and grasses, which provide good ground cover, the soil is better protected, and soil organic matter content and aggregate stability will improve (Morgan, 2015). Cover crops, such as oats, barley, mustard and sweet clover, can be used in the off-season, or as ground protection under trees (Almagro et al., 2016). In grazing land, rotation can also reduce soil erosion significantly. When livestock is moved from one pasture to another, this gives time for the grass to recover. In times of high erosion risk, vegetation should regenerate to 70% before the pasture can be used for grazing again (Morgan, 2015).

7. Conclusion

A review of the historical evolution of public perception and decision-making at different administrative levels related to soil conservation shows a shift from production-oriented exploitation of natural resources towards public awareness of both the importance and fragility of agriculture, indicated by nature conservation and holistically integrated management of coupled socio-ecosystems. Over the past century, declined productivity of degraded lands, international market development and policy incentives have resulted in large scale abandonment of rainfed agriculture, accompanied by reforestation projects and the expansion of irrigated agriculture in rural Spain. In some cases, these land use changes have resulted in greening up and land restoration, while further land degradation can also be observed. The large spatial scale at which agriculture, together with its abandonment, occurs has led to extensive documentation of both soil degradation and recovery by restored vegetation, with significant consequences for socio-ecosystems not only in Spain, but also worldwide. Soil degradation has been politically approached with a complex network of policies from the international to the regional level. Over the past decades, there is a growing insight in the need for better rural planning, paying attention to land restoration, protection of ecosystem services and development of innovative economic models that are necessary for sustainable environmental and socioeconomic development. Current instruments such as subsidies, designed to reduce soil erosion and restore degraded soil, are still controversial as it is not clear if their application along decades has resulted in net benefits. To improve future policies aiming for land degradation neutrality and sustainable socio-ecosystems, quantification of ecosystem services, identification of nature-based solutions and sustainable business models need to be further developed. To achieve large-scale implementation of these solutions, traditional top-down policy making must be integrated with bottom-up identification of most urgent problems and feasible solutions.

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