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Growth performance of Sainfoin and its effects on the runoff, soil loss and sediment concentration in a semi-arid region of Turkey

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ABSTRACT

Vegetation is one of the key factors affecting soil erosion in semi-arid environments. The evaluation of the influence of Sainfoin on soil erosion can provide important information about soil and water conservation. In this study, the effects of vegetation destruction and vegetation restoration on soil erosion were quantified using data from field runoff plots established in a semi-arid zone in Northeastern Turkey. This study was performed between 2005 (June) and 2009 (January). The experimental design at the site included a randomized complete block with four replicates (a total of 12 experimental plots: 3 treatments × 4 replicates). Each plot was 20-m long × 5-m wide, which is wide enough to minimize edge effects and large enough for downslope rills to develop. The control plot (A) was maintained, bare of vegetation by manual removal of the plant cover and, regular herbicide treatments. In the second plot (B), Sainfoin was seeded in 25 cm wide and 60 cm long rows, at a density of 8.5 g of seeds per square meter in October, 2005 after clearing the existing vegetation. The third plot contained natural vegetation shrub (*Paliurus spina-christi* Mill.) and perennial grass (*Cynodon dactylon* L., *Achillea* sp., *Astragalus* sp.) vegetation (C) that maintained at an approximately 63% coverage (October, 2005) of the soil surface.

From 4 randomly selected quadrats (1 m × 1 m) at a vegetation plot, the vegetation cover of all of the plant species was estimated for each cell, and the average vegetation cover for a plot was calculated. The plant height and cover were recorded monthly from March through October in 2006, 2007 and 2008, and the monthly averaged value for each indicator was used in this study.

Rainfall was recorded at the same field at 1-min intervals using a tipping-bucket system linked to a data-logger. The erosion plot results presented in this study clearly indicate a decrease in the erosion rates over time. The highest sediment concentration was measured on bare plots (10.4 g l^{-1}, 2006), while the lowest sediment concentration was measured on Sainfoin plots (1.76 g l^{-1}, 2008). The effective soil conservation ability of Sainfoin differed between seasons and years. In the spring season, when plant cover was 30%, Sainfoin began to exhibit an effective active soil conservation ability. In contrast, when the plant cover was greater than 50%, effective protection was observed in the summer. The results revealed that the plant cover was the main factor reducing surface runoff and sediment production, and that Sainfoin showed a great potential to both reduce erosion and runoff.

1. Introduction

Soil erosion is a serious problem throughout most of the world (Pimentel, 2006; Pimentel and Kounang, 1998). Each year, approximately 75 billion tons of soil is eroded from the world's terrestrial ecosystems (Duran Zuazo and Rodriguez Pleguezuelo, 2008). Soil erosion is of great environmental concern because it leads to a decline in soil fertility, and plant productivity and because the sedimentation of reservoirs (Bruce et al., 1995) contributes to global climate change (Duran Zuazo and Rodriguez Pleguezuelo, 2008). Semi-arid landscapes by definition are water-limited and exhibit a low amount of organic matter content (Duran Zuazo and Rodriguez Pleguezuelo, 2008; Smolikowski et al., 2001; Yüksek and Yüksek, 2011). Therefore, semi-arid regions are potentially more sensitive to environmental change and its effect on plant growth. Erosion is one of the most important soil problems in areas with a semiarid type climate. In these seasonally dry environments, the relationship between soil and plant communities plays a major role in preventing soil erosion. One particularly important interaction between these processes in patchy vegetated semi-arid lands is how these serve to control water erosion; retaining water and soil which increases vegetation growth (Ludwig et al., 2005). These interactions could also lead to microtopographic changes that could further affect water runoff and soil loss processes (Bergkamp, 1998).

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Many studies have proven that increasing vegetation cover is an important measure to control water erosion (Angima et al., 2002; Babalola et al., 2007; Calvo-Cases et al., 2003; Kothyari et al., 2004; Mohammad and Mohammad, 2010; Neave and Rayburg, 2007; Nunes et al., 2011; Udawatta et al., 2006; Usón and Ramos, 2001; Xu et al., 2006a, 2006b, 2008), and to improve soil environments (Casermeiroa et al., 2004; Chirino et al., 2006; Martinez-Mena et al., 1999; Owino et al., 2006; Ruiz-Colmenero et al., 2013; Thompson et al., 2005; Xu et al., 2008). In eroded sites, land is usually barren, and the soil quality is poor. To achieve the maximum success on erosion control studies in eroded sites, the vegetation must be of low height (<50 cm) and single-stemmed (Morgan and Rickson, 2004). The root network must promote an even pattern of water infiltration into the soil to avoid concentrations of water that might initiate or feed a network of subsurface pipes on rills (Morgan and Rickson, 2004). Additional properties of the vegetation that are important for erosion control areas are: a) rapid growth, both in the first year of revegetation and at the beginning of each growing season, b) ability to produce a maximum effect at the time of year when the rainfall intensities are highest, and c) a high rate of litter production, to build-up the organic content of the soil as rapidly as possible and to cover the soil surface with a protective layer of decaying humus (Morgan and Rickson, 2004). Sainfoin (*Onobrychis viciifolia* Scop.) is one of the most important forage legumes in dryland regions and is appreciated by farmers due to its high palatability and high nutritional value properties (Delgado et al., 2008; Frame et al., 1998; Gülcan, 1989; Yüksek, 1996; Yüksek et al., 2002). Sainfoin is capable of improving the soil organic matter content and nitrogen content by fixing atmospheric nitrogen (Mohajer et al., 2012; Yüksek, 1996). The roots of Sainfoin penetrate into the deeper layers of the soil and supply considerable amounts of organic matter when ploughed under (Mohajer et al., 2012). In abandoned areas and hill slopes where erosion may be a problem, Sainfoin seedlings may prevent desertification and erosion and maintain soil fertility. The melliferous flowers of Sainfoin attract bees and birds, thereby enhancing biodiversity (Mohajer et al., 2012; Yüksek, 1996). Although Sainfoin plants that feature these capabilities are preferred for the restoration of eroded soils in arid and semi-arid areas, studies that have investigated the use of Sainfoin for soil conservation in arid and semi-arid environments are scarce and lacking for Turkey.

The objectives of this study were (i) to determine the adaptation and growth performance of Sainfoin, (ii) to investigate under natural rainfall conditions the effect of both Sainfoin plantation and natural vegetation on runoff, sediment loss, and sediment concentration, and (iii) to evaluate the relationships between plant cover and response variables (runoff, sediment, and sediment concentration) in different seasons. The results of this research will support the decisions of whether extensive application of Sainfoin is a good vegetation management option for degraded semi-arid regions on eroded sites or not.

2. Materials and methods

2.1. Study site

The study site has one of the lowest rainfalls (291 mm/year, 1971) in Turkey and some of the highest levels of soil erosion (erosion site/total area, 86%). There is no acceptable land use and management plan for the study area and its surrounding environment. According to reports from local people in Pamukçular between 1940 and 1990, the majority of the forest community was damaged due to cutting, and the area was subsequently subjected to erosion.

The study was conducted in the Pamukçular Watershed in north-eastern Turkey from June 2005 to January 2009. The study area, the Pamukçular Watershed, is located at 40° 46′ 26″40° 46′ 35″ N and 41° 49′ 01″41° 49′ 10″. The altitude of the area is 1000 m a.s.l., with a mean slope of 20% (see Fig. 1).

The geological formation in the study area consists of two stratigraphic units: (i) a lower unit of pillowed and massive basalt and basaltic andesite intercalated with some thin-bedded silts and shales, and (ii) an upper unit of shallow-water sedimentary rocks with some interbedded basic volcanic rocks (Lower–Middle Jurassic shales and sandstones (Hamurkesen formation), Upper–Lower Cretaceous limestones (Berdiga formation), Dokuz, 2000). The soil types in the area were classified as Entisol. Because there was no reliable meteorological

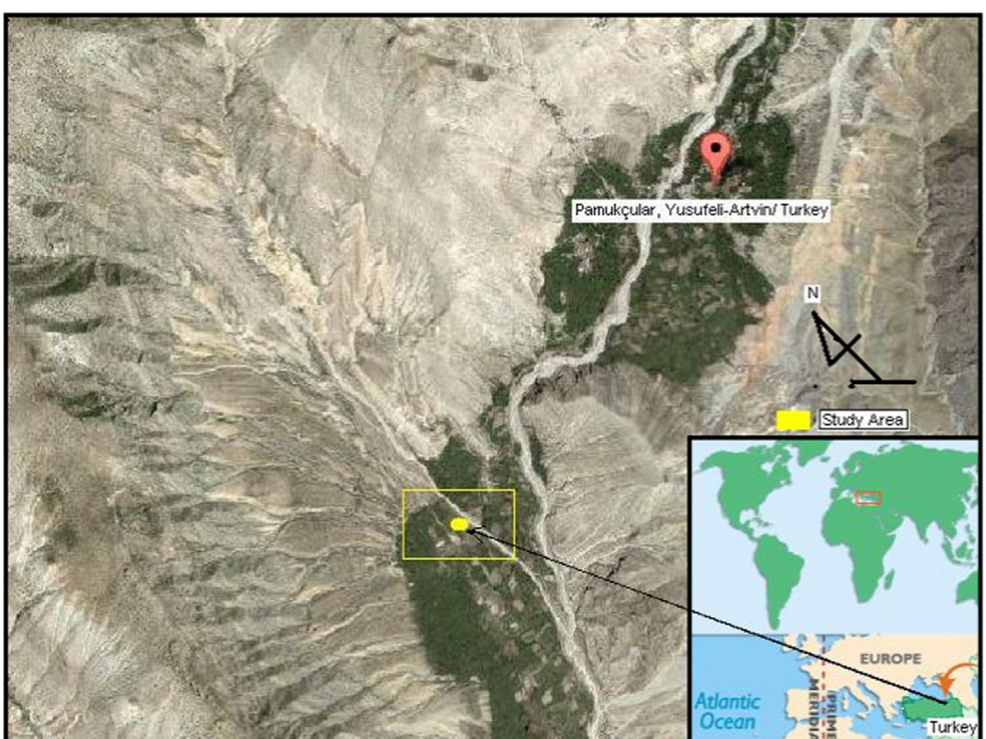

Fig. 1. Study area and experimental sites in Pamukcular watershed.