Influence of *Mahonia aquifolium* population on erosion control in a mountainous area in Hungary

Hudek, C.[1] – Rey, F. – Molnar, E.

Cemagref Grenoble, Unité de Recherche Ecosystèmes Montagnards, 2, rue de la Papeterie, St. Martin d'Hères, 38402, France. Tel.: +33 (0)4 76 76 27 27; Fax: +33 (0)4 76 51 38 03; E-mail: csilla.hudek@cemagref.fr

1. Abstract

After the regime changes of 1989 in Hungary, many farm owners faced problems typical of small sized farms (<1 ha) and a lack of various resources such as farming equipment and machinery, a well functioning trade market, etc. This led to many farms with great horticultural backgrounds being abandoned, especially in mountainous areas where erosion control is essential for soil conservation. Drastic changes can occur on soil through property abandonment. We must take into consideration the local socioeconomic aspects as well as the problem of soil degradation as this will be a motivating factor towards preservation initiatives. Under horticultural management, *Mahonia aquifolium* was tested to determine its efficiency in water erosion control in mountainous conditions in Hungary. Surface runoff and soil loss were examined in 6 different plots; four cultivated and two controlled. The four cultivated plots had four different age brackets of *M. aquifolium* population; 4 years old in the 210 m² area, 12 years old in the 340 m² area, 20 years old in the 1656 m² area and 25 years old in the 910 m² area. Grassland and bare soil represented the two types of controlled plots. The slope angle of all fields varied between 13-14 %. Soil loss and water runoff were measured after every rainfall events. The results show that the mechanical protection offered by its persistent, evergreen foliage and its litter covers, better protects the soil's physical and chemical structure when compared to the bare surface. They also indicate that as the population's age decreased, the cumulative runoff and sediment values increased.

Key words: erosion, runoff, soil loss, mountainous agroecosystem, *Mahonia aquifolium*

2. Introduction

In the 20th century, the structure of agriculture in Eastern-European countries, including Hungary, first changed from (1) polarized ownership to (2) collectivization and then with political changes, to (3) economic restructuring (Bouma et al., 1998). Polarised ownership was represented by small-scale private farming with low input and yields. Collectivization had a greater focus on high yield production. Chemical fertilisers, pesticides and herbicides were introduced to the new cropping technology along with new high yield crop varieties. These changes in land use practices resulted in harmful effects on the environment (Bouma et al., 1998). After 1989, the privatization of land brought mixed ownership and a huge majority of small-scale (<1 ha) farms. The market orientated production system and sustainability became the main priorities. Lack of capital goods in the agriculture sector slowed down its development. Today, we can say that agriculture was one of the great losers of the changeover (Karsai, 1999). A large percentage of the rural population's primary or only source of income is from agricultural activities, which includes the hilly areas of Hungary.

Land use changes in agriculture can exacerbate land degradation (Dunjó et al., 2003; Pardini et al., 2003; Cammeraat et al., 2005; Jordan et al., 2005; Withers et al., 2007). During the last century land degradation caused by inappropriate land use management had become widespread in hilly areas of Hungary (Gábris et al., 2003). Hungary has some 9.3 % weakly, 9.6 % moderately and 6 % strongly eroded areas (Németh et al., 2005). These are mostly linked to the Transdanubium and Northern hilly part of the country. This results in approximately 80-110 million tons of topsoil loss every year (Németh et al., 2005). The vulnerability of hillsides for erosion necessitates finding the best possible land use pattern to reduce soil loss and minimise any erosion processes, and sustain the environment to provide an important source of income to the rural population.

Oregon grape [*Mahonia aquifolium (Pursh) Nutt*] is a native, evergreen shrub of western North-America. It was introduced to Europe as an ornamental plant in 1822 and is now naturalised in many parts of Europe (Tóth, 1969; Seidemann, 1998). It is also used as a natural colorant, herbal medicine in human and veterinary medicine, furnishing food and cover for wildlife and it is part of human alimentation (e.g., Grae, 1974; Moerman, 1998; Samecka-Cymerman and Kempers, 1999). It has a high abiotic tolerance which makes it even more favourable and capable for cultivation under various conditions. Due to its high tolerance of chemical pollutants and favourable root morphology it has potential in bioengineering at highway cut slopes and urban landscaping (Lans et. al., 2007; Tóth, 1969). Effectively, it develops a large, elaborate tap root morphology in order to better secure itself in the soil. Oregon grape under cultivation has a steady decrease in root number with depth and a higher root density than those which are not under cultivation. In the top 10-15 cm of the soil, root density is significantly higher than at the lower soil levels (Hudek et al., submitted). Stems grow rapidly and can reach heights of up to 1.5-2 m. It appeared then interesting to analyse the performance of this species for erosion control.

The aim of this study was to test cultivated *M. aquifolium* age groups on their efficiency in water erosion control in mountainous conditions in Hungary, by measuring the surface runoff and associated transfer of sediment from a long existing horticultural farming area.

3. Materials and Methods

3.1. Study area description

The area is located in the Danube band in the north of Hungary. The Danube band and the vicinity lie on the boundary of lowland, alpine, and medium-height mountains. The study area belongs to the Visegrád region. In terms of geology, it is related to the Börzsöny, as they consist of andesite of volcanic origin from the Miocene.

The phytogeographical classification of the area is: Pannonicum floristic area, Matricum floristic province and Visegradense floristic district. Climatic conditions that influence hydrology and erosion are typical temperate continental characteristics with a mean temperature of 9 °C and an annual precipitation of 600-700 mm. According to Bacsó (1973) an index number (<20 - >70) indicates the risk of erosion. The index number varies between 30 and 50 in the studied area.

3.2. Farm description

It is a typical small-scale farm (0.56 ha) regarded as a secondary source of income. This involves the *M. aquifolium* plantations, animal husbandry (rabbits and chickens), a bee farm, the *M. aquifolium* nursery and a kitchen garden. The farm has had a strong horticultural background (vineyards and orchards) for centuries. From previous farm structure to the present, the conversion was gradual. *M. aquifolium* has been cultivated for 25 years for ornamental purposes, particularly for its green foliage. Two year old seedlings from the farmer's nursery were used to install the plantations (6.6 plants per m²) where there is no irrigation. Manure was applied to the bed before planting, and subsequently in every 5th year after that. A further 3-5 dkg/m² N fertiliser is used every year during spring time. Four to five times a year weed control is necessary manually and/or with a cultivator. Disease control is necessary several times a year. *M. aquifolium* is harvested from September until February depending on market demand.

3.3. Experimental site description

The experiment was carried out under field conditions at Tyukos dülő, located in the outskirts of Szentendre, (47°41' 45" N, 19°04'07"E). The altitude of the study area varied between 230 m and 285 m a.s.l. Its soil is brown forest soil with clay iluviation which is generally shallow (0-25 cm depth). Six hill slopes, with a total area of 0.33 ha were selected to measure runoff and erosion. All selected fields, four cultivated and two controlled, were farmlands. These individual fields were physically separate from each other; therefore they had no influence on each others collected samples. All fields were facing south with the slope angle of 13-14 %. The four cultivated plots had four different age brackets of *M. aquifolium* population; 4 years old in the 210 m² area (M4), 12 years old in the 340 m² area (M12), 20 years old in the 1656 m² area (M20) and 25 years old in the 910 m² area (M25). Bare soil (CBS) in 88 m² and a grass field (CG) in 108 m² areas represented the controlled fields. All plots were cultivated perpendicularly to the slope. A local meteorological station was installed for the duration of the study period, from the 1st of June, 2007 until the 31st of January, 2008, giving data on temperature and total precipitation on a daily basis. Pipes and collector tanks were established at the lowest end of the slope at all six plots in order to collect sediment and runoff during the period of experimentation. In cases when the rainfall event was small and resulted in a small amount of runoff, no sample was taken. Any runoff was left in the tanks and collected after the next valuable rainfall event. Pipes and tanks were emptied and cleaned of retained sediment after every collection. Runoff-water was measured for quantity, and soil sediment from the tanks and pipes measured for sediment yield.

3.4. Statistical evaluation

The effect of treatment on runoff and soil loss were analysed by an analysis of variance (ANOVA) after verifying the variance of normality and homogeneity. Post-hoc LSD test ($p<0.05$) were used to analyse the differences between pairs of treatments. Statistical analyses were performed by using the program STATISTICA, (Version 8, StatSoft, 2007).

4. Results

4.1. Rainfall distribution

There was a total of 63 rainfall occasions during the monitored period with a total precipitation of 405 mm. The heaviest rainfall events occurred in September with 11 rainy days, the least in July and December with 5. The wettest month was August with a total of 96 mm of rain and the driest was July with 24 mm. The heaviest rainfall of this period took place on the 5th of June with 35 mm in one day.

4.2. Runoff and soil loss

A total of 12 erosive episodes were evaluated. The volume of runoff was site specific. The cumulative runoff graph (Fig.1.a) of the 6 different experimental plots shows that *M. aquifolium* plantations (M4, M12, M20, M25), significantly reduce runoff compared to the two control plots (CG, CBS). The most cumulative runoff was captured from the two control sites; CBS (245.4 ml/m²), CG (170.5 ml/m²), followed by the cultivated plots: M4 (85.3 ml/m²), M12 (64.7 ml/m²), M20 (48.7 ml/m²) and M25 (48.5 ml/m²). Among the cultivated plots cumulative runoff showed differences between age brackets. Greater cumulative runoff was found at younger Oregon grape cultivations than at the older plots. M4, when compared to the older: M12, M20 and M25 plantations had 24%, 43% and 43% higher cumulative runoff respectively. When results from plot CBS were compared to the results of the shrub population the following decreases in runoff appeared: 65%, 73%, 80% and 80% with increasing population age (M4, M12, M20, M25). This indicates that after 2 years of setting up a new *M. aquifolium* plantation (with 2 years old seedlings) the cumulative runoff decreased by 65 % compared to the controlled bare soil. The cumulative runoff results showed comparable values for the two oldest plantations (M20 and M25), which indicates that there is no considerable changes in the cumulative runoff results after 20 years of cultivation. The ANOVA test result confirms significant differences between treatments in the quantity of runoff ($F = 9.0$, $p<0.000$). The differences between individual means are presented in Table 1.

The cumulative soil loss graph (Fig.1.b) shows that the lowest cumulative soil loss was collected from CG (0.05 g/m²) followed by the shrub plantations: M25 (1.24 g/m²), M20 (2.26 g/m²), M12 (2.90 g/m²) and M4 (3.74 g/m²). The highest result was given by plot CBS with a total of 13.37 g/m² soil loss. The differences between individual means are presented in Table 2. Results also confirm that *M. aquifolium* populations significantly reduce soil loss compared to the bare soil surface ($F = 3.3$, $p<0.01$).

The cumulative runoff and soil loss results of different age groups of cultivation show that the older population of Oregon grape has the lowest cumulative runoff and sediment results and as the population's age decreases the cumulative runoff and sediment values increase.

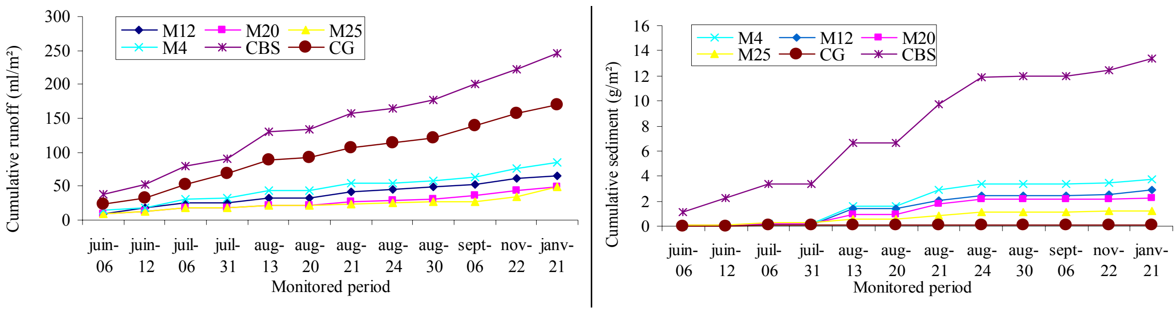

Fig.1.a; Cumulative runoff

Fig.1.b; Cumulative soil loss

Figure 1 a; Cumulative runoff and b; soil loss of the 6 different experimental plots during the study period

Table 1 Significant level of the Post hoc LSD test values to test the differences in Runoff between pairs of plots

	Treatment	1	2	3	4	5	6
1	M4		0,601237	0,106164	0,057547	0,017489	0,001885
2	M12	0,601237		0,269776	0,163912	0,004237	0,000359
3	M20	0,106164	0,269776		0,769093	0,000126	0,000007
4	M25	0,057547	0,163912	0,769093		0,000045	0,000002
5	CG	0,017489	0,004237	0,000126	0,000045		0,426358
6	CBS	0,001885	0,000359	0,000007	0,000002	0,426358	

Table 2.Significant level of the Post hoc LSD test values to test the differences in Soil loss between pairs of plots

	Treatment	1	2	3	4	5	6
1	M4		0,823047	0,109605	0,480123	0,423840	0,042746
2	M12	0,823047		0,169332	0,628389	0,486746	0,025321
3	M20	0,109605	0,169332		0,380849	0,939297	0,000370
4	M25	0,480123	0,628389	0,380849		0,639399	0,007390
5	CG	0,423840	0,486746	0,939297	0,639399		0,083076
6	CBS	0,042746	0,025321	0,000370	0,007390	0,083076	

5. Discussion

The age of a *M. aquifolium* population is a determining factor in erosion control. The fact that 2 years after setting up a new *M. aquifolium* plantation the cumulative runoff decreased by 65% indicates that Oregon grape plays a significant role in erosion control within a short timeframe. At the opposite, the older populations of *M. aquifolium* show visible evidence of soil accumulation at the root and stem section of the plant.

CG had highest runoff results however this was not reflected in the sediment results. The undisturbed surface of the soil makes it largely impenetrable by precipitation, and the high root density means it is almost impossible for the runoff to transport soil particles. Even though grass would provide the most effective erosion protection from the six studied plots, the land is ideally suited for horticultural purposes, for *M. aquifolium* cultivation. The dense canopy of the older Oregon grape population is a determining factor to reduce the energy of raindrops, which is responsible for soil particle detachment. Moreover, even with lower shear strength of fine roots, *M. aquifolium*'s root structure is comparable to other plant species in terms of erosion control and it provides an additional cohesion to the soil by which increases the soil shear strength (Hudek et al., submitted). This fact became more important after harvest, when the interception of rainfall by the canopies is less efficient. It would be beneficial to reduce cultivation before harvesting which would decrease the risk of loss of soil particles. To cover the soil with living or dead mulch after harvesting would also be a step towards reducing top soil loss.

6. Conclusion

The results showed that *M. aquifolium* plantations have a significant influence on the quantity of surface runoff and the yield of sediment. Soil protection increases with the age of the plant population. Therefore *M. aquifolium* is ideal for small scale farm practices on mountainous areas. This is due, not only to its reduction of soil loss and runoff, but also on its low requirements of economical and physical maintenance and its various means of marketability.

7. References

Bacsó, N., 1973. Bevezetés az agrometeorológiába. Mezőgazdasági Kiadó. Budapest.

Bouma, J., Varallyay, G, Batjes, N.H., 1998. Principal land use changes anticipated in Europe. Agriculture, Ecosystems and Environment 67 (2-3), pp. 103-119.

Cammeraat, E., Van Beek, R., Kooijman, A., 2005. Vegetation succession and its consequences for slope stability in SE Spain. Plant and Soil 278 (1-2), pp. 135-147.

Dunjó, G., Pardini, G., Gispert, M., 2003. Land use change effects on abandoned terraced soils in a Mediterranean catchment, NE Spain Catena 52 (1), pp. 23-37.

Gábris, Gy., Kertész, Á., Zámbó, L., 2003. Land use change and gully formation over the last 200 years in a hilly catchment. Catena 50 (2-4), pp. 151-164.

Grae Ida, 1974 Nature's Colors: Dyes from Plants MacMillan Publ., New York.

Hudek, C., Burylo, M., Rey, F., (submitted). Root density distribution and root tensile strength of Oregon grape (*Mahonia aquifolium*): implication for soil fixation in a horticultural context. Soil and tillage Res.

Jordan, G., Van Rompaey, A., Szilassi, P., Csillag, G., Mannaerts, C., Woldai, T., 2005. Historical land use changes and their impact on sediment fluxes in the Balaton basin (Hungary). Agriculture, Ecosystems and Environment 108 (2), pp. 119-133.

Karsai, G., 1999. A magyar gazdaság folyamatai, 1990-98. (Helyzetkép a TEP makro-forgatókönyveihez) Nemzeti Kutatási és Technologiai Hivatal Budapest.

Lans, C., Turner, N., Khan, T., Brauer, G., Boepple, W. 2007. Ethnoveterinary medicines used for ruminants in British Columbia, Canada . Journal of Ethnobiology and Ethnomedicine. 3 art. no. 11.

Moerman, D.E. 1998. Native American Ethnobotany Timber press Inc. Portland, Oregon USA.

Németh, T., Stefanovits, P., Várallyay, Gy., 2005. Talajvédelem. Országos Talajvédelmi Stratégia tudományos háttere, Kármentesítési tájékoztató. Környezetvédelmi és Vízügyi Minisztérium, Budapest.

Pardini, G., Gispert, M., Dunjó, G., 2003. Runoff erosion and nutrient depletion in five Mediterranean soils of NE Spain under different land use. Science of the Total Environment 309 (1-3), pp. 213-224.

Samecka-Cymerman, A., Kempers, A.J. 1999. Bioindication of heavy metals in the town Wroclaw (Poland) with evergreen plants. Atmospheric Environment 33 (3), pp. 419-430.

Seidemann, J., 1998. Die Mahonie (Mahonia aquifolium/Pursh/Nutt.), eine brauchbare Obstpflanze? Deutsche Lebensmittel-Rundschau 94 (7), pp. 217-220.

Tóth, I., 1969. Díszfák, díszcserjék. Mezőgazdasági Kiadó, Budapest.

Withers, P.J.A., Hodgkinson, R.A., Bates, A., Withers, C.L., 2007. Soil cultivation effects on sediment and phosphorus mobilization in surface runoff from three contrasting soil types in England. Soil and Tillage Research 93 (2), pp. 438-451.