UNIVERZA V LJUBLJANI
BIOTEHNIŠKA FAKULTETA
ODDELEK ZA GOZDARSTVO IN OBNOVLJIVE
GOZDNE VIRE

Carlos Manuel MORALEDA MELERO

WOODY BIOMASS OF INVADED KARSTIC PASTURES - A CASE STUDY AT PODGORSKI KRAS PLAIN

GRADUATION THESIS

Higher professional studies

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LESNA BIOMASA ZARAŠČAJOČEGA SE KRAŠKEGA PAŠNIKA – ŠTUDIJ PRIMERA NA PODGORSKEM KRASU

DIPLOMSKO DELO
Visokošolski strokovni študij

Ljubljana, 2010

Diplomsko delo je zaključek visokošolskega študija gozdarstva na Universidad de Castilla La Mancha (UCLM), Escuela Técnica Superior de Ingenieros Agrónomos (ETSIA), opravljeno pa je bilo na Oddelku za gozdarstvo in obnovljive gozdne vire BF.

Komisija za študijska in študentska vprašanja Oddelka za gozdarstvo in obnovljive gozdne vire BF je sprejela temo in za mentorja diplomskega dela imenovala doc. dr. Toma Levaniča in za somentorja prof. dr. Dominika Vodnika.

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AI Raziskava je del projekta, ki preučuje ogljikov cikel na zaraščajočih kraških pašnikih v submediteranskem območju Slovenije na Podgorskem Krasu (JZ Slovenija). Analize smo opravili na dveh raziskovalnih ploskvah v različnih stadijih zaraščanja z gozdom (pašnik in z drevjem deloma zarasel pašnik). Cilj našega dela je bila ocena biomase lesnatih rastlin na zaraščajoči površini in primerjava s pašnikom. Delali smo v skladu z metodologijo kot jo predlaga Terrestrial Carbon Observation Panel (TCO), ki je del Global Terrestrial Observing System (GTOS) – http://www.fao.org/gtos. Na podlagi natančne inventure lesnatih rastlin smo s pomočjo alometrijskih funkcij izračunali biomaso lesnatih rastlin. Skupna biomasa lesnatih rastlin na zaraščajočem se pašniku je bila ocenjena na 32.065 t ha-1. Glavnina (86%) vse biomase odpade na puhasti hrast (Quercus pubescens L.). Z dendrokronološko študijo smo na vzorcu 18 dreves preučili tudi priraščanje biomase v času in prostoru. Ugotavljamo, da je v 52 letih gozd zasedel kar 21% suhega kraškega pašnika. Analiza volumenskega prirastka je še pokazala, da nobeno od analiziranih dreves še ni doseglo kulminacije volumenskega prirastka in da je to z vidika ponora ogljika zaželeno. Naša spoznanja so pomembna za razumevanje prostorskih in časovnih sprememb v zalogah ogljika in o pomenu gozda za shranjevanje ogljika in blaženje klimatskih sprememb.

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AB Our research was part of a broader study that deals with the carbon cycling in abandoned karstic pastures of Slovenian sub-mediterranean region (Podgorski kras, SV). At this site two study plots that differ in succession (pasture and grassland invaded by woody plants) are researched. The aim of our work was to make estimation of woody plants biomass at invaded area. The method for the field measurements of biomass was one proposed by Terrestrial Carbon Observation panel (TCO) of, the Global Terrestrial Observing System programme (GTOS) (http://www.fao.org/gtos/). We did an inventory and we calculate total woody biomass for each species with different allometric equation. Total woody biomass of the site was estimated to 32,065 $t\,ha^{-1}$, and was mainly contributed by pubescent oak (*Quercus pubescens* L., 86 % of total). We did also a dendrocronological measurement, we took samples from 14 trees with a increment borer and we also collected disks from 4 trees. In 52 years the forest overgrowth 21% of dry karstic pastures we can see that in ours samples trees, we observe a significant growth in these years analizing our samples trees. None of the trees in our case culminate and biomass production is in all trees in exponential increase that culmination is reached at very high ages so basically carbon storage is constantly increasing. The information on diameter increment and growth patterns of trees contributes to understand the changes in carbon stock during woody plant encroachment.

TABLE OF CONTENTS (INDEX)

Str.

INDEX OF TABLES

INDEX OF FIGURES

SYMBOLS AND ABBREVIATE WORDS

GPP	Gross Primary Production
NPP	Net Primary Production
NEP	Net Ecosystem Production
NEE	Net Ecosystem Exchange
CS	Carbon storage
SOC	Soil organic Carbon
TCO	Terrestrial Carbon Observation
GTOS	Global Terrestrial Observing System programme
USDA	United States Department of Agriculture
TWB	Total woody biomass
TBP	Statistical parameter
GLK	Gleichlauf igkeits koeffizient (Synchronization accuracy coefficient)
DI	Data index
CO2	Carbon dioxide
NO2	Nitrogen dioxide
CH4	Methane

VOCABULARY

Biosphere - It is the global ecological system integrating all living beings and their relationships.

Pedosphere - It is the outermost layer of the Earth that is composed of soil and subject to soil formation processes.

Sigmoide curve - Many natural processes and complex system learning curves display a history dependent progression from small beginnings that accelerates and approaches a climax over time

1 INTRODUCTION

Global changes in the composition of the atmosphere as a result of emissions of greenhouse gases have been caused and increased by human activities: production, processing, handling and consumption of energy, industrial processes, agriculture and waste production, among others. The current relevance of the protective role of our forests and their capacity to sequester atmospheric C are factors to consider when establishing criteria for the timing, intensity and frequency of interventions, improved reconciling force of the mass , protection against fire and carbon balance.

The United Nations, through its Framework Convention on Climate Change and the Kyoto Protocol, are working at finding international agreement on incorporating forestry activities in the international response to this major environmental challenge. Kyoto Protocol expresses the possibility of using forests as carbon sinks improving the CO_2 sequestration capacity of forest systems through silvicultural activities. The objective is the "stabilization and reconstruction of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Forests play a major role in the natural global carbon cycle by capturing C from the atmosphere through photosynthesis, converting that photosynthate to forest biomass, and emitting C back into the atmosphere during respiration and decomposition. Globally, these exchanges of C between forests and the atmosphere are being influenced by human-caused and natural disturbances.

Currently, the biosphere constitutes a carbon sink that absorbs about 2.3 gigatonnes of C per year, which represents about 30 percent of fossil-fuel emissions. The increasing atmospheric CO_2 concentration can stimulate the process of photosynthesis (currently substrate-limited) and consequently plant growth, as extensive experimental research has shown (IPCC, 2001). The extent of this stimulation varies according to different estimates, being larger for forest (up to 60 percent) and smaller for pastures and crops (about 14 percent). Current scientific evidence suggests that managed and mature oldgrowth forests act as active carbon sinks sequestering C at rates of up to 6 tonnes/ ha/year (for boreal and temperate forests).

2 AIMS AND HYPOTHESES

The invasion of woody vegetation into deserts, grasslands and savannas is generally thought to lead to an increase in the amount of carbon stored in those ecosystems. For this reason, shrub and forest expansion into grasslands is also suggested to be a substantial, if uncertain, component of the terrestrial carbon sink.

There have been some research that examined the effect of woody plants enroachment on the carbon balance of invaded grasslands. For many types of ecosystems and successions, however, this issue remains non-investigated or underinvestigated. This holds true also for dry calcareous grasslands of submeditteraneous region. Therefore we decided to make estimation of woody plants biomass in the invaded karstic grasslands of slovenian submeditteranean region. Our research was part of a broader study that deals with the carbon cycling in abandoned karstic pastures (Vodnik and Simončič, 2009).

3 LITERATURE REVIEW

In this chapter we describe carbon cycle in terrestrial ecosystems in general and its specific characteristics in grasslands and forests. We focus on the changes of carbon cycling that followe woddy plants invasion into grasslands.

3.1 THE CARBON CYCLE IN TERRESTRIAL ECOSYSTEMS

The carbon cycle is the biogeochemical cycle by which carbon is exchanged among the biosphere, pedosphere, geosphere, hydrosphere and atmosphere of the Earth. It is one of the most important cycles of the Earth and allows for the most abundant element to be recycled and reused throughout the biosphere and all of its organisms.

The carbon cycle is usually thought of as five major reservoirs of carbon interconnected by pathways of exchange. These reservoirs are:

- the atmosphere,
- the terrestrial biosphere, which is usually defined to include fresh water systems and non-living organic material, such as soil carbon,
- the oceans, including dissolved inorganic carbon and living and non-living marine biota,
- the sediments including fossil fuels,
- the earth's interior, carbon from the earth's mantle and crust is released to the atmosphere and hydrosphere by volcanoes and geothermal systems.

The annual movements of carbon, the carbon exchanges between reservoirs, occur because of various chemical, physical, geological, and biological processes. The ocean contains the largest active pool of carbon near the surface of the Earth, but the deep ocean part of this pool does not rapidly exchange with the atmosphere.

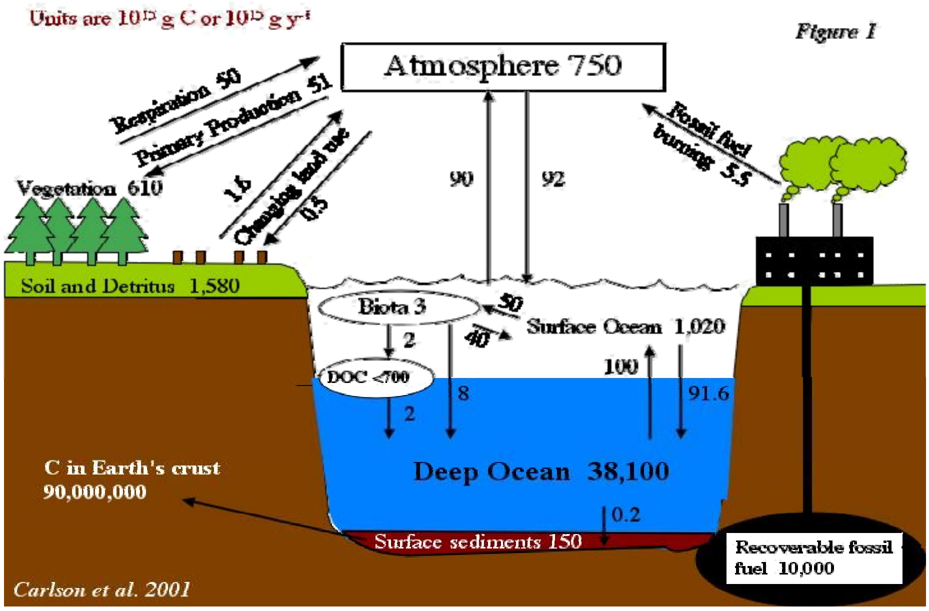

Figure 1: General figure of carbon cycle (Carlson, 2001)

The global carbon budget is the balance of the exchanges (incomes and losses) of carbon between the carbon reservoirs or between one specific loop (e.g., atmosphere ↔ biosphere) of the carbon cycle. An examination of the carbon budget of a pool or reservoir can provide information about whether the pool or reservoir is functioning as a source or sink for carbon dioxide.

When describing the carbon balance of terrestrial ecosystems the following parameters are applied:

Gross Primary Production (GPP). Considers all the carbon that enters ecosystems through photosynthesis.

Net Primary Production (NPP) is the net carbon gain by vegetation, calculated as:

$$NPP = GPP - R_{plant} \quad (1)$$

where Rplant is plant respiration.

Net Ecosystem Production (NEP) is a measure of ecosystem's productivity and considers all carbon losses of the ecosystem (respiration, leaching, disturbances,..):

$$NEP = GPP - (R_{plant} + R_{heterotr} + R_{disturb} + R_{leaching}) \quad (2)$$

where Rplant is plant respiration and Rheterotr is heterotrophic respiration. Rdisturb and Rleaching represent losses of carbon by disturbance and leaching.

Net Ecosystem Exchange (NEE) is the net CO2 exchange between ecosystem and atmosphere:

$$NEE = GPP - (R_{plant} + R_{heterotr}) = GGP - R_{e\cos ystem} \quad (3)$$

where Recosystem is the respiration of the ecosystem.

NEE varies in short and long term in dependece of photosythetic and respiration rates. Under conditions that promote carbon assimilation, GPP is larger than respiration, so NEE > 0. On the other hand NEE is expected to be negative during non-photosynthetic periods (night) and when the photosynthesis is limited by enviromental constrains. Along plant life, NEE is positive but when the plant dies, it gradually releases the CO2 uptaken. Seasonal and latitudinal variations in the CO2 concentration of the atmosphere provide a clear indication of global-scale patterns of NEE. At high northern latitudes photosynthesis exceeds total respiration during summer causing a decline in CO2 atmospheric concentration (NEE > 0). In winter, on the contrary, respiration is dominant in carbon exchange, resulting in NEE < 0. Ecosystem management tries to reduce these releases keeping the C stored meanwhile humans improve technology to reduce CO2 releases. No-managed ecosystems C cycle is not modified and its NEE is lower.

Presented parameters are combined in Figure 2 that presents carbon balance of terrestrial ecosystems.

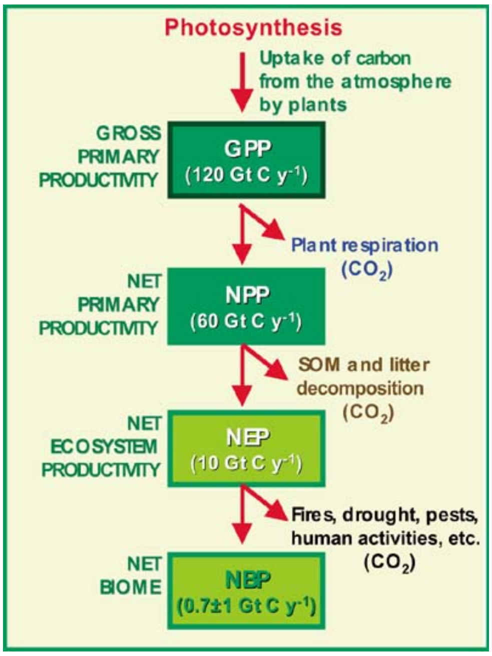

Figure 2: Carbon balance of terrestrial ecosystems. (Source: Adapted from IPCC, 2001).

3.2 CARBON CYCLING AND CARBON POOLS IN GRASSLANDS

Grasslands are the natural biome in many drylands, partly because rainfall is insufficient to support trees, and partly because of prevailing livestock management. However, grassland productivity and carbon storage (CS) have been controversial. The productivity of tropical grasslands is now known to be much higher than was previously thought, and consequently they sequester much more C (Scurlock and Hall, 1998). Estimates for C stored under grassland are about 70 tonnes/ha, which is comparable with values for forest soils. Although many of the grassland areas in drylands are poorly managed and degraded, they offer potential for CS as a consequence.

The average annual input of organic matter into grassland is about double the 1 - 2 tonnes/ha that is contributed to cropped soils (Jenkinson and Rayner, 1977). This fact is borne out by the results of studies from various locations. The data have shown that grassland, even where subject to controlled grazing, generally has higher soil C levels than cropland (e.g. Franzluebbers et al., 2000).

The key factor responsible for enhanced carbon storage in grassland sites is the high carbon input derived from plant roots. It is this high root production that provides the potential to increase soil organic matter in pastures and vegetated fallows compared with cropped systems. Root debris tends to be less decomposable than shoot material because of its higher lignin content (Woomer et al., 1994). Consequently, the key to maintaining and increasing CS in grassland systems is to maximize grass productivity and root inputs (Trumbmore et al., 1995). Grasses have also been shown to sequester more C than leguminous cover crops. Grasses also have the potential to sequester C on previously degraded land. (Garten and Wullschleger, 2000) used a modelling approach that estimated a 12-percent increase in soil C could be obtained under switchgrass (*Panicum virgatum* L.) on degraded land in ten years.

Grassland carbon pools are mostly belowground since grassland's vegetation does not produce large quantities of recalcitrant biomass. Plant material is delivered to the soil which can represent large stores of carbon and thus they can act as a net sink of atmospheric CO2. Aboveground carbon stocks of tropical grasslands are larger since their growing season is continuous. On the other hand the aboveground carbon stocks are smaller in temperate grasslands, and can be additionally reduced by regular harvesting. In addition, crop tillage makes belowground carbon stocks lower by their oxidation. Nature, frequency and intensity of disturbance plays a huge a role in C balance.

Table 1: NPP of different types of grasslands. NPP is expressed in units of dry mass. NPP estimated from harvest excludes NPP that is not avaliable to harvest as a result of consumption to herbivores, root exudation, transfer to mycorrhizae, and volatile emissions (Stuart et al., 2002).

Biome	Aboveground NPP $(g\,m^{-2}\,yr^{-1})$	Belowground NPP $(g\,m^{-2}\,yr^{-1})$	Belowground NPP (% of total)	Total NPP $(g\,m^{-2}\,yr^{-1})$
Tropical grasslands	540	540	0,50	1080
Temperate grasslands	250	500	0,67	750
Crops	530	80	0,13	610

Temperate grasslands activity is very influenced by the season. NEE dynamics is dependent on the early-spring and summer precipitation, low temperatures in late winter and the abscence or presence of autumn regrowth (Nagy et al., 2007). With low temperatures, no photosynthesis is going on. On the growing season, contrasty, development occurs in grasslands. Photosynthesis and vegetation growing, animal and vegetation waste decomposition... which releases CO2, NO2 and CH4. Furthermore, grasslands have bigger risk of erosion than other ecosystems because its reduced canopy and that could involve C stocks losses from the belowground pool

3.3 CARBON CYCLING AND CARBON POOLS IN FORESTS

In forested ecosystems, carbon accumulates through the absorption of atmospheric CO2 and its assimilation into biomass. Carbon is stored in various pools in a forest ecosystem: above- and below-ground living biomass, including standing timber, branches, foliage and roots; and necromass, including litter, woody debris, soil organic matter and forest products. Approximately 50% of the dry biomass of trees is carbon. Any activity that affects the amount of biomass in vegetation and soil has the potential to sequester carbon from, or release carbon into, the atmosphere. In total, boreal forests account for more carbon than any other terrestrial ecosystem (26%), while tropical and temperate forests account for 20% and 7%, respectively (Prentice et al . 2001).

There are, however, considerable variations among forest types in where carbon accumulates. Up to 90% of the carbon in boreal ecosystems is stored in soil, while in tropical forests the total is split fairly evenly above and below ground. The primary reason for this difference is temperature, which at high latitudes restricts soil-organic-matter decomposition and nutrient recycling, but at low latitudes encourages rapid decomposition and subsequent recycling of nutrients. In wetlands carbon in plant biomass is also a small proportion of the total carbon present: slow decomposition rates in water-laden soils (e.g. peaty soils) has led to a high carbon density in these environments.

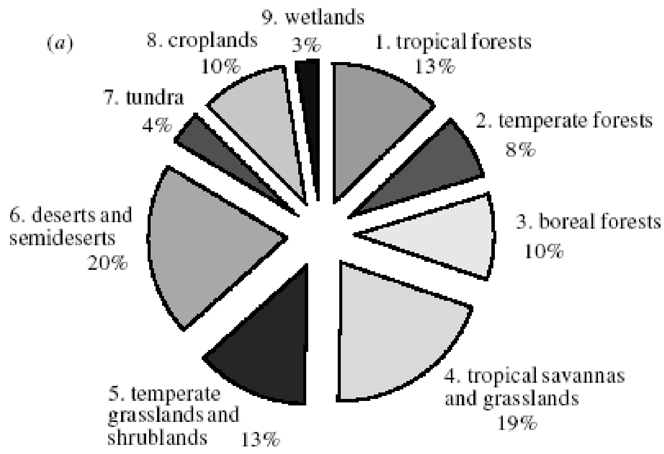

Figure 3: Global area and carbon content of diferent vegetation types. (a) The area of each vegetation type as a percentage ofthe global total (13.73 x 10^9 ha) (Mahli et al., 2002)

However, forests and ecosystems in general may have a limited capacity to accumulate C. First, this is because the capacity to sequester C is limited by other factors, such as nutrient availability and other biophysical factors. Second, photosynthesis may have a CO2 saturation point, above which it will no longer respond to an increase in atmospheric CO2 concentration. A third reason is that climate change may lead to ecosystem degradation, in turn, limiting the capacity to sequester C.

3.4 WOODY PLANTS ENCROACHMENT AND THE CHANGES OF CARBON STOCKS IN ECOSYSTEM.

It is generally accepted that the C stocks are increased when a grasslands is turned into forest. However, it is quite unknown how the woody species influece the belowground C. When the vegetation is shifted from herbaceous to woody plants, the two carbon pools most likely to change are woody plant biomass and soil organic matter. New woody biomass storage depends on the age, density and species of the new stand but changes in SOC are much harder to predict (Stuart et al., 2002). At the begining of the afforestation, large SOC losses are observed because the forest do not generate enough litter to replenish the losses. In adittion, the material produced by woody plants is more recalcitrant and woody plants may be less effective than grassland at storing C in soil because of they deposit larger fraction of total inputs on the surface where decomposition is faster due to favourable conditions. Next, when the new vegetation is stablished, the SOC accumulation rate is determinated by the amount of organic matter, which increases with temperature and humidity. This shows a relationship between precipitation and changes in SOC. Along the rainfall gradient, woody plant invasion increased contents of SOC at the drier sites and decreased them at the wetter sites.

As a result, C stocks are shifted with woody plant invasion into grasslands. Aboveground biomass increases but SOC drops what makes C stocks more vulnerable to disturbances as fire, harvesting or plagues. On the other hand, soil and vegetation respiration rates should be considered as they present high changes from grassland to forest.

Plant invasion potentially alters ecosystem carbon (C) and nitrogen (N) cycles. However, the overall direction and magnitude of such alterations are poorly quantified.

Pool variables showed significant changes in invaded ecosystems relative to native ecosystems, ranging from a 5% increase in root carbon stock to a 133% increase in shoot C stock. Flux variables, such as above-ground net primary production and litter decomposition, increased by 50–120% in invaded ecosystems, compared with native ones.

Table 2:Percentage of change related to cycles in response to plant invasion (Liao et al. 2008)

Variable	Percentage Change.
Carbon Pools	132.71 ± 2.38
Shoots	5.15 ± 3.07
Roots	49.31 ± 9.14
Litter	6.86 ± 0.91
Soil	34.12 ± 5.88
Microbe	132.71 ± 2.38

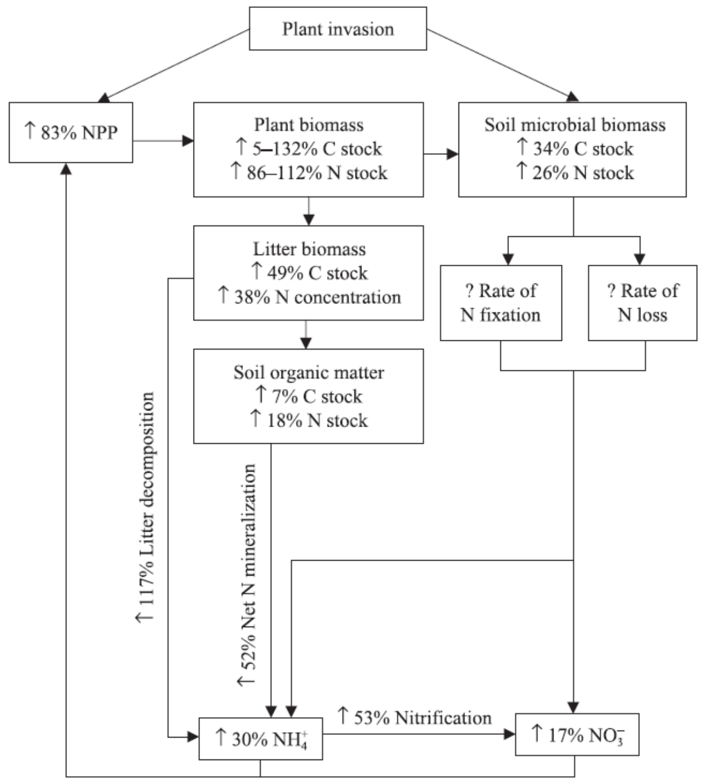

Figure 4: Potential positive feedbacks between plant invasion and carbon and nitrogen cycles in invaded ecosystems. ↑, positive response to plant invasion; ?, not clear for the response to plant invasion. NPP, net primary production. (Liao et al., 2008)

Afforestation of agricultural lands implemented as part of a policy for C sequestration should increase terrestrial C storage. Agricultural practices alter soils and this historical legacy affects tree establishment and ultimately soil C sequestration. (Morris et al., 2007).

Afforestation of agricultural soils can provide a very large sink for atmospheric CO2, both in the vegetation and in the soil. Good estimates of soil C change resulting from afforestation are difficult to acquire and necessitate an understanding of the changes that land-use change has on the ecosystems studied. Agriculture alters bulk density, horizon depth, and movement of C, N, cations and P throughout the soil profile. Understanding changes in soil C dynamics with Land-use change requires an incorporation of bulk density and horizon depth information and recluires reporting values on an aerial basis to depth (Morris et al, 2007).

4 MATERIAL AND METHODS

4.1 SITE DESCRIPTION

The study was conducted at the Podgorski kras plateau (45°33' N, 13°55' E, 400-430 m.a.s.l.) in the submediterranean region of Slovenia (SW Slovenia). Due to its position at the transition between the Mediterranean and central Europe the karstic landscape of this area is subjected to major human influences since at least 3000 years BP. Overgrazing effects in the past centuries almost completely destroyed vegetation cover and caused severe soil erosion which resulted in stony, bare landscape. Later, the economic development lead to abandonment of agricultural land use which caused slow but extensive spontaneous afforestation. Some Austrian pine (*Pinus nigra*) plantations were also established. Historic human activities and natural conditions resulted in today's diverse landscape with co-occurring succession stages ranging from grasslands to the secondary oak forests (Ferlan, 2009).

Prevailing soil type is rendzina lying on the paleogenic limestone bedrock. Soil depth is very uneven ranging from 0 cm (rocky outcrops) to several decimeters in soil pockets between rocks. Rocks occupy on average 50% soil volume of the upper 40 cm of the soil profile. Soils have clay texture and are low in plant nutrients, especially phosphorus. Percent of soil organic matter of the topsoil is 12-15%. Soil reaction is slightly basic to slightly acidic. In small depressions and sinkholes (small dolines) eutric cambisols of much larger soil depth are developed.

The climate is transient (submediterranean – continental) with hot and dry summers, and relatively cold and wet winters. Mean annual temperature is 10.0°C, mean daily temperature in January is 0.8°C and in July 18.7°C. Annual precipitation is between 1300 and 1600 mm, with the majority of precipitation falling between September and May with few rain events in summer. The site is only periodically covered by snow in the winter. The growing season ranges between May and October.

The average height of tree layer, which is mostly represented by *Quercus pubescens*, is 6 m. The coverage of woody species is uneven. With the continuing succession woody species spread from nests of shrubs, which are presumably located on the deeper soil, leaving larger or smaller gaps covered by herbaceous species. The composition of herbaceous layer is similar as for the grassland site, with *Bromopsis erecta*, *Carex humilis* and *Stipa eriocaulis* being the most abundant species. Sinkholes on the afforestation site are densely covered or surrounded by woody species and presumably have no mayor influence on wind direction and speed. The slope of the site does not exceed 3 degrees.

Here we have some photos of the species in the zone;

Figure 5: *Quercus pubescens Willd.* (Eler, 2009)

Figure 6: *Juniperus communis* L. Eler, 2009.

Figure 7: *Pinus nigra* Arnold. Eler, 2009.

Figure 8: *Bromopsis erecta* Hudson. Eler, 2009.

Figure 9: *Carex humilis* Leyss Eler, 2009.

Figure 10: *Stipa eriocaulis* Borbas. Eler, 2009.

4.2 METHODS

4.2.1 Woody biomass measurements and calculations

The method for the field measurements of biomass was one proposed by Terrestrial Carbon Observation panel (TCO) of, the Global Terrestrial Observing System programme (GTOS) (http://www.fao.org/gtos/) Main aims of TCO are to:

i) better identify the potential end users and the required data and scale;
ii) organize and coordinate reliable data and information on carbon;
iii) link science community and potential users.

The plot design is consistent with the design used by the USDA Forest Service Forest Inventory and Analysis (FIA) program, where there are four subplots within a plot. The design is appropriate for regional scaling and periodic remeasurement cycles.
We have two plots and four subplots with 10 meters of diameter, it is 314,16 m^2 each one and we measured the followings parameters:

1. Height (m) (H)
2. Circumference (mm) (C)
3. Crown max (cm) (Cr)
4. Crown min (cm) (Cm)
5. Diameter 1.3 m (cm) (D)
6. Mean stem diameter (cm)
7. Number of stems

Figure 11: Center of the plots and area where pubescent oak were sampled.

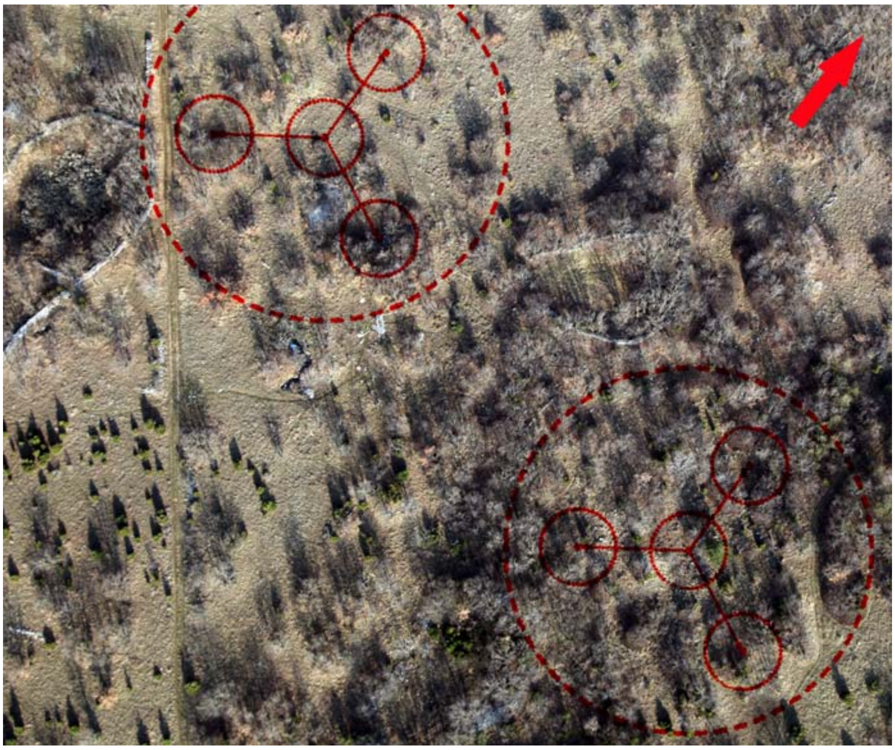

Figure 12: Plots and Subplots

The way to calculate biomass was using equations of biomass dtermination, I found that equation in the next list of documents:

Table 3: Equations of Biomass.

Equation	Units	Source of eq.
Quercus pubescens W=0.00035164*10^(1.1119*LOG(D)+0.3108*LOG(D)^2+0.5356 *LOG(H)+0.2139* LOG(H)^2)*976.71*0.6*1.36	W=kg(105°C),d=cm,h=m	smf004.pdf
Fraxinus minor W=e^(-2.4598+2.4882*LN(D))*0.6	W=kg (105°C), d=cm	smf004.pdf
Prunus sp. W= (55.076*(D^2.306))/1000	W=kg (105°C), d =cm	rn_nc299.pdf
Juniperus Communis T=(59.205*D^2.202/1000; F=30.387*D^1.650)/1000	T=kg (105°C), d=cm, F=kg(105°C)	rn_nc299.pdf
Rosa s.p. T=(37.637*D^2.779)/1000, F=(7.561*D^2.112)/1000	T=kg (105°C), d=cm, F=kg(105°C)	rn_nc299.pdf
Other species W=((0.2617*D^2)*h*10^-4)*720.52*0.6*1.36	W=kg (105°C),d=cm,h=m	

Quercus pubescens:

First of all I calculated Total woody biomass (TWB) kilograms of dry substance (105°C) with the equation and then I calculated TWB in m^3 of dry substance (105°C).

$$\text{TWB in m}^3 \text{ of dry substance (105°C)} = \frac{\text{TWB kilograms of dry substance (105°C)}}{(976.71*0.6)}$$

The last step for Q.pubescens was:

$$\text{TWB in m}^3 \text{ of wet/fresh wood (green wood)} = \frac{\text{TWB in m3 of dry substance (105°C).}}{0.6}$$

***Fraxinus minor, Prunus sp*:**

I calculated TWB kilograms of dry substance (105°C) with the equation and then I calculated TWB in m^3 of dry substance (105°C).

$$\text{TWB in } m^3 \text{ of dry substance (105°C)} = \frac{\text{TWB kilograms of dry substance (105°C)}}{390}$$

The last step was:

$$\text{TWB in } m^3 \text{ of wet/fresh wood (green wood)} = \frac{\text{TWB in } m^3 \text{ of dry substance (105°C).}}{0.6}$$

***Juniperus communis*:**

I calculated T and F with the equations and then I calculated TWB kilograms of dry substance(105°C)

$$\text{TWB kilograms of dry substance (105°C)} = T - F$$

then I calculated TWB in m^3 of dry substance (105*C).

$$\text{TWB in } m^3 \text{ of dry substance (105°C)} = \frac{\text{TWB kilograms of dry substance (105°C)}}{432.312}$$

The last step for J.comunis was:

$$\text{TWB in } m^3 \text{ of wet/fresh wood (green wood)} = \frac{\text{TWB in } m^3 \text{ of dry substance (105°C).}}{0.6}$$

***Rosa sp*:**

I calculated T and F with the equations and then I calculated TWB kilograms of dry substance(105°C)

$$\text{TWB kilograms of dry substance (105°C)} = T - F$$

then I calculated TWB in m^3 of dry substance (105°C).

$$\text{TWB in } m^3 \text{ of dry substance (105°C)} = \frac{\text{TWB kilograms of dry substance (105°C)}}{390}$$

The last step for Rosa sp. was:

$$\text{TWB in } m^3 \text{ of wet/fresh wood (green wood)} = \frac{\text{TWB in } m^3 \text{ of dry substance (105°C).}}{0.6}$$

Rest:

I calculated TWB kilograms of dry substance (105°C) with the equation and then I calculated TWB in m^3 of dry substance (105°C).

$$\text{TWB in } m^3 \text{ of dry substance (105°C)} = \frac{\text{TWB kilograms of dry substance (105°C)}}{432.312}$$

The last step was:

$$\text{TWB in } m^3 \text{ of wet/fresh wood (green wood)} = \frac{\text{TWB in } m^3 \text{ of dry substance (105°C).}}{0.6}$$

4.2.2 Growth analysis of *Quercus pubescens.*

We took samples from 14 trees with a increment borer. Additionally we collected disks from 4 trees. We dried these samples for a week and then each core sample was mounted using white glue. Both cores and disks were sanded to a high polish following standard dendrochronological procedures (Stokes & Smiley, 1996). To enhance visibility of oak rings we rubbed white chalk into earlywood vessels.

Cores were then digitized using ATRICS® system (Levanič, 2007). In our case we use 1.5x magnification. Images derived from the ATRICS program and processed in any of the available programs for automatic tree-ring recognition are of much higher detail than those from flatbed scanners, as optical magnification has many advantages over digital magnification (especially in areas with extremely narrow tree rings).

Annual radial growth was measured to the nearest 0.01 mm using WinDENDRO™ software; WinDENDRO has been specifically designed for dendrometrists and dendrochronologists looking for a precise and efficient way to measure annual tree-ring widths and other related parameters (minimum, maximum and average density, earlywood width and more). We obtained tree ring width using WinDENDRO™ software.

Figure 13: Core of Tree 1.

Each tree ring series was then visually crossdated in PAST-4 using both visual comparisons and well established statistical parameters, including tBP (Baillie & Pilcher 1973), Gleichlaufigkeitskoeffizient - GLK% (Eckstein & Bauch 1969), and Date Index - DI (Schmidt 1987). Values of t_{BP} higher than 4.0, GLK% values higher than 65%, and DI values higher than 100 were considered significant.

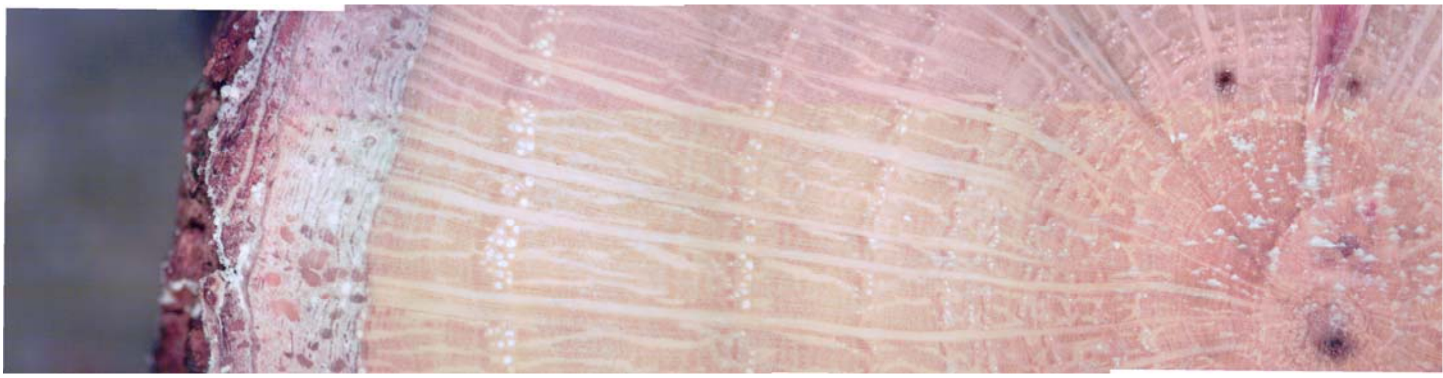

Figure 14: Tree 14 a.

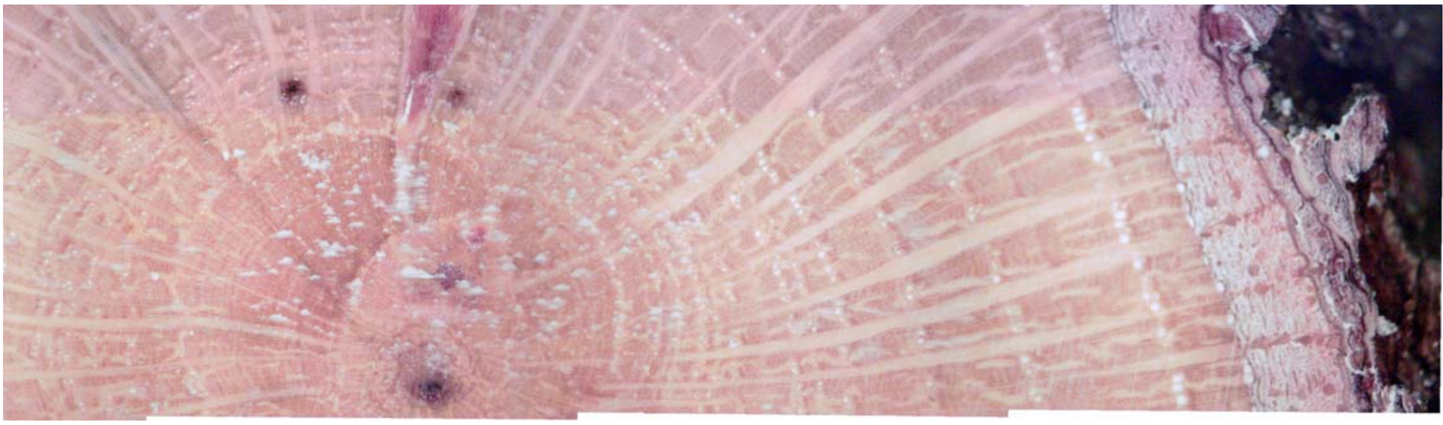

Figure 15: Tree 14 b

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5 RESULTS

5.1 WOODY BIOMASS

Here we have a table with the final result of Woody Biomass:

$$\text{TWB kilograms of dry substance} (105 * C) = \frac{8058.8884 * 10000}{2513.2741} = 32065.3 \text{ kg/ha}$$

$$\text{TWB in m3/ha of dry substance} (105 * C) = \frac{14.5267 * 10000}{2513.2741} = 57.8 \text{ m}^3/\text{ha}$$

$$\text{TWB in m3/ha of wet/fresh wood (green wood)} = \frac{24.2028 * 10000}{2513.2741} = 96.3 \text{ m}^3/\text{ha}$$

Table 4:Totals of Biomass

			TWB in m^3 of wet/fresh wood (green wood)	TWB in m^3 of dry substance (105*C)	TWB kilograms of dry substance (105*C)
Totals m^3			24.2028	14.5267	
Totals m^3/Ha			**96.3**	**57.8**	
Total Kg					8058.8884
Total Kg/Ha					**32065.3**

Table 5: We can see in this table the woody biomass per species

	TWB kilograms of dry substance (kg/ha)	**TWB of dry substance (m^3/ha)**	**TWB of wet/fresh wood (green wood) (m^3/ha)**
Fraxinus minor	519.1	1.3	2.2
Juniperus Communis	1218.6	2.8	4.7
Other species	1491.5	3.5	5.8
Prunus s.p.	1030.0	2.6	4.4
Quercus pubescens	27710.0	47.3	78.8
Rosa s.p.	96.0	0.2	0.4
Totall	**32065.3**	**57.8**	**96.3**

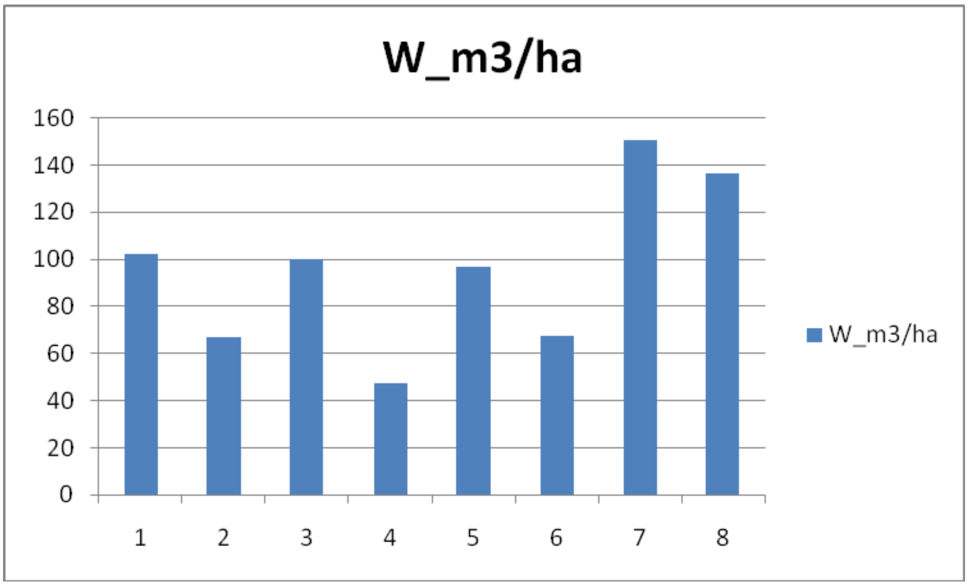

Figure 16: Woody biomass m^3/ha of wet wood per subplots. (All species)

5.2 GROWTH ANALYSIS.

Based on a tree-ring width measurements we could calculate changes of basal area and biomass in time. Height growth was estimated using linear regression (since we didn't have stem analysis data for height increment). Growth of the tree can be split into three phases: (1) Formation stage with small growth rate and slow but steady growth, (2) Juvenile stage with rapid growth rate increase and (3) Maturation stage where growth rate decreased, exhibiting a characteristic of this stage is very slow growth and tree is close to its growth limit.

In figures 17-19 we selected three typical growth rhythms. The tree number 1 was a 54 years old tree with a diameter of 21.06 cm and height of 6 meters. In figure 17 we can see perfect sigmoid curve (``s´´ curve). This plot was achieved by plotting cumulative growth against the age. By this we obtain the typical sigmoid curve of growth showing total diameter attained by the tree at any particular age. Tree number 1 is close to the maturation stage.

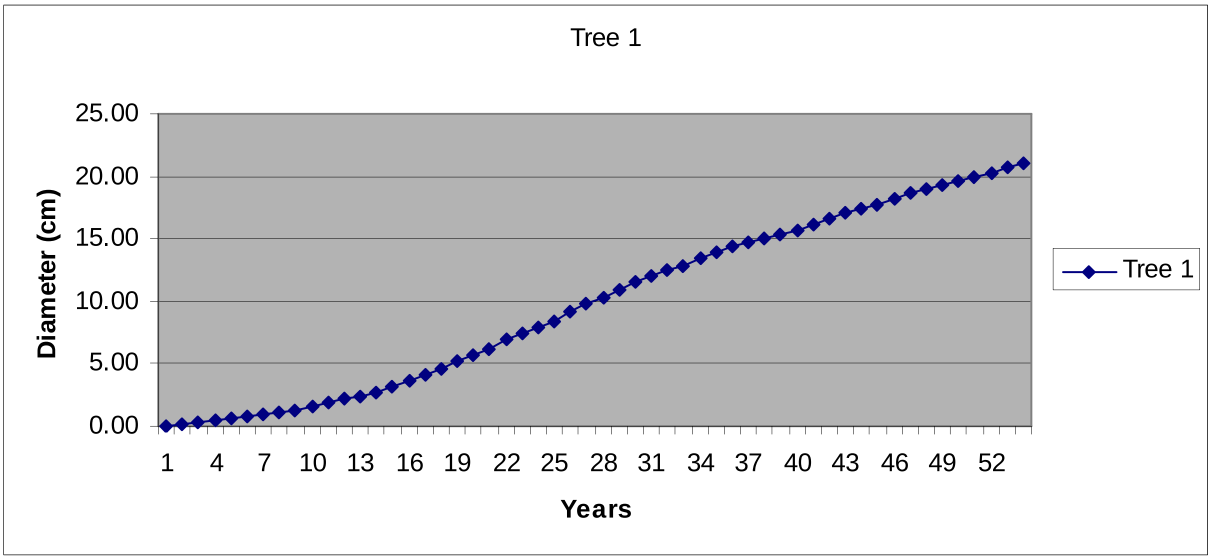

Figure 17: Tree 1. Diameter against years.

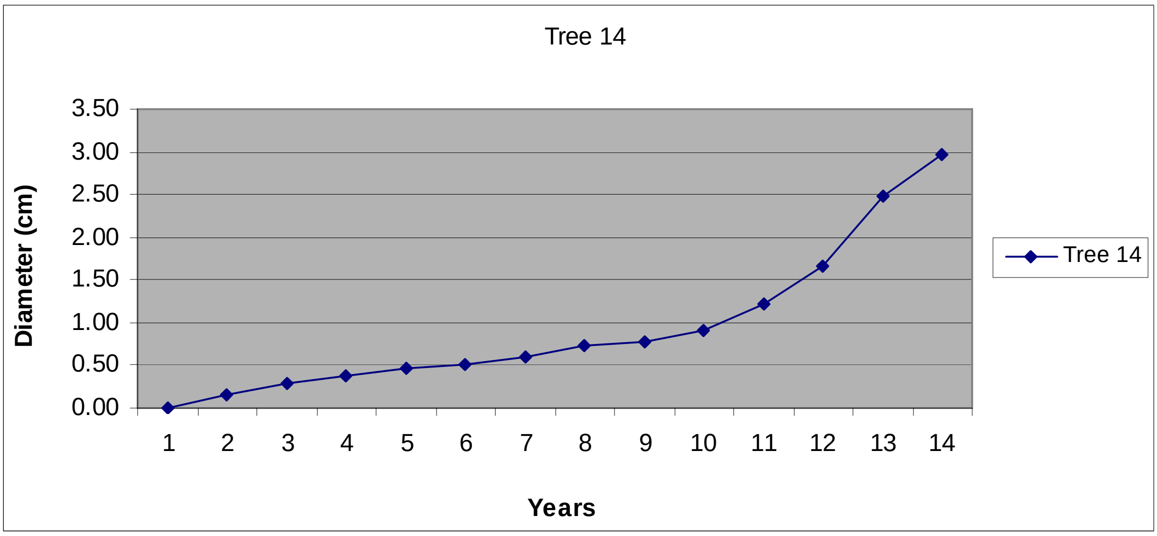

Figure 18: Tree 14. Diameter against years.

The tree number 14 is 14 years old; it is 2.96 cm of diameter and 2 meters of height. This tree is in the second, juvenile phase with a fast-growth of diameter. Radial growth in the first 10 years was relatively slow. In 11th year tree started to grow faster and this is also the beginning of the second growth stage.

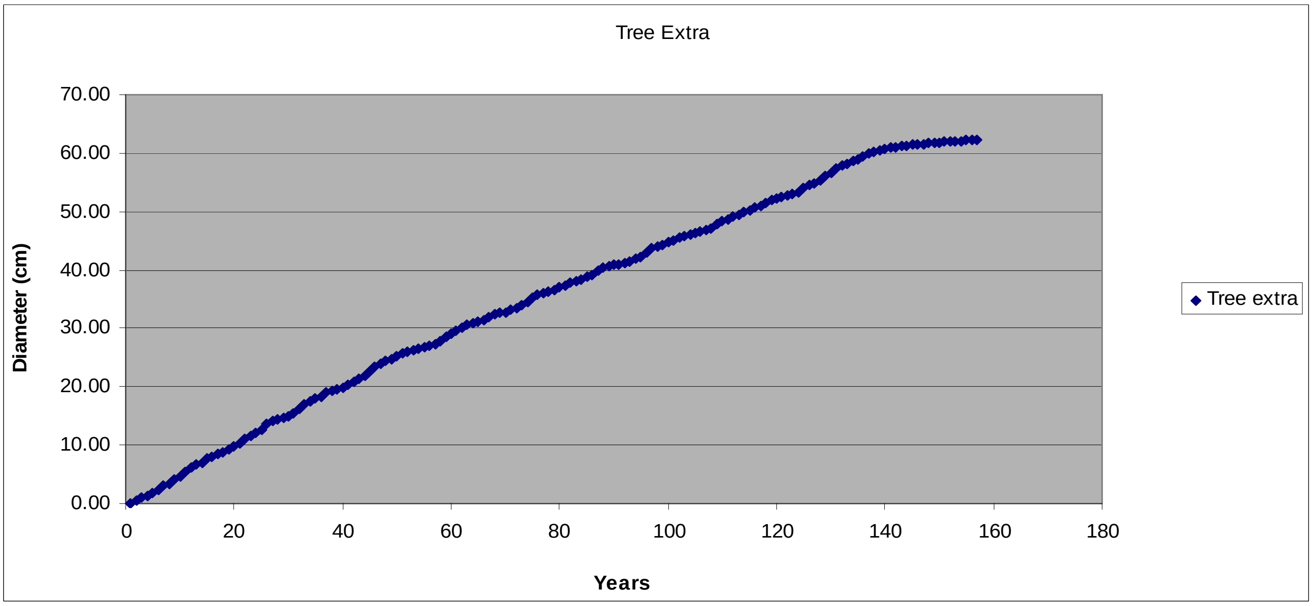

Figure 19: Tree extra. Diameter against years.

Tree EXTRA, is comparing to other two trees, very old. It is more than 150 years old. Radial growth is more or less finished. Changes in radial increment are small. Particulary interesting in this tree is absence of the formation phase and no obvious culmination of the radial growth. S shape curve is not clearly visible.

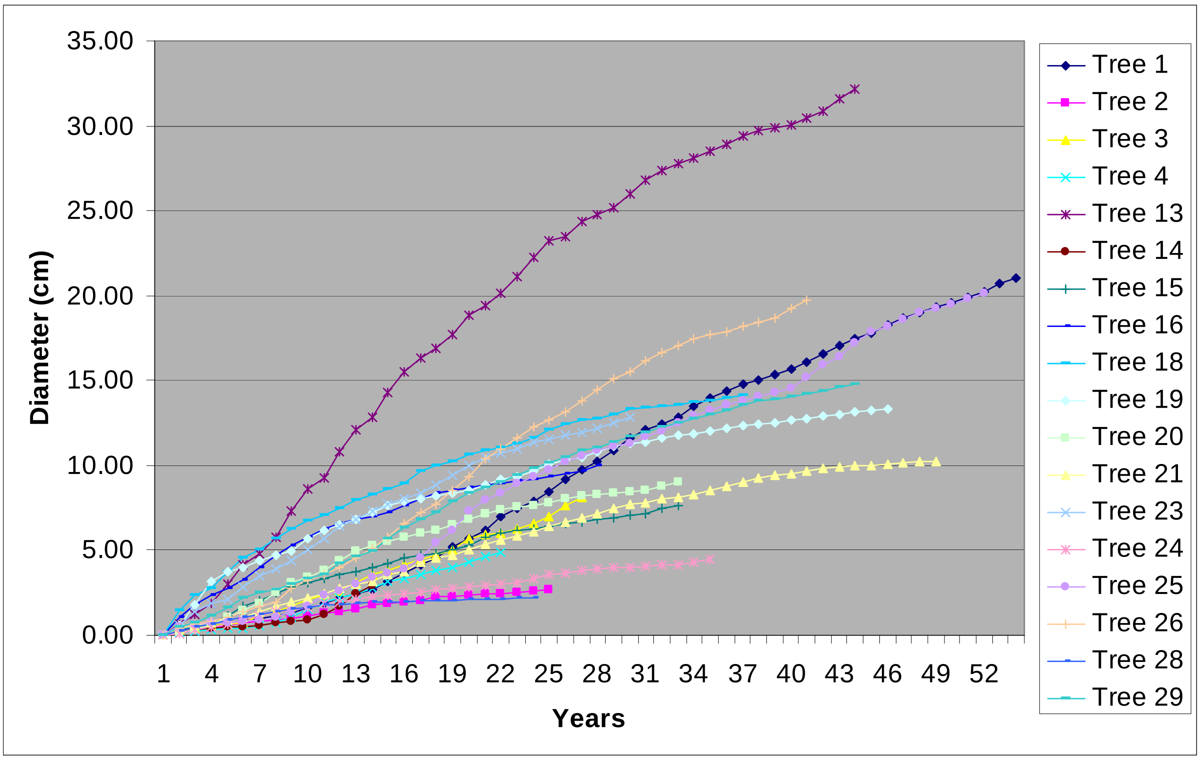

Figure 20: Diameter against years of samples trees.

Volume growth also follows typical S curve form. Culmination of the volume growth usually happens very late, when trees are very old (in many cases they are felled before they reach volume growth culmination). None of the trees in our case culminate and biomass production is in all trees in exponential increase.

Talking about biomass we have a exponential curve, showing his biggest increment in 2008.

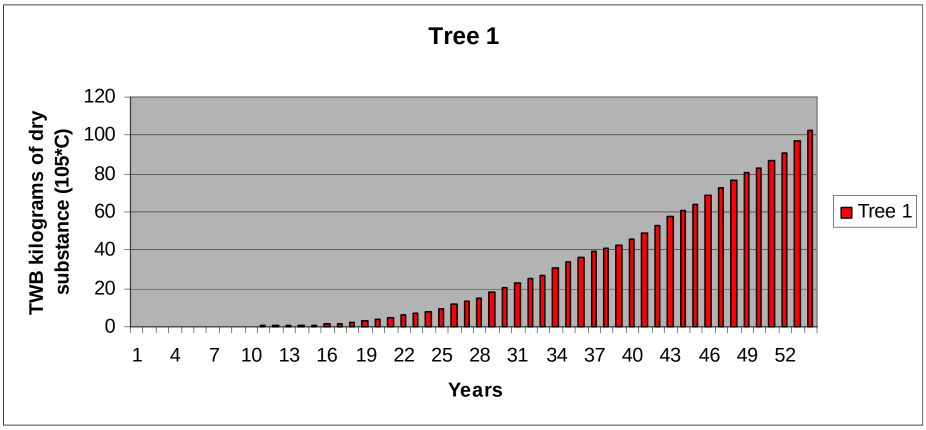

Figure 21: TWB in kilograms of dry substance for tree #1

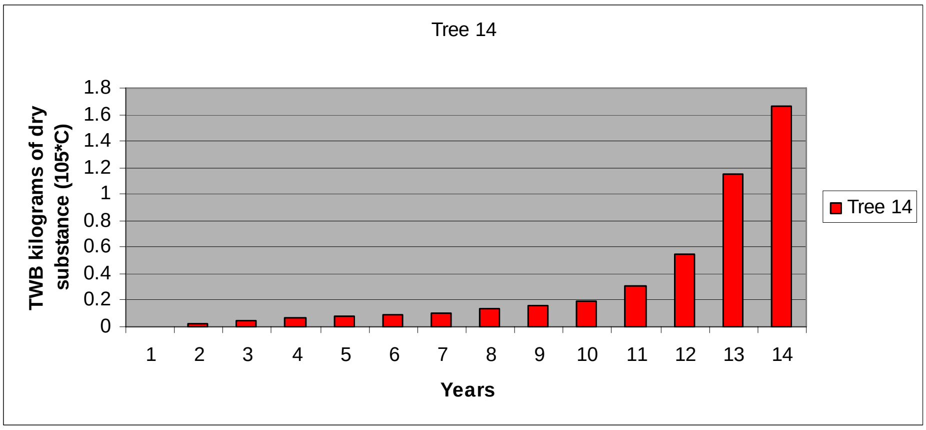

Figure 22: TWB in kilograms of dry Substance tree #14

The tree number 14 was with competition in his first years.

There is two key periods of years (1997-1999) and (2008-2009) These periods are the biggest increment of biomass in the research trees.

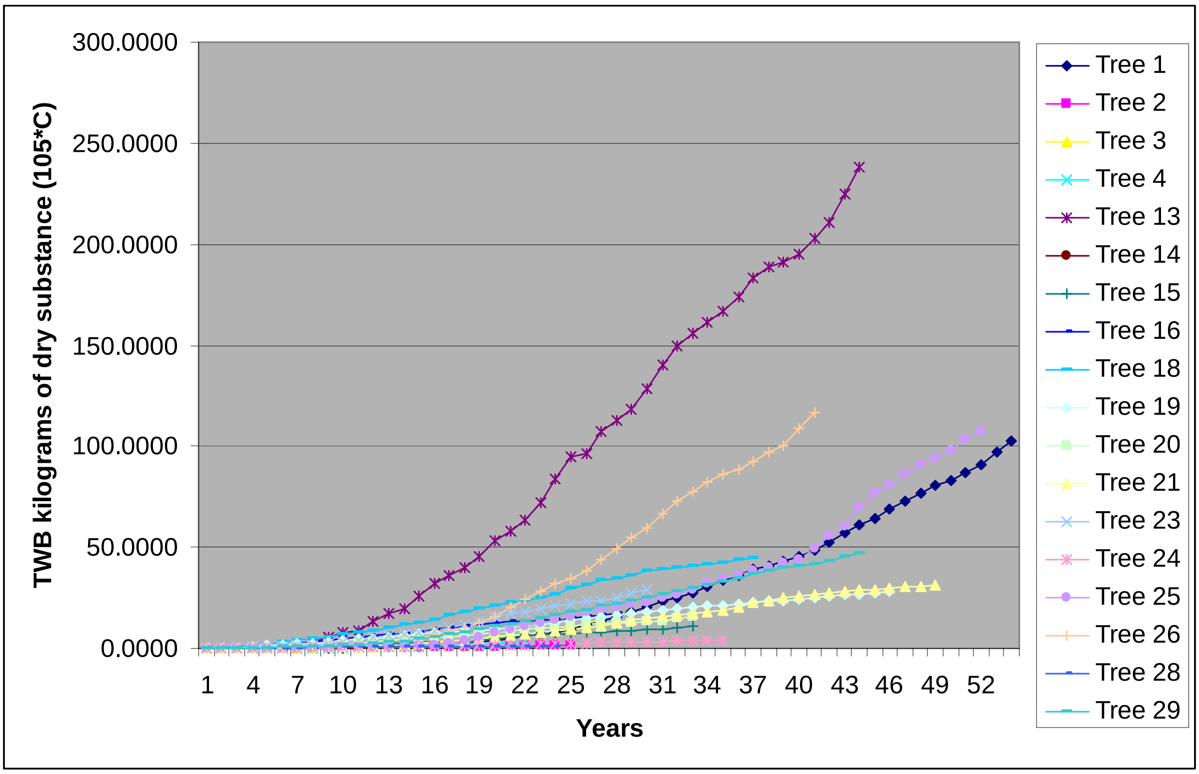

Figure 23: TWB in kilograms against years of samples trees.

Table 6: Average of year, biomass and height per year

AVERAGE

Year	Diameter (cm)	Biomass (kg)	Height (m)
1956	0.000	0.000	0.00
1957	0.206	0.031	0.06
1958	0.382	0.052	0.11
1959	0.497	0.070	0.16
1960	0.667	0.099	0.21
1961	0.775	0.120	0.24
1962	0.712	0.116	0.27
1963	0.824	0.141	0.32
1964	0.981	0.181	0.39
1965	1.020	0.198	0.39
1966	1.510	0.338	0.54
1967	1.589	0.435	0.54
1968	2.030	0.634	0.69
1969	2.381	0.798	0.80
1970	2.527	0.938	0.84
1971	3.024	1.263	0.99
1972	3.381	1.560	1.11
1973	3.804	1.989	1.23
1974	4.041	2.406	1.30
1975	4.661	3.193	1.51
1976	4.500	3.369	1.46
1977	5.296	4.685	1.74
1978	4.833	4.768	1.60
1979	5.146	5.423	1.71
1980	5.657	6.622	1.89
1981	5.720	7.308	1.93
1982	6.194	8.356	2.10
1983	6.169	8.655	2.11
1984	6.212	9.270	2.14
1985	6.710	10.721	2.32
1986	6.584	10.964	2.29
1987	6.504	11.332	2.28
1988	6.938	12.856	2.45
1989	6.982	13.919	2.48
1990	7.355	15.544	2.62
1991	7.651	16.661	2.74
1992	8.005	18.378	2.88
1993	8.237	19.467	2.97
1994	8.457	20.589	3.06
1995	8.751	22.268	3.18
1996	9.076	24.171	3.38
1997	8.907	24.689	3.33
1998	9.219	26.405	3.46
1999	9.512	28.287	3.58
2000	9.715	29.754	3.66
2001	9.973	31.654	3.76
2002	10.253	33.721	3.88
2003	10.431	35.057	3.95
2004	10.578	36.186	4.00
2005	10.724	37.330	4.06
2006	10.901	38.785	4.12
2007	11.095	40.252	4.19
2008	11.428	42.949	4.31
2009	11.694	45.322	4.40

6 DISCUSSION

In karst region (SW Slovenia) the process of woody plants invasion into grasslands has been extensive since the agriculture is limited due to unfavourable soil and climatic conditions. It can be regarded as fairly negative when the consequences such as decreased biodiversity, decreased soil water table, increased risk of fires, ... are taken into account. The portion of abandoned grasslands in Slovenia is so high that is not possible to limit the negative consequences completely. The change from grasslands to forests brings however, also positive consequences, which have to be elucidated and could be of benefit with the proper land use in the future. Among these, the role of forested ecosystem as sinks for CO_2 is of primary interest.

In the case of the studied area at Podgorski kras, woody plants invading the pastures are dominated by pubescent oak (Quercus pubescens). In our survey this species represented 86 % of total in total woody biomass expressed in kilograms of ha^{-1} (82 % in m3 ha^{-1}). It can be concluded that pubescent oak has to be taken into account as a crucial of aboveground carbon stock of the ecosystem. Similar patterns of woody plant invasion are reported from elsewhere. Kunstler et al. (2007) studied woody plants encroachment at submediterranean grasslands of Cause de Larzac (France) and found pubescent oak seedlings to have large advantage over beech (*Fagus sylvatica*) for establishement in open areas. They explain this advantage by a higher seedling production per unit of canopy area and longer effective dispersal distances. The majority of regeneration took place under shrub canopy, e.g. under *Juniperus communis* which is a common species at Podgorski kras, too.

The woody biomass stocks at the studied are is relatively low when compared to some other ecosystems. In the Comparative study of aboveground biomass of three Mediterranean species in a post-fire succession (Montés et al 2004) performed at Quercus coccifera stand regenerated after the fire, similar amount of biomass was formed in ten years. Low biomass can be atributed by low growth rate. Looking the land use history od Podgorski Kras we have three aero-photographs from years 2009, 1975 and 1957 we observed in 52 years the forest overgrowth 21% of dry karstic pastures we can see that in ours samples trees, the growth analysis shows a steady growth but not very fast due to both environmental and soil conditions, except the extra none of the trees in our case culminate and biomass production is in all trees in exponential increase that culmination is reached at very high ages so basically carbon storage is constantly increasing. In any area with excessive vegetation, we could cut come trees to improve the condition and health of forests.

The availability of information on diameter increment and growth patterns for trees is an important asset in forest management which allows the selection of tree species for protection as well as the estimation of cutting cycles and the prescription of silvicultural treatments. In our case it helps to understand the changes in carbon stock during woody plant encroachment. Diameter increment measurements are also required to feed statistical models of forest dynamics both for modelling and simulation (Pereira da Silva et al., 2002). In this way, growth pattems can facilitate the search for solutions in the management of Quercus pubecens, especially in the case of coppices where the growth pattern often justifies

The objective of this study was to develop a diameter growth pattern for Q. pubescens that allows the development and evaluation of growth functions for later improvement of existing stand-based longterm forest management planning packages.

The results of diploma project will enable a better understanding of biomass in Mediterranean shrub communities will provide useful information on the growth pattern of these species, biomass mapping, remote sensing and regional estimations of primary productivity in these areas, growth patterns for trees is an important asset it helps to understand the changes in carbon stock during woody plant encroachment.

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