Using perennial rangeland grasses for bioenergy and cattle grazing

Feldman, S.R.[1]; Sacido, M.B.[2]; Jozami, E.[2]; Castagnani, L.[2]

[1]Facultad de Ciencias Agrarias UNR, CIUNR & IICAR; ** Facultad de Ciencias Agrarias UNR

Key words: biofuels, lignocellulosic, *Spartina*, sustainability

Abstract

Increasing energy demand is an outstanding characteristic of XXI century, and though biofuels are an interesting solution they must fulfill environmental safeguards, mostly biodiversity preservation, low greenhouse gas emissions and no competition for land devoted to food production. *Spartina argentinensis* Parodi is a C4 grass with high growth rates found in extended areas of inland marshes in Argentina that are marginal for agricultural production, and which can continue growing after severe disturbances, such as fire. Indeed, cattle raisers use fire to manage this plant as newly sprouted leaves, though not high quality forage, have better digestibility and protein figures than mature leaves. Cutting and removing of vegetation do not affect the plant or arthropod diversity of the soil or alter soil carbon. Pellets can be obtained and are suitable for heating homes. Plant biomass can be used for biofuels production, i.e. bioethanol and other products obtained by pyrolysis and electricity production, previous gasification. We also found that newly sprouted leaves can be used for livestock grazing with rest periods between cuts to ensure the continuity of the plant community.

Introduction

The invention of the steam engine and the ongoing development of internal combustion engines started the industrial revolution, and rising use of fossil fuels caused the accumulation of greenhouse gases (GHG). There is strong evidence that this accumulation is responsible for the increasing trend in temperature (IPCC 2014). Therefore, it is essential to transition from fossil fuels to renewable energy, using renewable energy sources such as biofuels. First generation biofuels (i.e. corn bioethanol or soybean biodiesel) are controversial due to competition with food crops and high energy demand during production. Second generation or lignocellulosic materials include perennial grasses (*Panicum virgatum*, *Miscanthus* spp., among others) and trees with high growth rates (mainly short rotation coppice, *Salix* spp. and *Populus* spp.).

We focused on a perennial C4 grass with high growth rates even in soils marginal for agricultural production, and which does not compete with food production: *Spartina argentinensis* Parodi (=*Sporobolus spartinus* (Trin.) P.M. Peterson & Saarela). *Spartina* rangelands occupy circa 30000 km^2 and have been extensively studied (Lewis *et al.,* 1990), including their high resilience after disturbances (Feldman *et al.,* 2004; Feldman and Lewis 2005; 2007). Prescribed fire is frequently used in these areas because newly sprouted leaves are tender and have higher digestibility and protein content. But such controlled burns often turn into uncontrolled fires that affect non-target areas, from fences to homes. Using satellite images, Veron *et al.,* (2012) found that up to 2 million hectares of all Argentinean rangelands are burned annually, releasing large amounts of CO_2 into the atmosphere without energy use. Sosa *et al.,* (2019) did not detect changes in the vegetation or in the soil arthropod communities after cutting and removal of biomass from *S. argentinensis* rangeland. Therefore, we propose that using biomass that grows spontaneously in soils not suitable for agriculture and that sustains extensive cattle raising, is an alternative energy source that should be explored (Hill *et al.,* 2006; Tilman *et al.,* 2009). Our aims were to 1) establish the bioenergy outputs of *S. argentinensis*, 2) explore how to include animal grazing in *S. argentinensis* production for biofuel, and 3) compare CO_2 emissions of 1 km of displacement in a vehicle using gasoline vs. *S. argentinensis* bioethanol.

Joint XXIV International Grassland and XI International Rangeland Kenya 2021 Virtual Congress Oral Papers Proceedings

Materials and Methods

Data were collected in the Pampean region of Argentina (32 ° 5'S; 61 ° 22'W). The area is a plain, with a temperate humid climate, annual mean temperatures of 23.7 °C and 11.8 °C, maximum and minimum respectively; and about 1000 mm average annual rainfall (most of it occurring in the warm season, from September to March). Available standing biomass (DM dry matter: 72 hs at 60°C) was determined in a control area (without previous vegetation removal) and at 26 and 78 days after cutting in 3 50 x 50 cm treatment plots. The percentage of protein (AOAC, 1984), NDF (neutral detergent fibre), ADF (acid detergent fibre), and lignin (Goering and Van Soest, 1963) was determined, and *in vitro* dry matter digestibility (DMM; Ustarraoz *et al.,* 1997) and metabolizable energy were calculated. Metabolizable energy (ME) was calculated using: ME= 3.61 DMM, and maximum stocking rate (MSR) as the possibility of feeding an animal with a requirement of 18.5 Mcal day^{-1}. The supply of forage for cattle (newly sprouted *S. argentinensis* leaves) was calculated considering metabolizable energy of 50% harvest for cuts at 26 and 78 days, and 30% for the control and 219 days. Data were expressed per hectare (ha: 10000 m^2), as usual in forage measurements in Argentina and compared using Anova and Tukey using Infostat (Di Rienzo *et al.,* 2014).

The bioethanol production system was modelled from the biomass of *S. argentinensis* (field and industrial stages) working with the Simapro 8.4 Faculty software (PRé Consultants, 2017), considering as a functional unit the production of bioethanol to move 1 km a Taurus Sedan model vehicle (US EPA, 2000) Flex Fuel Vehicle (FFV). The following biomass harvesting tasks were considered: i) tillage with a disk harrow (20 L diesel ha^{-1}); ii) cutting with a brush cutter (10 L diesel ha^{-1}); iii) rotary bale (10 L diesel ha^{-1}); and iv) transport to an industrial plant (30 km from the field), as well as industrial stages (biorefinery: acid hydrolysis, fermentation, filtration, and transport to fuel station). Global warming potential (GWP, CO_2 equivalent emissions) was calculated according to the methodology established by Recipe (Goedkoop *et al.,* 2103) and compared with gasoline. Data of field stages were our own while industrial ones were according to Jungbluth (2007) and Kumar and Murphy 2012. The ethanol to move a Taurus Sedan model vehicle 1 km was compared with the transport of a gasoline vehicle (Wernet *et al.,* 2016) without considering the assembly of the vehicle and the road (asphalt) construction. GWP was compared considering electric production (1 MWh) considering standard Argentinean electric power plants (Argentinean mix) versus electric generation using syngas obtained through gasification procedure.

Results

Plants had the highest growth rates: 37.56 and 38.46 kg DM ha^{-1} day^{-1}, 26 and 78 days after cutting and removal, respectively. The percentage of crude protein reached values greater than twice that of control plots during the experimental period (26 and 78 days after cutting), with values close to the recommended protein content for livestock production. Protein values remained above the control during the 7 months of growth, approximately. No changes in cell wall fibres percentage were detected throughout the analysed period, while there was accumulation of ash (Table 1).

Table 1: Crude protein (CP), neutral detergent fibre (NDF), acid detergent fibre (ADF), lignin and ash content (%) in plants of *S. argentinensis* during the experimental period.

days after cutting	CP	NDF	ADF	Lignin	Ashes
control	3.32 a	73.06 a	38.04 a	4.81 b	5.43 a
26	7.81 c	74.60 a	37.27 a	3.98 a	8.80 b
78	6.80 b	74.24 a	37.81 a	4.88 b	7.43 b

Means within a column with the same letter are not significantly different

Though i*n vitro* digestibility and ME showed slight differences during the experiment, MSR increased after 26 and 78 days if experiment onset (Table 2) due to higher figures of available forage (aboveground biomass).

Table 2: Aboveground biomass, *in vitro* dry matter digestibility (DMD), and maximum stocking rate (MSR) of *S. argentinensis* plots along the experimental period

days after cutting	biomass (DM) kg ha^{-}	DMD (%)	MSR ha^{-1}
control	5926 c	59.27 a	0.56 a
26	976 a	59.87 a	2.19 b
78	3000 b	59.45 a	2.23 b

Means within a column with the same letter are not significantly different

The GWP of 1 MWh of the Argentine electricity matrix is 675 kg CO_2eq, determining an emission reduction of 91% for the scenario with use of electricity for industrial processes from the grid (60.4 kg CO_2eq) for gasification and 95.5% with self-supply (29.8 kg CO_2eq).

The GWP of a standard vehicle using fossil fuel is 302 g CO_2eq km^{-1}, while using *S. argentinensis* bioethanol, the Simapro software established as 154 g CO_2eq km^{-1}, reducing emissions by approximately 50%.

Conclusions

Our results show that using *S. argentinensis* as a source of bioenergy implies significant savings in GHG emissions. These are interesting figures because they were obtained in spite of the fact that we considered the worst scenario when we included fuel consumptions during the harvest procedures, as well as thermochemical pre-treatments during bioethanol production. Using ligninolitic enzymes would lower fuel consumption during pre-treatments, therefore lowering GHG emissions.

Biomass removal for bioenergy should be carried out in spring to have a better quality and homogeneous forage supply, which leads to greater harvest efficiency by cattle. After cutting *S. argentinensis* for bioenergy, we recommend rotational grazing of cattle with high instantaneous loads and low occupation time. This grazing should be carried out around 70-80 days post-cutting, since at that time the plants have good CP content, digestibility and accumulated biomass. We still have to establish the optimal grazing intensity and duration of the rest period to ensure that *S. argentinensis* and the entire plant community recover, but current initial results are promising.

Today we face what Tilman *et al.,* (2009) called a "trilema": food, energy and environmental demand. As food demand increases, using farmland for energy crops is unwise, energy demand continues increasing, and greenhouse gasses emissions are among the highest contaminant concerns due to global climate change. We propose using perennial rangeland species, i.e. *S. argentinensis* for bioenergy and livestock production to contribute towards solving this trilema.

Acknowledgements

This research was supported by a grant of the Universidad Nacional de Rosario, Argentina.

References

AOAC. 1984. *Official Methods of Analysis. Association of Official Analytical Chemists*. S. William. Washington D. C.

Di Rienzo, J.A, Casanoves, F.; Balzarini, M.G., Gonzalez, L., Tablada, M., and Robledo, C.W. 2008. *InfoStat versión 2014.* Grupo InfoStat, FCA, Córdoba, Argentina.

Feldman, S.R. and Lewis, J.P. 2007. Effect of fire on Spartina argentinensis Parodi demographic characteristics. *Wetlands,* 27:785-793.

Feldman, S.R. and Lewis, J.P. 2005. Effect of fire on the structure and diversity of a Spartina argentinensis tall grassland. *Appl. Veg. Sci.,* 8:77-84.

Feldman, S.R., Bisaro, V. and Lewis, J.P. 2004. Photosynthetic and growth responses to fire of the subtropical-temperate grass Spartina argentinensis Parodi. *Flora,* 199:491-499.

Goedkoop, M., Heijungs, R., Huijbregts, M., Schryver, A., Struijs, J., and Van Zelm, R. 2103. *Quick introduction into ReCiPe LCIA Methodology*.

Goering, H. and Van Soest, P. 1970. Forage fiber analysis (apparatus, reagents, procedures and some applications). *Agricultural Handbook Nº 379*, USDA, Washington DC.

Hill, J., Nelson, E., Tilman D., Polasky S. and Tiffany. D. 2006. Environmental, economic, and energetic costs and benefits of biodiesel and ethanol biofuels. *Proc. Natl. Acad. of Sic.,* 103:11206-11210.

IPCC (Intergovernmental Panel on Climate Change). 2014. Climate Change 2014: *Mitigation of Climate Change. Fifth Assessment.* Cambridge University Press, New York.

Jungbluth, N. (ed.) 2007 Life Cycle Inventories of Bioenergy. *Ecoinvent report No. 17*, Vol. Data v2.0.

Kumar, D., and Murphy, D.S. 2012. Life cycle assessment of energy and GHG emissions during ethanol production from grass straw using various pretreatment processes. *Int. J. Life Cycle Assess.*, 17:88-401.

Lewis, J.P., Pire, E. F., Prado, D.E., Stofella, S.L., Franceschi, E.A. and Carnevale, N.J. 1990. Plant communities and phytogeographical position of a large depression in the Great Chaco, Argentina. *Vegetatio,* 6:25-38.

PRé Consultants. 2017. *SimaPro 8.4.* Available from: https://simapro.com/global-partner-network/pre-consultants.

Sosa, L. L., Jozami, E., Oakley, L.J., Montero. G.A., Ferreras, L.A., Venturi, G. and Feldman, S.R. 2019. Using C4 perennial rangeland grasses for bioenergy. *Biomass & Bioenergy,* 128:105299.

Tilman, D., Socolow, R., Foley, J.A.,Hill, J., Larson, E., Lynd, L., Pacala, S., Reilly, J., Searchinger, T., Somerville, C. and Williams, R. 2009.Beneficial Biofuels—The Food,Energy, and Environment Trilemma. *Science,* 325:270-271.

Ustarroz E., Latimori, N. and Peuser, R. 1997. Módulo de programación forrajera. *Alimentación en bovinos para carne*. INTA Manfredi.

Verón, S.R., Jobbágy, E.G., Di Bella, C.M., Paruelo, J.M. and Jackson, R.B. 2012. Assessing the potential of wildfires as a sustainable bioenergy opportunity. *GCB Bioenergy,* 4:634-641.

Wernet, G., Bauer, C. Steubing, B., Reinhard, J., Moreno-Ruiz E, and Weidema, B. 2016. The ecoinvent database version 3 (part I): overview and methodology. *Int. J. Life Cycle Assess.,* 21:1218–1223.